ASME AG-1–2019
(Revision of ASME AG-1–2017)

Code on Nuclear Air and Gas Treatment

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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Code on Nuclear Air and Gas Treatment

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The American Society of Mechanical Engineers
Two Park Avenue • New York, NY • 10016 USA

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The next edition of this Code is scheduled for publication in 2021.

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

Errata to codes and standards may be posted on the ASME website under the Committee Pages to provide corrections to incorrectly published items, or to correct typographical or grammatical errors in codes and standards. Such errata shall be used on the date posted.

The Committee Pages can be found at http://cstools.asme.org/. There is an option available to automatically receive an e-mail notification when errata are posted to a particular code or standard. This option can be found on the appropriate Committee Page after selecting "Errata" in the "Publication Information" section.

The American Society of Mechanical Engineers
Two Park Avenue, New York, NY 10016-5990

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FOREWORD

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, approved by the American National Standards Institute (ANSI) on April 30, 1985 and issued on February 28, 1986, was the new Code resulting from the increased scope. The first revised edition was approved by ANSI on May 22, 2017.

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 the Correspondence With the Committee page.)

This edition of ASME AG-1 was approved by ANSI on August 8, 2019, and issued on January 17, 2020. The requirements of this Standard take effect upon its issue date.

ASME COMMITTEE ON NUCLEAR AIR AND GAS TREATMENT

(The following is the roster of the Committee at the time of approval of this Code.)

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A. M. Kouvolo, *Contributing Member*, Consultant

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D. Miro-Quesada, *Secretary*, The American Society of Mechanical Engineers
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R. R. Weidler, Consultant

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R. R. Bellamy, Camfil USA, Inc.
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B. Valentin, *Contributing Member*, SGT, Inc./NASA Goddard Space Flight Center

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D. Gibbs, Camfil USA, Inc.
R. Giberson, Clayton Associates, Inc.
N. Handschke, Camfil USA, Inc.
Z. Hostetler, SSM Industries
S. Khabir, Washington River Protection Solutions/Hanford
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C. Massar, Ruskin Co.
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J. C. Royer, Sargent & Lundy, LLC
A. Soma, Camfil USA, Inc.
M. T. Sorna, Puget Sound Naval Shipyard
T. Wander, AAF International
W. H. Lampkin, *Contributing Member*, Greenheck Fan Corp.
D. Schoepflin, *Contributing Member*, Pacific Northwest National Laboratory
G. D. Singleton, *Contributing Member*, AAF International

SUBCOMMITTEE ON FILTRATION

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A. Stillo, *Vice Chair*, Camfil USA, Inc.
D. J. Adamson, Savannah River National Laboratory
W. Bergman, Aerosol Science
H. Cho, Mississippi State University
S. Dinakaran, AAF Flanders
D. M. Dykes, Consultant
G. Garcia, Bechtel National, Inc.
M. R. Hahn, U.S. Department of Energy
N. Handschke, Camfil USA, Inc.
C. A. Hart, Air Techniques International Test Laboratory
S. Khabir, Washington River Protection Solutions/Hanford
J. Levinson, BWX Technologies, Inc.
L. E. Major, Lydall
M. A. Mitchell, Lawrence Livermore National Laboratory
G. W. Moore, Camfil USA, Inc.
D. P. Nguyen, U.S. Army Edgewood Chemical Biological Center
G. G. Pyle, Knolls Atomic Power Laboratory
C. I. Ricketts, Engineering Services Company, LLC
K. L. Rubow, Mott Corp.
L. J. Rudenas, ANSTO
S. Salisbury, Los Alamos National Laboratory
M. T. Sorna, Puget Sound Naval Shipyard
J. A. Stormo, Mississippi State University — Institute for Clean Energy Technology
C. A. Waggoner, Mississippi State University — Institute for Clean Energy Technology
N. S. Zaremba, Newport News Shipbuilding
J. S. MacMurray, *Contributing Member*, Savannah River National Laboratory
D. Schoepflin, *Contributing Member*, Pacific Northwest National Laboratory
L. D. Weber, *Contributing Member*, Stony Brook University

PROJECT TEAM ON SECTION FA: MOISTURE SEPARATORS

M. A. Doersam, *Chair*, Ellis & Watts Global Industries, Inc.
G. Dalton, Bechtel National, Inc.
S. Khabir, Washington River Protection Solutions/Hanford
H. A. Mearns, U.S. Army Combat Capabilities Development Command Chemical Biological Center
C. I. Ricketts, Engineering Services Company, LLC

PROJECT TEAM ON SECTION FC: HEPA FILTERS

A. Stillo, *Chair*, Camfil USA, Inc.
H. A. Mearns, *Vice Chair*, U.S. Army Combat Capabilities Development Command Chemical Biological Center
D. J. Adamson, Savannah River National Laboratory
B. M. Baker, SciTech Services, Inc.
S. Barnette, U.S. Department of Energy
H. Cho, Mississippi State University
S. Dinakaran, AAF Flanders
D. M. Dykes, Consultant
C. Fosseen, Newport News Shipbuilding
N. Galante, AAF International
G. Garcia, Bechtel National, Inc.
M. R. Hahn, U.S. Department of Energy
N. Handschke, Camfil USA, Inc.
C. A. Hart, Air Techniques International Laboratory
S. Khabir, Washington River Protection Solutions/Hanford
J. R. Kriskovich, Kurion, Inc.
J. Levinson, BWX Technologies, Inc.
L. E. Major, Lydall
E. McCormick, Washington Department of Health, Radioactive Air Emissions
J. C. Medley, Nevada National Security Site
G. W. Moore, Camfil USA, Inc.
J. Nagengast, Lawrence Livermore National Laboratory
D. P. Nguyen, U.S. Army Edgewood Chemical Biological Center
G. G. Pyle, Knolls Atomic Power Laboratory
C. I. Ricketts, Engineering Services Company, LLC
S. Salisbury, Los Alamos National Laboratory
D. Schoepflin, Pacific Northwest National Laboratory
M. T. Sorna, Puget Sound Naval Shipyard
J. A. Stormo, Mississippi State University — Institute for Clean Energy Technology
C. A. Waggoner, Mississippi State University — Institute for Clean Energy Technology
T. Wander, AAF International
J. Webb, Y-12 National Security Complex
N. S. Zaremba, Newport News Shipbuilding
J. S. MacMurray, *Contributing Member*, Savannah River National Laboratory

PROJECT TEAM ON SECTION FI: METAL MEDIUM FILTERS

H. Cho, *Chair*, Mississippi State University
D. J. Adamson, Savannah River National Laboratory
M. Bauer, Westinghouse Electric Germany GmbH
W. Bergman, Aerosol Science
C. B. Chadwick, Microfiltrex Ltd
E. Duvekot, Porvair Filtration Group, Inc.
C. A. Hart, Air Techniques International Test Laboratory
D. Klein, AREVA NP, Inc.
K. G. Nelson, Porvair Filtration Group, Inc.
D. P. Nguyen, U.S. Army Edgewood Chemical Biological Center
K. L. Rubow, Mott Corp.
S. Salisbury, Los Alamos National Laboratory
J. R. Shultz, U.S. Department of Energy
A. Stillo, Camfil USA, Inc.
J. A. Stormo, Mississippi State University – Institute for Clean Energy Technology
C. A. Waggoner, Mississippi State University – Institute for Clean Energy Technology

PROJECT TEAM ON SECTION FK: SPECIAL HEPA FILTERS

G. W. Moore, *Chair*, Camfil USA, Inc.
N. S. Zaremba, *Vice Chair*, Newport News Shipbuilding
B. M. Baker, SciTech Services, Inc.
S. Barnette, U.S. Department of Energy
P. Basile, Clayton Associates, Inc.
H. Cho, Mississippi State University
G. Dalton, Bechtel National, Inc.
S. Dinakaran, AAF Flanders
E. Duvekot, Porvair Filtration Group, Inc.
D. M. Dykes, Consultant
C. Fosseen, Newport News Shipbuilding
G. Garcia, Bechtel National, Inc.
R. Giberson, Clayton Associates, Inc.
M. R. Hahn, U.S. Department of Energy
C. A. Hart, Air Techniques International Test Laboratory
Z. Hostetler, SSM Industries
S. Khabir, Washington River Protection Solutions/Hanford
J. R. Kriskovich, Kurion, Inc.
J. Levinson, BWX Technologies, Inc.
L. E. Major, Lydall
E. McCormick, Washington State Department of Health, Radioactive Air Emissions
H. A. Mearns, U.S. Army Combat Capabilities Development Command Chemical Biological Center
K. G. Nelson, Porvair Filtration Group, Inc.
D. P. Nguyen, U.S. Army Edgewood Chemical Biological Center
G. G. Pyle, Knolls Atomic Power Laboratory
C. I. Ricketts, Engineering Services Company, LLC
S. Salisbury, Los Alamos National Laboratory
J. R. Shultz, U.S. Department of Energy
M. T. Sorna, Puget Sound Naval Shipyard
A. Stillo, Camfil USA, Inc.
J. A. Stormo, Mississippi State University — Institute for Clean Energy Technology
B. Swinnerton, Sellafield Ltd
C. A. Waggoner, Mississippi State University — Institute for Clean Energy Technology
J. Webb, Y-12 National Security Complex
G. L. Laws, *Contributing Member*, Washington State Department of Health, Office of Radiation Protection
J. S. MacMurray, *Contributing Member*, Savannah River National Laboratory

PROJECT TEAM ON SECTION FM: HIGH STRENGTH HEPA FILTERS

C. I. Ricketts, *Chair*, Engineering Services Company, LLC
B. M. Baker, SciTech Services, Inc.
S. Barnette, U.S. Department of Energy
W. Bergman, Aerosol Science
G. Dalton, Bechtel National, Inc.
S. Dinakaran, AAF Flanders
E. Duvekot, Porvair Filtration Group, Inc.
M. R. Hahn, U.S. Department of Energy
J. R. Kriskovich, Kurion, Inc.
J. S. MacMurray, Savannah River National Laboratory
L. E. Major, Lydall
D. P. Nguyen, U.S. Army Edgewood Chemical Biological Center
G. G. Pyle, Knolls Atomic Power Laboratory
J. R. Schultz, U.S. Department of Energy
A. Stillo, Camfil USA, Inc.
J. A. Stormo, Mississippi State University — Institute for Clean Energy Technology
N. S. Zaremba, Newport News Shipbuilding
G. L. Laws, *Contributing Member*, Washington State Department of Health, Office of Radiation Protection

SUBCOMMITTEE ON GAS PROCESS TREATMENT EQUIPMENT

R. T. Jubin, *Chair,* Oak Ridge National Laboratory
M. R. Hargan, *Vice Chair,* Hargan Engineering
T. B. Axley, Jr., North Wind Group
M. Bauer, Westinghouse Electric Germany GmbH
J. O. Bettle, U.S. Nuclear Regulatory Commission
S. Brink, ANSTO
M. J. Fox, ECU Corp.
D. Ghosh, Southern Nuclear
D. Klein, AREVA NP, Inc.
J. R. Kriskovich, Kurion, Inc.
D. Ryland, Canadian Nuclear Laboratories
M. Sulva, APTIM — Kings Bay Support Services, LLC
C. Wojcik, PMT Nuclear
C. A. Curtis, *Contributing Member,* West Valley Nuclear
W. P. Drosjack, *Contributing Member,* Retired
I. Kutuzov, *Contributing Member,* Alfa Laval, Inc. (Canada)

PROJECT TEAM ON SECTION GA: HEAT EXCHANGERS

M. J. Fox, *Chair*, ECU Corp.
M. R. Hargan, *Vice Chair*, Hargan Engineering
D. Ghosh, *Contributing Member*, Southern Nuclear
J. R. Kriskovich, *Contributing Member*, Kurion, Inc.
I. Kutuzov, *Contributing Member*, Alfa Laval, Inc. (Canada)
C. Wojcik, *Contributing Member*, PMT Nuclear

PROJECT TEAM ON SECTION GB: NOBLE GAS HOLDUP EQUIPMENT

M. Sulva, *Chair*, APTIM — Kings Bay Support Services, LLC
T. B. Axley, Jr., North Wind Group
S. Brink, ANSTO
D. M. Dykes, Consultant
D. Ghosh, Southern Nuclear
M. R. Hargan, Hargan Engineering
R. T. Jubin, Oak Ridge National Laboratory
J. B. Roberts, National Security Technologies, LLC
D. Ryland, Canadian Nuclear Laboratories
N. Soelberg, Idaho National laboratory
A. Soma, Camfil USA, Inc.

PROJECT TEAM ON SECTION GC: MULTISTAGE BLOWERS

M. J. Fox, *Chair*, ECU Corp.
M. R. Hargan, *Vice Chair*, Hargan Engineering
T. B. Axley, Jr., North Wind Group
A. M. Kouvolo, Consultant
W. P. Drosjack, *Contributing Member*, Retired

PROJECT TEAM ON SECTION GE: HYDROGEN RECOMBINERS

M. Sulva, *Chair*, APTIM — Kings Bay Support Services, LLC
M. Bauer, *Vice Chair*, Westinghouse Electric Germany GmbH
T. B. Axley, Jr., North Wind Group
M. R. Hargan, Hargan Engineering
R. T. Jubin, Oak Ridge National Laboratory
D. Klein, AREVA NP, Inc.
J. B. Roberts, National Security Technologies, LLC
G. Roca, Westinghouse Electric Spain
D. Ruiz Varona, Nuclenor
D. Ryland, Canadian Nuclear Laboratories
R. Cowen, *Contributing Member*, GE Hitachi
D. M. Dykes, *Contributing Member*, Consultant
D. Ghosh, *Contributing Member*, Southern Nuclear

PROJECT TEAM ON SECTION GG: SCRUBBERS

T. B. Axley, Jr., *Chair*, North Wind Group
J. O. Bettle, U.S. Nuclear Regulatory Commission
D. M. Dykes, Consultant
M. R. Hargan, Hargan Engineering
R. T. Jubin, Oak Ridge National Laboratory
D. Ryland, Canadian Nuclear Laboratories
N. Soelberg, Idaho National Laboratory
M. Bauer, *Contributing Member*, Westinghouse Electric Germany GmbH
R. Cowen, *Contributing Member*, GE Hitachi
W. P. Drosjack, *Contributing Member*, Retired
D. Ghosh, *Contributing Member*, Southern Nuclear

PROJECT TEAM ON SECTION GH: CYCLONES

T. B. Axley, Jr., *Vice Chair*, North Wind Group
J. O. Bettle, U.S. Nuclear Regulatory Commission
D. M. Dykes, Consultant
R. T. Jubin, Oak Ridge National Laboratory
R. Cowen, *Contributing Member*, GE Hitachi
W. P. Drosjack, *Contributing Member*, Retired

SUBCOMMITTEE ON GENERAL SUPPORT SERVICES

J. C. Royer, *Chair*, Sargent & Lundy, LLC
R. K. Aggarwal, *Vice Chair*, Sargent & Lundy, LLC
J. O. Bettle, U.S. Nuclear Regulatory Commission
M. A. Doersam, Ellis & Watts Global Industries, Inc.
R. Flye, Consultant
D. J. Grover, Consultant
S. Khabir, Washington River Protection Solutions/Hanford
K. G. Nelson, Porvair Filtration Group, Inc.
G. Roca, Westinghouse Electric Spain
T. J. Schaefer, Sargent & Lundy, LLC
M. Sulva, APTIM — Kings Bay Support Services, LLC
T. Vogan, Sargent & Lundy, LLC
W. F. Williams, AREVA Inc.
R. Blose, *Contributing Member*, SSM Industries, Inc.
N. Galante, *Contributing Member*, AAF International

PROJECT TEAM SYSTEMS DESIGN

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R. K. Aggarwal, Sargent & Lundy, LLC
B. C. Elliott, Super Radiator Coils
N. Galante, AAF International
D. Ghosh, Southern Nuclear
D. Gibbs, Camfil USA, Inc.
L. Krooswyk, Burns & McDonnell
G. Roca, Westinghouse Electric Spain
A. Soma, Camfil USA, Inc.
M. Sulva, APTIM — Kings Bay Support Services, LLC

SUBCOMMITTEE ON TECHNOLOGY

A. Soma, *Chair*, Camfil USA, Inc.
N. S. Zaremba, *Vice Chair*, Newport News Shipbuilding
R. K. Aggarwal, Sargent & Lundy, LLC
T. B. Axley, Jr., North Wind Group
E. M. Banks, NUCON International, Inc.
M. A. Doersam, Ellis & Watts Global Industries, Inc.
C. Fosseen, Newport News Shipbuilding
D. Ghosh, Southern Nuclear
C. E. Graves, NUCON International, Inc.
J. R. Kriskovich, Kurion, Inc.
J. C. Medley, Nevada National Security Site
D. P. Nguyen, U.S. Army Edgewood Chemical Biological Center
J. C. Royer, Sargent & Lundy, LLC
R. R. Sommer, NUCON International, Inc.
M. T. Sorna, Puget Sound Naval Shipyard
C. B. Summers, NUCON International, Inc.
T. J. Vogan, Sargent & Lundy, LLC
C. A. Waggoner, Mississippi State University — Institute for Clean Energy Technology
T. Wander, AAF International
J. Webb, Y-12 National Security Complex
G. L. Laws, *Contributing Member*, Washington State Department of Health, Office of Radiation Protection

SUBCOMMITTEE ON TESTING AND INSPECTION

N. S. Zaremba, *Chair*, Newport News Shipbuilding
S. Khabir, *Vice Chair*, Washington River Protection Solutions/Hanford
E. M. Banks, NUCON International, Inc.
S. Barnette, U.S. Department of Energy
S. M. Cox, NCS Corp.
K. S. Eng, U.S. Army Research, Development and Engineering Command
R. Flye, Consultant
C. Fosseen, Newport News Shipbuilding
R. Giberson, Clayton Associates, Inc.
M. R. Hahn, U.S. Department of Energy
G. L. Laws, Washington State Department of Health, Office of Radiation Protection
J. Levinson, BWX Technologies, Inc.
J. S. MacMurray, Savannah River National Laboratory
E. McCormick, Washington State Department of Health, Radioactive Air Emissions
J. C. Medley, Nevada National Security Site
B. Prinkey, NCS Corp.
G. G. Pyle, Knolls Atomic Power Laboratory
A. Salvatore, U.S. Army Research, Development and Engineering Command, Chemical Biological Center
D. Schoepflin, Pacific Northwest National Laboratory
R. R. Sommer, NUCON International, Inc.
M. T. Sorna, Puget Sound Naval Shipyard
T. Wander, AAF International
J. Webb, Y-12 National Security Complex
D. P. Nguyen, *Contributing Member*, U.S. Army Edgewood Chemical Biological Center
G. D. Singleton, *Contributing Member*, AAF International

SUBCOMMITTEE ON VENTILATION AIR CONDITIONING EQUIPMENT

D. Ghosh, *Chair*, Southern Nuclear
M. J. Fox, *Vice Chair*, ECU Corp.
T. B. Axley, Jr., North Wind Group
B. C. Elliott, Super Radiator Coils
S. J. Fackleman, Ellis & Watts Global Industries
M. R. Hargan, Hargan Engineering
G. Roca, Westinghouse Electric Spain
T. J. Schaefer, Sargent & Lundy, LLC
C. Wojcik, PMT Nuclear
W. P. Drosjack, *Contributing Member*, Retired
R. Kim, *Contributing Member*, Finetec Century America, Inc.
R. N. Knoche, *Contributing Member*, Consultant
I. Kutuzov, *Contributing Member*, Alfa Laval, Inc. (Canada)

CORRESPONDENCE WITH THE COMMITTEE ON NUCLEAR AIR AND GAS TREATMENT

General. ASME Standards are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Code may interact with the Committee by requesting interpretations, proposing revisions or a case, and attending Committee meetings. Correspondence should be addressed to:

Secretary, Standards Committee on Nuclear Air and Gas Treatment
The American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990
http://go.asme.org/Inquiry

Proposing Revisions. Revisions are made periodically to the Code to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Code. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Code. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Proposing a Case. Cases may be issued to provide alternative rules when justified, to permit early implementation of an approved revision when the need is urgent, or to provide rules not covered by existing provisions. Cases are effective immediately upon ASME approval and shall be posted on the ASME Committee web page.

Requests for Cases shall provide a Statement of Need and Background Information. The request should identify the Code and the paragraph, figure, or table number(s), and be written as a Question and Reply in the same format as existing Cases. Requests for Cases should also indicate the applicable edition(s) of the Code to which the proposed Case applies.

Interpretations. Upon request, the Standards Committee on Nuclear Air and Gas Treatment (CONAGT) will render an interpretation of any requirement of the Code. Interpretations can only be rendered in response to a written request sent to the Secretary of CONAGT.

Requests for interpretation should preferably be submitted through the online Interpretation Submittal Form. The form is accessible at http://go.asme.org/InterpretationRequest. Upon submittal of the form, the Inquirer will receive an automatic e-mail confirming receipt.

If the Inquirer is unable to use the online form, he/she may mail the request to the Secretary of CONAGT at the above address. The request for an interpretation should be clear and unambiguous. It is further recommended that the Inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry in one or two words.
Edition:	Cite the applicable edition of the Code for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. Please provide a condensed and precise question, composed in such a way that a "yes" or "no" reply is acceptable.
Proposed Reply(ies):	Provide a proposed reply(ies) in the form of "Yes" or "No," with explanation as needed. If entering replies to more than one question, please number the questions and replies.
Background Information:	Provide the Committee with any background information that will assist the Committee in understanding the inquiry. The Inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in the format described above may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

Moreover, ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Code requirements. If, based on the inquiry information submitted, it is the opinion of the Committee that the Inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME Committee or Subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

Attending Committee Meetings. CONAGT regularly holds meetings and/or telephone conferences that are open to the public. Persons wishing to attend any meeting and/or telephone conference should contact the Secretary of CONAGT.

ORGANIZATION OF ASME AG-1

(19)

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
- Section AB: System Design Guide

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 for Air-Cleaning Equipment
- Section FH: Other Adsorbers
- Section FI: Metal Media Filters
- Section FJ: Low Efficiency Filters
- Section FK: Special HEPA Filters
- Section FL: Deep Bed Sand Filters
- Section FM: High-Strength HEPA Filters
- Section FN: Filter Media: High Efficiency
- Section IA: Instrumentation and Controls

Division III: Process Gas Treatment
- Section GA: Heat Exchangers
- Section GB: Noble Gas Hold-Up Equipment
- Section GC: Gas Compressors and Exhausters
- Section GE: Hydrogen Recombiners and Igniters
- Section GF: Gas Sampling
- Section GG: Scrubbers
- Section GH: Cyclones
- Section GJ: Filters
- Section GK: Mist Eliminators
- Section GM: Noble Gas Hold-Up Media

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 lowercase letters in parentheses to major subparagraph numbers, such as BA-1111.1(a) or RA-1111.2(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-1-2019
SUMMARY OF CHANGES

Following approval by the ASME AG Committee and ASME, and after public review, ASME AG-1-2019 was approved by the American National Standards Institute on August 8, 2019.

ASME AG-1-2019 includes the following changes identified by a margin note, **(19)**.

Page	*Location*	*Change*
xlv	Organization of ASME AG-1	Paragraph 1 revised
1	AA-1400	Definitions of *manufacturer's qualified standard or material* and *safe shutdown earthquake* editorially revised
27	AA-6324.3	Paragraph editorially revised
27	AA-6324.4	Paragraph editorially revised
30	AA-6511	First sentence editorially revised
39	Table AA-10540-1	Table editorially revised
41	Article AA-A-3000	Editorially revised
50	AA-A-7311	Editorially revised
60	Article AA-C-2000	Editorially revised
62	Section AB	Added
75	BA-1400	Definitions of *axial fans*, *fan arrangement number*, *inlet/outlet cones*, and *stall/surge limit* editorially revised
78	BA-4121	Editorially revised
86	BA-A-1400	Editorially revised
91	DA-1480	Definition of *fire damper construction* editorially revised
99	Article DA-9000	Title editorially revised
99	DA-9100	Title editorially revised
102	Figure DA-II-1000-2	Title added
102	Figure DA-II-1000-3	Title added
103	Figure DA-II-1000-4	Title added
103	Figure DA-II-1000-5	Title added
104	Figures DA-II-1000-6	Title added
108	Table DA-A-1000-1	For DA-9000, Item editorially revised
110	SA-1400	(1) Definitions of *accessories* and *grille* editorially revised (2) *damper, splitter* editorially revised to *splitter damper* and its definition editorially revised
115	SA-4410	In subpara. (b), second sentence editorially revised
115	SA-4430	First sentence editorially revised
115	SA-4451	Subparagraphs (c)(1) through (c)(3) editorially revised
116	SA-4455	Added
116	SA-4533	Editorially revised
119	SA-6122	Editorially revised

Page	*Location*	*Change*
122	Table SA-6400-2	In first row, entry in first column corrected by errata to read “Less than 12”
123	Table SA-6400-3	Definition of *t* revised
126	Article SA-B-1000	Title added
126	SA-B-1100	First sentence editorially revised
126	SA-B-1221	First sentence editorially revised
133	SA-B-1233	In subpara. (c), reference editorially revised
133	SA-B-1234	(1) First sentence editorially revised (2) Reference to CFR editorially revised
137	SA-B-1330	In third paragraph, second sentence editorially revised
142	Article SA-C-1000	Title added
142	SA-C-1100	References editorially revised
142	SA-C-1210	In subpara. (a)(1), second sentence editorially revised
143	SA-C-1300	Second sentence revised
143	Table SA-C-1300-1	Title added
146	Article HA-2000	AISI S100 added
147	HA-4211	Definition of *hydrostatic load* editorially revised
148	HA-4220	First paragraph editorially revised
149	HA-4248	Revised
150	HA-4434	Last sentence editorially revised
151	HA-4444	Added
153	HA-5310	Title editorially revised
154	HA-6214	Last sentence editorially revised
155	HA-6312	Editorially revised
158	Article HA-B-1000	Title added
158	HA-B-1100	Editorially revised
158	HA-B-1210	In subpara. (a), second sentence editorially revised
158	HA-B-1220	Subparagraphs (a) through (c) editorially revised
160	Article HA-C-1000	Title added
160	HA-C-1100	Title added
161	HA-C-1430	Last sentence editorially revised
167	Article HA-D-1000	Title added
167	HA-D-1300	Paragraph HA-D-1330 deleted
167	HA-D-1350	Second paragraph editorially revised
168	HA-D-1720	Last sentence editorially revised
169	Section RA	Revised in its entirety
212	CA-5220	In subpara. (a), quotation marks around second sentence deleted
218	Table CA-A-1000-1	For CA-9000, Item editorially revised
222	Table FA-4100-1	U.S. Customary symbols for values editorially revised
222	Figure FA-4100-1	Callouts editorially revised
226	FB-1400	In first paragraph, cross-reference editorially revised to AA-1400
231	FC-1400	(1) Definition of *available-to-flow medium area* added (2) Definition of *medium face velocity* revised (3) Definition of *most penetrating particle size* deleted
231	Article FC-2000	Revised

Page	*Location*	*Change*
232	FC-3110	Revised
232	FC-3111	(1) Subparagraph (c) corrected by errata to read “B18.21.1/ B18.21.2M (2) Subparagraphs (e) through (h) deleted (3) Subparagraphs (i) through (k) revised and redesignated as (e) through (g)
232	FC-3121	Revised
232	FC-3122	Revised
233	FC-3130	Cross-reference revised
233	FC-3140	Revised
233	FC-3160	Subparagraph (b) editorially revised
233	FC-3170	Added
233	FC-3210	Editorially revised
233	FC-4110	Subparagraph (b) revised
234	Figure FC-4110-1	Revised
234	Figure FC-4110-2	Revised in its entirety
235	Figure FC-4110-3	Revised
233	FC-4130	(1) In subpara. (c), value of crest-to-crest contacts variation revised (2) Value in last sentence of subpara. (d) revised
237	FC-4141	Revised
237	FC-4142	Revised
237	Figure FC-4142-1	Revised
237	FC-4151	(1) In subpara. (b), last Celsius temperature revised (2) In subpara. (c), reference revised
238	FC-4200	Subparagraph (e) revised
238	FC-4300	Revised
238	FC-5100	Revised in ts entirety
239	FC-5130	First pragraph revised
239	FC-5140	Last paragraph revised
240	Table FC-5140-1	Second column revised
240	FC-5160	Second and third paragraphs revised
240	FC-5200	Revised
241	FC-6211	Revised
241	FC-6212	Revised
241	Article FC-7000	Revised
241	Article FC-9000	Title revised
241	FC-9100	Revised in its entirety
242	Mandatory Appendix FC-I	Deleted
243	Table FC-A-1000-1	For FC-9000, Item revised
247	FD-4320	Subparagraph (c) editorially revised
249	FD-6400	Editorially revised
249	FD-7300	Subparagraph (b) editorially revised
252	Article FD-II-1000	Title added
252	FD-II-1300	Definition of *test tray assembly* editorially revised
252	Article FD-II-2000	In last paragraph, first sentence editorially revised

Page	*Location*	*Change*
255	Table FD-A-1000-1	For FD-9000, Item editorially revised
256	FE-1400	First paragraph revised
257	FE-4110	Editorially revised
261	FE-4621	Revised
263	FE-9100	First sentence editorially revised
265	Article FE-II-3000	Editorially revised
266	FE-III-4300	In second paragraph, first sentence editorially revised
268	Article FE-IV-3000	(1) Fifth paragraph and subparas. (a) through (e) editorially revised (2) In eighth paragraph, second sentence editorially revised
269	Figure FE-IV-3000-1	Title added
270	Figure FE-IV-4100-1	Title added
270	FE-IV-4500	Last sentence editorially revised
271	Article FE-V-1000	Title added
271	Article FE-V-2000	Last paragraph editorially revised
273	FE-A-1300	Editorially revised
273	FE-A-1400	Subparagraph (c) editorially revised
277	FF-5213	Editorially revised
278	Article FF-9000	Title editorially revised
279	Table FF-A-1000-1	For FF-9000, Item editorially revised
280	FG-1200	Revised
284	FG-4220	Editorially revised
284	FG-4310	Last paragraph editorially revised
285	FG-4330	References editorially revised
294	FH-4230	Third paragraph editorially revised
297	FH-6400	Editorially revised
299	Table FH-A-1000-1	For FH-9000, Item editorially revised
301	FJ-1400	Definition of "MERV" deleted
302	FJ-5110	Editorially revised in its entirety
305	Table FJ-A-1000-1	For FJ-9000, Item editorially revised
306	FK-1330	First sentence editorially revised
306	FK-1400	Definition of *most penetrating particle size* deleted
308	FK-3130	Revised
308	FK-3160	Subparagraphs (a) and (b) editorially revised
309	FK-3170	Second sentence editorially revised
309	Table FK-4111-1	U.S. Customary unit for maximum resistance editorially revised
310	FK-4112	First and third paragraphs editorially revised
315	Table FK-4112-1	U.S. Customary unit for maximum resistance editorially revised
313	FK-4131	Editorially revised
317	FK-5140	Second paragraph editorially revised
318	FK-5150	Third paragraph editorially revised
318	FK-5160	Third paragraph editorially revised
318	FK-5200	Fifth paragraph editorially revised
320	FK-5260	Third paragraph editorially revised
321	FK-5410	U.S. Customary unit editorially revised

Page	*Location*	*Change*
321	FK-5440	Second and fourth paragraphs editorially revised
321	FK-5450	Third paragraph editorially revised
322	FK-5460	Third paragraph editorially revised
323	Article FK-9000	Subparagraph (f) editorially revised
326	FL-1400	Definition of *design life* editorially revised
326	Article FL-2000	Reference to Industrial Ventilation added
329	FL-4210	Subparagraphs (b), (c), (d), and (e) editorially revised
331	FL-5120	First sentence editorially revised
332	FL-5232	Reference editorially revised
333	FL-6340	Reference editorially revised
335	Mandatory Appendix FL-I	Title revised
335	Article FL-I-4000	Title revised
336	FL-I-4200	Subparagraph (b) editorially revised
337	Mandatory Appendix FL-II	Title revised
337	FL-II-3100	Subparagraph (c) editorially revised
337	FL-II-3200	Title revised
343	FL-B-4210	Second sentence editorially revised
345	Section FN	Added
354	IA-4110	Editorially revised
358	IA-5220	Editorially revised
358	IA-5230	Editorially revised
359	IA-6100	Editorially revised
360	IA-9100	Editorially revised
364	Article IA-C-1000	Title added
366	Article GA-2000	In first paragraph, cross-reference revised
371	GA-4412	Editorially revised
375	GA-5220	Editorially revised
376	GA-6100	Subparagraph (a) editorially revised
377	GA-7100	Subparagraph (d) editorially revised
382	Article GA-B-1000	Title added
384	Article GC-2000	Contents of GC-2100 moved to Article GC-2000 and its heading editorially deleted
387	GC-4152.1	Title and first sentence editorially revised
387	GC-4211.5	Editorially revised
397	Table GC-A-1000-1	For GC-9400, Item editorially revised
399	Section GD	Deleted
400	GE-1400	Definitions of *design-basis accident* and *thermal/active recombiner* editorially revised
404	GE-4410	Subparagraph (a) editorially revised
411	GE-C-1100	Editorially revised
411	GE-C-1120	Subparagraph (b) editorially revised
415	Section GI	Deleted
418	Section GL	Deleted
420	GM-5210	Subparagraph (b) editorially revised
420	GM-7100	First sentence editorially revised

Page	*Location*	*Change*
421	GM-7320	Expression of transmission rate editorially revised
422	Article GM-9000	Title editorially revised
422	GM-9100	First sentence editorially revised
424	GM-B-1200	Editorially reformatted
426	Article GM-B-5000	Editorially revised
429	TA-1300	First sentence editorially revised
429	TA-1400	Definitions of *challenge gas* and *test canister* editorially revised
434	TA-4140	Editorially revised
434	TA-4160	Editorially revised
437	TA-4440	First sentence editorially revised
438	TA-4540	Editorially revised
439	TA-4550	Last sentence corrected by errata to read "TA-4551 through TA-54559"
439	TA-4560	Editorially revised
439	Table TA-4610-1	First column head editorially revised
440	Table TA-4710-1	First column head editorially revised
444	Article TA-I-1000	Title editorially revised
446	Mandatory Appendix TA-II	Title revised
446	Article TA-II-1000	Title editorially revised and first sentence revised
446	Article TA-II-4000	Title revised
447	Mandatory Appendix TA-III	Title revised
447	Article TA-III-1000	Title editorially revised and first sentence revised
447	Article TA-III-4000	Title revised
449	Mandatory Appendix TA-IV	Title revised
449	Article TA-IV-1000	Title editorially revised and first sentence revised
449	Article TA-IV-2000	Editorially revised
449	Article TA-IV-3000	Editorially revised
449	Article TA-IV-4000	Title revised and subpara. (c) editorially revised
450	Mandatory Appendix TA-V	Title revised
450	Article TA-V-1000	Title editorially revised and first sentence revised
450	Article TA-V-4000	Title revised
452	Mandatory Appendix TA-VI	Title revised
452	Article TA-VI-1000	Title editorially revised and first sentence revised
452	Article TA-VI-4000	Title revised
453	Mandatory Appendix TA-VII	Title revised
453	Article TA-VII-1000	Title editorially revised and first sentence revised
453	Article TA-VII-4000	Title revised and subpara. (c) editorially revised
454	Mandatory Appendix TA-VIII	Title revised
454	Article TA-VIII-4000	Title revised
454	TA-VIII-4000	Title revised
454	TA-VIII-4100	Title revised
456	Nonmandatory Appendix TA-A	Title revised
456	Article TA-A-1000	Revised
456	Article TA-A-4000	Title revised

Page	*Location*	*Change*
457	Article TA-B-1000	Title editorially added
458	TA-C-1000	Title editorially added
458	TA-C-1100	Editorially revised
458	TA-C-1200	Editorially revised

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Division I
General Requirements

SECTION AA
COMMON ARTICLES

ARTICLE AA-1000
INTRODUCTION

AA-1100 SCOPE

This Code provides requirements for the performance, design, fabrication, installation, inspection, acceptance testing, and quality assurance of equipment used in air and gas treatment systems in nuclear facilities.

AA-1200 PURPOSE

The purpose of this Code is to ensure that equipment used in nuclear facilities for air and gas treatment systems is acceptable in all aspects of design and operation.

AA-1300 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.

The requirements of ASME AG-1 for air and gas treatment components may be used for engineered safety features systems and normal systems in nuclear power generation facilities, and for air cleaning systems in other nuclear facilities. The design and procurement specifications shall delineate the design, qualification, and quality assurance requirements appropriate for the application.

(19) AA-1400 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 Article.

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 (cfm, acfm, scfm, acms, scms): expressed in terms of cubic feet of air per minute (cfm). Actual cfm (acfm) is a cubic foot of air with a density at actual existing conditions. Standard cfm (scfm) is a cubic foot of air with a standard density. The terms “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 attesting that the materials are in accordance with specified requirements.

certificate of conformance: a document signed or otherwise authenticated by an authorized individual certifying the degree to which items or services meet specified requirements.

Certified Material Test Report (CMTR): a document provided by the Material Manufacturer or Material Supplier and signed by an authorized individual that contains sufficient data and information to verify the physical and chemical properties of the furnished material.

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; 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 component that serves to control and limit the consequences of releases of energy and radioactivity.

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 the Owner's 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 1,000 cycles due to a localized stress concentration.

manufacturer's qualified standard or material: a standard or material used by a particular manufacturer that 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.

nuclear safety function: a term applying to any component, system, or structure performing a 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

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 functions 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 airflow 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.

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

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

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

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.

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

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 that, through the use of applicable and recognized mathematical techniques, verifies 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 structural elements used to 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 gauge: 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

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. Individual facilities may be designed to different editions and addenda of the documents than those listed below. It is the responsibility of the end user to reconcile the design basis edition and addenda of these documents to the editions and addenda provided herein.

AISC 325, Steel Construction Manual, 13th edition
Specification for the Design, Fabrication and Erection of Structural Steel for Buildings, ninth edition
Publisher: American Institute of Steel Construction (AISC), 130 East Randolph Street, Suite 2000, Chicago, IL 60601 (www.aisc.org)

AISI D100-08, Cold-Formed Steel Design Manual, 2008 edition
Publisher: American Iron and Steel Institute (AISI), 2000 Town Center, Southfield, MI 48075 (www.steel.org)

ASHRAE 52.2, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size
ASHRAE Terminology: A Comprehensive Glossary of Terms for the Built Environment, www.ashrae.org/ashraeterms
Publisher: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329 (www.ashrae.org)

ASME B31.1, Power Piping
ASME Boiler and Pressure Vessel Code ("ASME BPVC")
Section II, Materials
Section III, Rules for Construction of Nuclear Facility Components
Section V, Nondestructive Examination
Section VIII, Rules for Construction of Pressure Vessels, Division 1
Section IX, Qualification Standard for Welding, Brazing, and Fusing Procedures; Welders; Brazers; and Welding, Brazing, and Fusing Operators
ASME NQA-1, Quality Assurance Requirements for Nuclear Facility Applications
Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990 (www.asme.org)

ASNT SNT-TC-1A-2006, Recommended Practice for Personal Qualification and Certification in Nondestructive Testing
Publisher: American Society for Nondestructive Testing (ASNT), 1711 Arlingate Lane, P.O. Box 28518, Columbus, OH 43228-0518 (www.asnt.org)

ASTM A370A-2007, Standard Test Methods and Definitions for Mechanical Testing of Steel Products
ASTM A380-2006, Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
ASTM D3843-2000 (R2008), Standard Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities
ASTM D4227-2005, Standard Practice for Qualification of Coating Applicators for Application of Coatings to Concrete Surfaces
ASTM D4228-2005, Standard Practice for Qualification of Coating Applicators for Application of Coatings to Steel Surfaces
ASTM D4537A-2004, Standard Guide for Establishing Procedures to Qualify and Certify Personnel Performing Coating and Lining Work Inspection in Nuclear Facilities
ASTM D5161A-2004, Standard Guide for Specifiying Inspection Requirements for Coating and Lining Work (Metal Substrates)
ASTM E165-2009, Standard Practice for Liquid Penetrant Examination for General Industry
Manual of Coating Work for Light-Water Nuclear Power Plant Primary Containment and Other Safety-Related Facilities, first edition, Chapter 8, 1979
Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 (www.astm.org)

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, Specification for Filler Metals for Brazing and Braze Welding
AWS C1.1/C1.1M-2000 (R2006), Recommended Practices for Resistance Welding
AWS C3.3-2008, Recommended Practices for Design, Manufacture, and Examination of Critical Brazed Components
AWS D1.1/D1.1M-2008, Structural Welding Code — Steel
AWS D1.3/D1.3M-2008, Structural Welding Code — Sheet Steel
AWS D1.6/D1.6M-2007, Structural Welding Code — Stainless Steel
AWS D9.1/D9.1M-2007, Sheet Metal Welding Code
AWS Z49.1-2005, Safety in Welding, Cutting and Allied Processes
Publisher: American Welding Society (AWS), 8669 NW 36 Street, No. 130, Miami, FL 33166 (www.aws.org)

DOE HDBK-1169-2003, Nuclear Air Cleaning Handbook
Publisher: U.S. Department of Energy, 1000 Independence Avenue SW, Washington, DC 20585 (www.energy.gov)

ERDA 76-21 (1976), Nuclear Air Cleaning Handbook
Publisher: National Technical Information Service, 5301 Shawnee Road, Alexandria, VA 22312 (www.ntis.gov)

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

IEEE 323-2003, 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 Qualification of Class 1E Equipment for Nuclear Power Generating Stations
Publisher: Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Lane, Piscataway, NJ 08854 (www.ieee.org)

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); Department of Energy, Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831 (www.osti.gov)

NEMA MG-1-2006, Motors and Generators
Publisher: National Electrical Manufacturers Association (NEMA), 1300 North 17th Street, Rosslyn, VA 22209 (www.nema.org)

PS 1-07, Structural Plywood
Publisher: APA — The Engineered Wood Association (formerly American Plywood Association), 7011 South 19th Street, Tacoma, WA 98466 (www.apawood.org)

SSPC-SP 10, Near-White Metal Blast Cleaning
Publisher: The Society for Protective Coatings (SSPC), 800 Trumbull Drive, Pittsburgh, PA 15205 (www.sspc.org)

UL 586, UL Standard for Safety High-Efficiency, Particulate, Air Filter Units
UL 900, UL Standard for Safety Air Filter Units
Publisher: Underwriters' Laboratories, Inc. (UL), 333 Pfingsten Road, Northbrook, IL 60062-2096; Order Address: Comm 2000, 151 Eastern Avenue, Bensenville, IL 60106 (www.ul.com)

ARTICLE AA-3000 MATERIALS

AA-3100 GENERAL

Materials of construction for all components and accessories shall conform to the ASME or ASTM material specifications listed in Table AA-3100-1. The latest edition of the material specification should be used, unless otherwise specified.

Each section of this Code may also delineate material requirements applicable to that section.

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 A370 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.

AA-3200 MATERIAL SUBSTITUTION

Substitute materials may be used provided they are equivalent to or exceed the stated requirements. In addition, other materials permitted by Section III of the ASME Boiler and Pressure Vessel Code (hereafter referred to as ASME BPVC) are acceptable materials. The materials selected shall be evaluated for suitability with service conditions and compatibility with other materials used in the system or component.

AA-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.

AA-3400 CERTIFICATION OF MATERIALS

The design specifications shall require that Material Manufacturers or Material Suppliers provide Certified Material Test Reports for all pressure boundary and structural materials required for proper function of the air system components. Specific requirements or additional requirements or both may be provided in each Code section.

All other components used in the construction of components and accessories shall be provided with a Manufacturer's certificate of conformance covering the ASME, ASTM, or other material specification, grade, and class, if applicable.

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-C contain guidance on implementing these rules.

Table AA-3100-1 Allowable Materials

ASME Designator	ASTM Designator	Publication Title
Carbon Steel Plate, Sheet, and Strip		
SA-36/SA-36M	A36/A36M	Standard Specification for Carbon Structural Steel
...	A242/A242M	Standard Specification for High-Strength Low-Alloy Structural Steel
SA-283/SA-283M	A283/A283M	Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates
SA-285/SA-285M	A285/A285M	Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
SA-414/SA-414M	A414/A414M	Standard Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy for Pressure Vessels
...	A514/A514M	Standard Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding
SA-515/SA-515M	A515/A515M	Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
SA-516/SA-516M	A516/A516M	Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
SA-568/SA-568M	A568/A568M	Standard Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for
...	A606	Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance
...	A635/A635M	Standard Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Alloy, Carbon, Structural, High-Strength Low-Alloy, and High-Strength Low-Alloy with Improved Formability, General Requirements for
...	A653/A653M	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
...	A659/A659M	Standard Specification for Commercial Steel (CS), Sheet and Strip, Carbon (0.16 Maximum to 0.25 Maximum Percent), Hot-Rolled
...	A879/A879M	Standard Specification for Steel Sheet, Zinc Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface
SA-1008/SA-1008M	A1008/A1008M	Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable
SA-1011/SA-1011M	A1011/A1011M	Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength
Carbon Steel Forgings and Castings		
...	A27/A27M	Standard Specification for Steel Castings, Carbon, for General Application
...	A148/A148M	Standard Specification for Steel Castings, High Strength, for Structural Purposes
SA-216/SA-216M	A216/A216M	Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
...	A668/A668M	Standard Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use
Carbon Steel Pipe, Tubing, and Fittings		
SA-53/SA-53M	A53/A53M	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
SA-105/SA-105M	A105/A105M	Standard Specification for Carbon Steel Forgings for Piping Applications
SA-106/SA-106M	A106/A106M	Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service
SA-134	A134	Standard Specification for Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over)
SA-135	A135/A135M	Standard Specification for Electric-Resistance-Welded Steel Pipe
SA-181/SA-181M	A181/A181M	Standard Specification for Carbon Steel Forgings, for General-Purpose Piping

Table AA-3100-1 Allowable Materials (Cont'd)

ASME Designator	ASTM Designator	Publication Title
Carbon Steel Pipe, Tubing, and Fittings (Cont'd)		
SA-182/SA-182M	A182/A182M	Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
SA-209/SA-209M	A209/A209M	Standard Specification for Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes
SA-234/SA-234M	A234/A234M	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
SA-335/SA-335M	A335/A335M	Standard Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service
SA-420/SA-420M	A420/A420M	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service
SA-450/SA-450M	A450/A450M	Standard Specification for General Requirements for Carbon, and Low Alloy Steel Tubes
...	A519	Standard Specification for Seamless Carbon and Alloy Steel Mechanical Tubing
SA-530/SA-530M	A530/A530M	Standard Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
Structural Carbon Steel Bars and Shapes		
SA-36/SA-36M	A36/A36M	Standard Specification for Carbon Structural Steel
...	A108	Standard Specification for Steel Bar, Carbon and Alloy, Cold-Finished
...	A500/A500M	Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
...	A501	Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
...	A510/A510M	Standard Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel, and Alloy Steel
...	A575	Standard Specification for Steel Bars, Carbon, Merchant Quality, M-Grades
...	A576	Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality
...	A588/A588M	Standard Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point, with Atmospheric Corrosion Resistance
Stainless Steel Plate, Sheet, and Strip		
SA-240/SA-240M	A240/A240M	Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
SA-480/SA-480M	A480/A480M	Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
SA-666	A666	Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar
Stainless Steel Forgings and Castings		
SA-217/SA-217M	A217/A217M	Standard Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service
SA-351/SA-351M	A351/A351M	Standard Specification for Castings, Austenitic, for Pressure-Containing Parts
SA-484/SA-484M	A484/A484M	Standard Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings
...	A743/A743M	Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application
...	A744/A744M	Standard Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
Stainless Steel Pipe, Tubing, and Fittings		
SA-213/SA-213M	A213/A213M	Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes

Table AA-3100-1 Allowable Materials (Cont'd)

ASME Designator	ASTM Designator	Publication Title
Stainless Steel Pipe, Tubing, and Fittings (Cont'd)		
…	A269	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
SA-312/SA-312M	A312/A312M	Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
SA-376/SA-376M	A376/A376M	Standard Specification for Seamless Austenitic Steel Pipe for High-Temperature Service
SA-403/SA-403M	A403/A403M	Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings
SA-450/SA-450M	A450/A450M	Standard Specification for General Requirements for Carbon, and Low Alloy Steel Tubes
…	A511	Standard Specification for Seamless Stainless Steel Mechanical Tubing and Hollow Bar
…	A554	Standard Specification for Welded Stainless Steel Mechanical Tubing
…	A632	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service
Stainless Steel Structural Bars and Shapes		
SA-276	A276	Standard Specification for Stainless Steel Bars and Shapes
SA-479/SA-479M	A479/A479M	Standard Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
…	A493	Standard Specification for Stainless Steel Wire and Wire Rods for Cold Heading and Cold Forging
…	A555/A555M	Standard Specification for General Requirements for Stainless Steel Wire and Wire Rods
…	A580/A580M	Standard Specification for Stainless Steel Wire
…	A581/A581M	Standard Specification for Free-Machining Stainless Steel Wire and Wire Rods
…	A582/A582M	Standard Specification for Free-Machining Stainless Steel Bars
Cast Iron		
SA-47/SA-47M	A47/A47M	Standard Specification for Ferritic Malleable Iron Castings
…	A48/A48M	Standard Specification for Gray Iron Castings
…	A126	Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings
SA-536	A536	Standard Specification for Ductile Iron Castings
Nonferrous Alloys		
…	B3	Standard Specification for Soft or Annealed Copper Wire
…	B8	Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
SB-26/SB-26M	B26/B26M	Standard Specification for Aluminum-Alloy Sand Castings
…	B33	Standard Specification for Tin-Coated or Annealed Copper Wire for Electrical Purposes
SB-62	B62	Standard Specification for Composition Bronze or Ounce Metal Castings
…	B68/B68M	Standard Specification for Seamless Copper Tube, Bright Annealed
…	B75/B75M	Standard Specification for Seamless Copper Tube
…	B88	Standard Specification for Seamless Copper Water Tube
…	B88M	Standard Specification for Seamless Copper Water Tube (Metric)
SB-98/SB-98M	B98/B98M	Standard Specification for Copper-Silicon Alloy Rod, Bar and Shapes
…	B105	Standard Specification for Hard-Drawn Copper Alloy Wires for Electric Conductors
SB-108	B108	Standard Specification for Aluminum-Alloy Permanent Mold Castings
…	B122/B122M	Standard Specification for Copper-Nickel-Tin Alloy, Copper-Nickel-Zinc Alloy (Nickel Silver), and Copper-Nickel Alloy Plate, Sheet, Strip, and Rolled Bar

Table AA-3100-1 Allowable Materials (Cont'd)

ASME Designator	ASTM Designator	Publication Title
Nonferrous Alloys (Cont'd)		
SB-152	B152/B152M	Standard Specification for Copper Sheet, Strip, Plate, and Rolled Bar
SB-187/SB-187M	B187/B187M	Standard Specification for Copper, Bus Bar, Rod, and Shapes and General Purpose Rod, Bar, and Shapes
...	B206/B206M	Standard Specification for Copper-Nickel-Zinc (Nickel Silver) Wire and Copper-Nickel Alloy Wire
SB-209	B209	Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
...	B209M	Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate (Metric)
SB-210	B210/B210M	Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes
SB-211	B211/B211M	Standard Specification for Aluminum and Aluminum-Alloy Rolled or Cold Finished Bar, Rod, and Wire
SB-221	B221	Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
...	B221M	Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles and Tubes (Metric)
	B250/B250M	Standard Specification for General Requirements for Wrought Copper Alloy Wire
SB-308/SB-308M	B308/B308M	Standard Specification for Aluminum-Alloy 6061-T6 Standard Structural Profiles
...	B344	Standard Specification for Drawn or Rolled Nickel-Chromium and Nickel-Chromium-Iron Alloys for Electrical Heating Elements
Other Material		
...	A740	Standard Specification for Hardware Cloth (Woven or Welded Galvanized Steel Wire Fabric)
Bolts, Nuts, Fasteners, and Hardware		
SA-193/SA-193M	A193/A193M	Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications
SA-194/SA-194M	A194/A194M	Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
SA-307	A307	Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60 000 PSI Tensile Strength
SA-320/SA-320M	A320/A320M	Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service
SA-325	A325	Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
...	A325M	Standard Specification for Structural Bolts, Steel, Heat Treated 830 MPa Minimum Tensile Strength (Metric)
SA-354	A354	Standard Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
SA-449	A449	Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use
...	A489	Standard Specification for Carbon Steel Lifting Eyebolts
SA-563	A563	Standard Specification for Carbon and Alloy Steel Nuts
SA-574	A574	Standard Specification for Alloy Steel Socket-Head Cap Screws
Coatings		
...	A123/A123M	Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
...	A153/A153M	Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

Table AA-3100-1 Allowable Materials (Cont'd)

ASME Designator	ASTM Designator	Publication Title
Coatings (Cont'd)		
…	A308/A308M	Standard Specification for Steel Sheet, Terne (Lead-Tin Alloy) Coated by the Hot-Dip Process
…	B633	Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel
…	B766	Standard Specification for Electrodeposited Coatings of Cadmium
Gasket Materials		
…	D1056	Standard Specification for Flexible Cellular Materials — Sponge or Expanded Rubber

AA-4110 Environmental Qualification

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.

deadweight (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 due to the force created by a moving air mass in the duct where flow experiences a change in velocity (in magnitude or direction).

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, deadweight, external loads, and inertia loads.

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

normal operating pressure differential (NOPD): the maximum positive or negative pressure differential that may occur during normal plant operation, including plant start-up 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 a safe shutdown earthquake (SSE). Both orthogonal components of the horizontal seismic excitation are applied simultaneously 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-4212-1.

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

Table AA-4212-1 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.

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).

(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: 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: 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-4230-1.

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.

Table AA-4230-1 Deflection Limits

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

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-4243 Structural Attachments. Structural attachments may be of either the integral or the 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-4244 Rotating Equipment. For ductwork system design, frequency of rotating equipment shall be considered.

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 (nonstrain 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 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-4321-1 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).

Table AA-4321-1 Plate- and Shell-Type Components: Primary Stress Allowables

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

Table AA-4323-1 Linear-Type Systems: Primary Stress Allowables

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

GENERAL NOTE: NA = not applicable.

NOTES:
(1) $\overline{S}$ refers to the primary allowable stresses developed in ASME BPVC, Section III, Division 1, Subsection NF, 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.

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

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

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.

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

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

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 post-buckling failure in the plate. Buckling stresses shall be verified against Service Level D allowable values of Table AA-4323-1.

AA-4323.1 Local Yielding and Buckling. The maximum stress for the load-carrying capacity of plates shall be based on the post-buckling 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 ASME BPVC, 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 3 times the stress limits of ASME BPVC, 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 ASME BPVC, 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 ASME BPVC, 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 Functionality Requirements

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

AA-4341 Functionality 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 functionality of the equipment shall be ensured using the method outlined in AA-4350.

AA-4342 Functionality 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 Seismic Qualification Testing

AA-4351 General. Design verification by seismic qualification 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 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 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 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 their ultimate capability. The devices shall be mounted on the shake table in a manner that dynamically simulates the in-service 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 in-service 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 to test such equipment in an inoperative mode with the actual or simulated devices installed. The test shall determine the vibration response at the device location by either direct measurement at full excitation or 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 $f_c \pm \Delta f_c$, $f_c \pm 2\Delta f_c$, ... , $f_c \pm n\Delta f_c$, where Δf_c corresponds to a $\frac{1}{6}$ to $\frac{1}{3}$ octave interval, until the entire broadened 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 Figure AA-4355.3-1. 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).

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 Figure AA-4355.4-1. 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

Figure AA-4355.3-1 Sine Beat Frequency and Amplitude

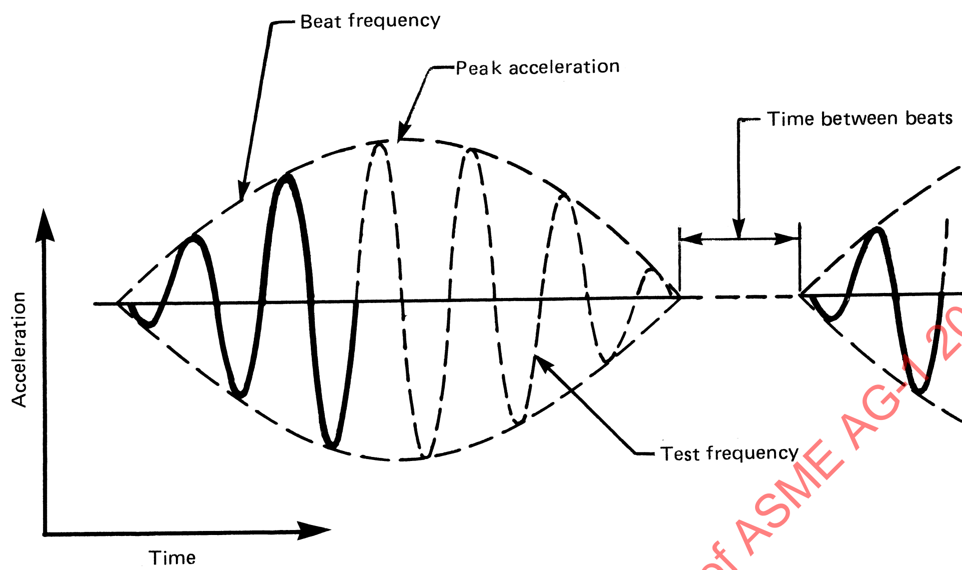

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Figure AA-4355.4-1 Sine Amplitude Decay Rate

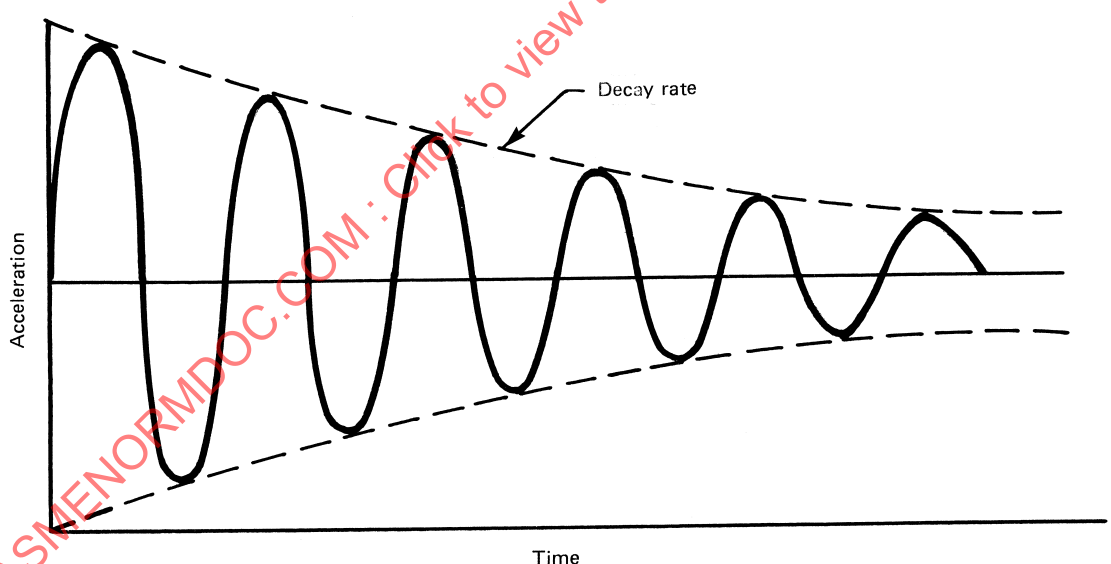

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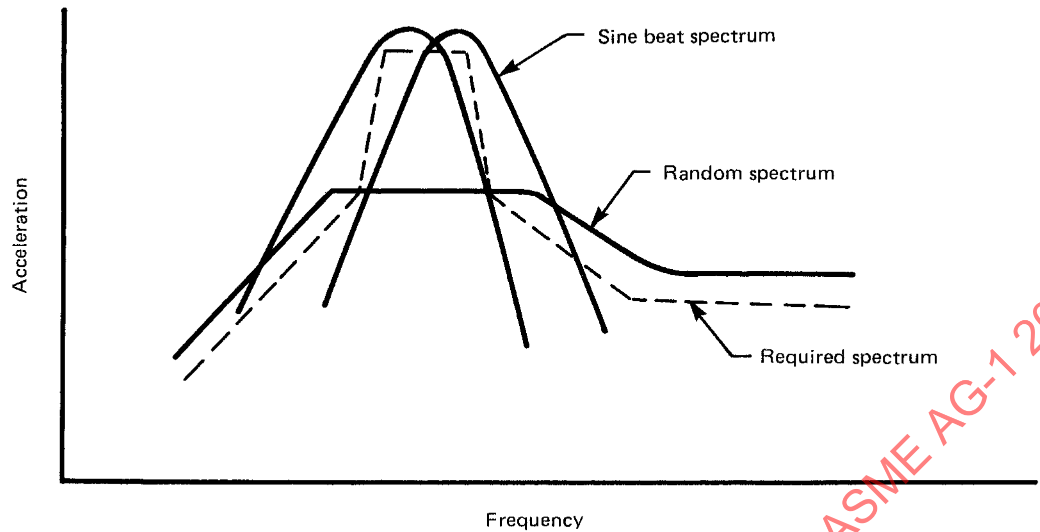
Figure AA-4356.4-1 Response Spectrum of Composite Excitation



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required input to the equipment. It shall be demonstrated that 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 ⅓ 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.

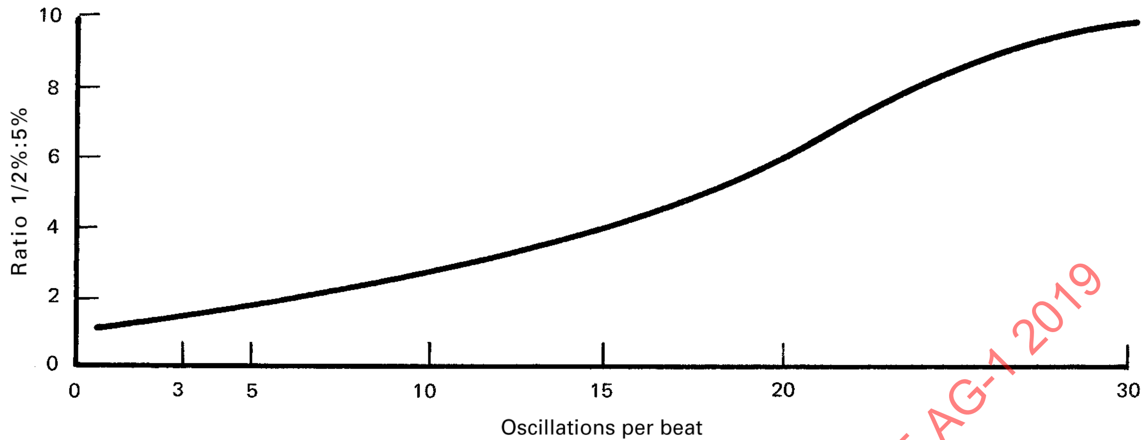
The peak value of the input excitation shall equal or exceed the ZPA of the RRS. The duration of the random excitation shall be as described in AA-4357.

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 Figure AA-4356.4-1). The optimum number of oscillations per beat shall be determined from a plot showing the ratio between the ½% and 5% spectrum damping values and the oscillations per beat, as shown in Figure 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 ⅓ 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 ½% 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 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-

Figure AA-4356.4-2 Oscillations per Beat



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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-yr-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 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 ASME BPVC, Section III, Division 1, Subsection NF, 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 of the following items:

(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 of the following items:

(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 in-service mounting; justification for all differences must be addressed

(e) method used to simulate significant in-service 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 functions as defined in AA-4431 were not compromised during or after the simulated dynamic loading

(l) results of measurements performed to verify equipment functionality

(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 fc (540 lx) for general inspection and to a minimum of 100 fc (1 080 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

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

(e) 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 ASME BPVC, Section III or Section VIII 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 do 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), locknuts, 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 anti-spatter 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 ASME BPVC, 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 BPVC, Section IX
(-b) AWS D1.1
(-c) AWS D9.1
(-d) AWS C1.1
(-e) AWS C1.3
(-f) AWS D1.3
(-g) AWS D1.6

(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 anti-spatter 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 uninjurious 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 Figure AA-6324.2-1.

AA-6324.3 The faces of fillet welds may be slightly convex, flat, or slightly concave, as shown in Figure AA-6324.2-1, illustrations (a) and (b), with none of the unacceptable profiles shown in illustration (c). (19)

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 $\frac{1}{8}$ in. (3.2 mm) in height and shall have a gradual transition to the plane of the base metal surface. See Figure AA-6324.2-1, illustration (d). They shall be free of the discontinuities shown for butt joints in illustration (e). (19)

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. ($0.5t/25.4$ mm) of weld, where t is the thinner base metal thickness

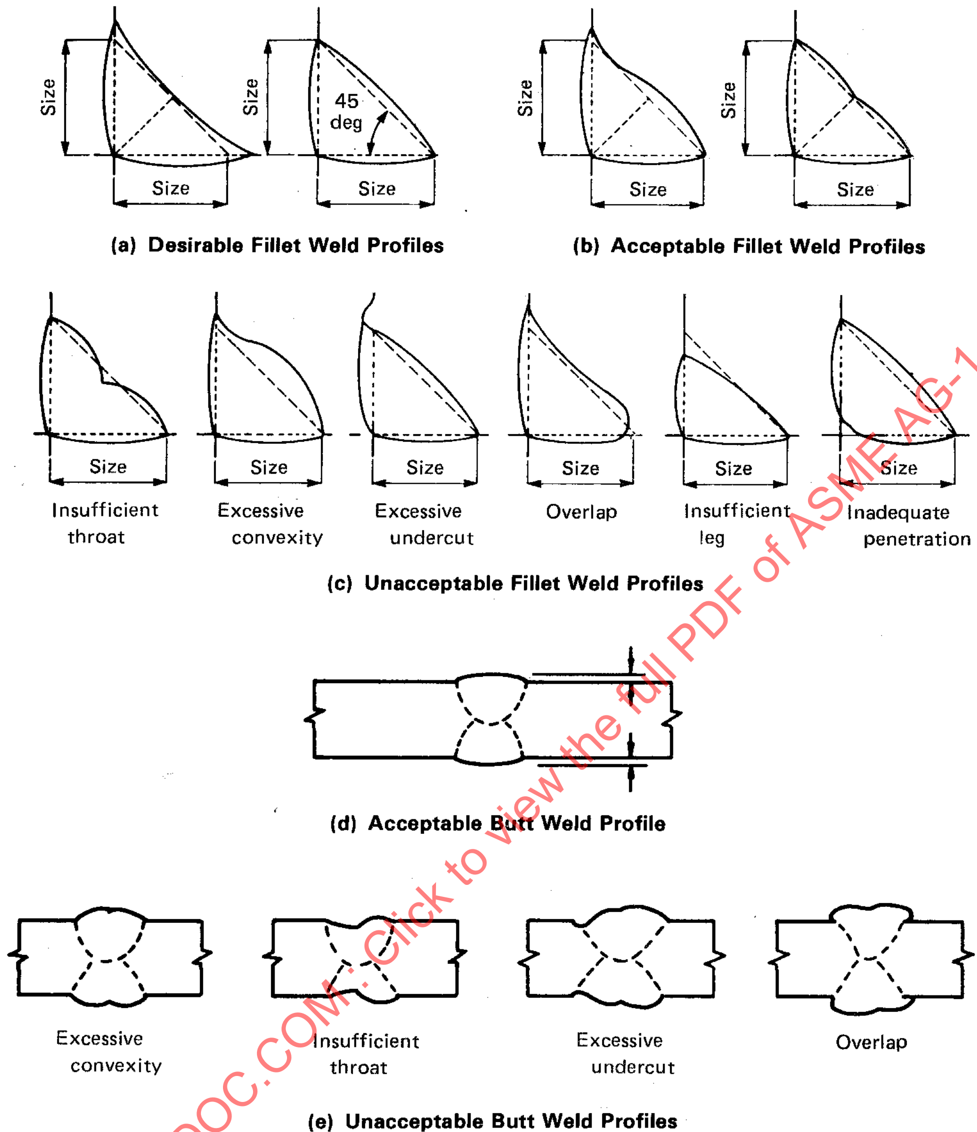
(f) undercut: no undercut exceeding $0.15t$, where t is 0.125 in. (3.2 mm) or thinner, or exceeding $\frac{1}{32}$ in. (0.79 mm), where t exceeds 0.125 in. (3.2 mm)

(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 for the Design, Fabrication and Erection of Structural Steel for Buildings and AWS D1.1.

Figure AA-6324.2-1 Acceptable and Unacceptable Weld Profiles



GENERAL NOTE: Courtesy of the American Welding Society.

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 gauge 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.

AA-6334.2 Surface inspection, when required, shall be performed using the dye penetrant method. The standard methods set forth in ASTM E165 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 ASME BPVC, Section V 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 ¼ times the base metal thickness per linear inch (25.4 mm) of weld, are permitted.

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 ASME BPVC, 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 BPVC, 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 E165 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 ASME BPVC, Section V 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. 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.

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 D5144, 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 D5144 also provides definitions for pertinent terms used for classification of coating systems within the service levels described below.

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 coatings will not fail in a manner that will compromise the function of a structure, system, or component.

AA-6511 Service Level I Areas. Service Level I areas are (19)
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 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 facilitate decontaminability in those areas outside the reactor-containment subject to radiation exposure and radionuclide contamination.

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 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 Considerations for Coating

AA-6521 General. 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 D5144 provides useful information on relevant standards for selecting, testing, and evaluating coatings for use in nuclear power plants. When possible, coating systems should complement 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 equal to or better than 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 D5144 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-PA 1, "Shop Field and Maintenance Painting"; and SSPC-PA Guide 3, "A Guide to Safety in 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 A380 before any welding.

AA-6541.2 Cleanliness of Filter Cells. Metal surfaces shall be cleaned and degreased in accordance with ASTM A380 before any welding, installation of gaskets or seal pads, and filling with adsorbent.

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

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 the 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 further mechanical or chemical surface preparation. Solvent cleaning shall be in accordance with the requirements of SSPC-SP 1. Halogen based materials or chlorinated degreasers shall not be used for surface preparation.

AA-6543.1 Surface Preparation

(a) Surface preparation of metal surfaces for air cleaning equipment and material 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-SP 10, 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) 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 for air cleaning equipment and material 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-SP 6 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.

(c) Surfaces prepared for coating shall not be allowed to deteriorate below minimum surface preparation requirements or to be contaminated in any way between completion of the preparation phase and coating application. If visible deterioration has occurred, the surface preparation shall be repeated.

AA-6543.2 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-PA 1 and to the recommendations of the coating manufacturer.

(b) Application equipment, its use, and its maintenance shall conform to the requirements of SSPC-PA 1 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 C.F.R. 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 D3843 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 C.F.R. 50, Appendix B, Criterion 9.

AA-6552 Inspection. Coating 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 D5161 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 D4537 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 D3843 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 D4227 (concrete substrates) and ASTM D4228 (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 C.F.R. 50 (2019), Appendix B, or be commercially dedicated for use in a safety-related application. ASTM D3843 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

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 its 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 Owner's 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 the Owner's 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

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 used.

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 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

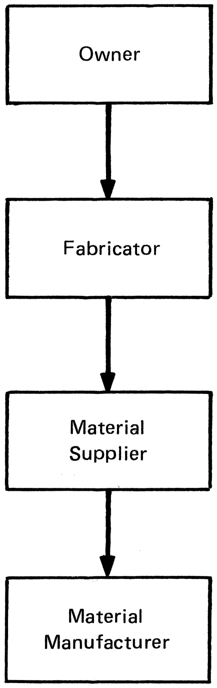
(a) Some or all of the responsibilities of lower tier organizations may be assumed by any higher tier organization (e.g., the Owner may assume some of the responsibilities, such as certifying test results, of the Material Manufacturer). The organization assuming lower tier responsibility shall meet the 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 Figure AA-8130-1 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 Figure AA-8130-1 shall be responsible for notifying the party that qualified their program of planned modifications that might affect the quality of the delivered product.

Figure AA-8130-1 Hierarchy of Responsibility



(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 their 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.

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 conformance are allowed, heat number or heat code identification need not be indicated either on the material or on 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 Conformance, as applicable. Certificates of conformance shall meet the requirements of NQA-1, Requirement 7, para. 503.

(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 (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 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 ASME BPVC. No other third party inspection or certification is required by this Code.

AA-9200 REQUIREMENTS

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

(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-9210 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-9220 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 ASME BPVC, 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 an 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 activities shall meet the requirements of the original ASME AG-1 construction Code or as allowed in (a), (b), and (c).

(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).

(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) 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) non-load-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

Table AA-10530-1 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

(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

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-10530-1 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.

AA-10540 Nonpermanent Records

The records listed in Table AA-10540-1 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-10540-1. In no case will there be a need for nonpermanent records to be maintained for longer than 10 yr after the installation is complete.

(19) **Table AA-10540-1 Nonpermanent Repair and Replacement Records**

Record	Retention Period
Quality assurance (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

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.

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-1000-1.

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.

Table AA-A-1000-1 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

(19)
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 E50, E60, or E70 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 $\frac{3}{4}$ in. (18 mm)]. Anchor bolts used to hold down a framing system may be of either 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, baseplates, 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 with either 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 Figure AA-A-7200-1. 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 Figure AA-A-4200-1. 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 Figure AA-A-4300-1. 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 Figure AA-A-4400-1. 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 Figure AA-A-4500-1. This model can be used for evaluating the equipment support for deadweight, operating loads, and dynamic loads.

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 LOADS

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

Figure AA-A-4200-1 Isometric View of a Typical Fan Model

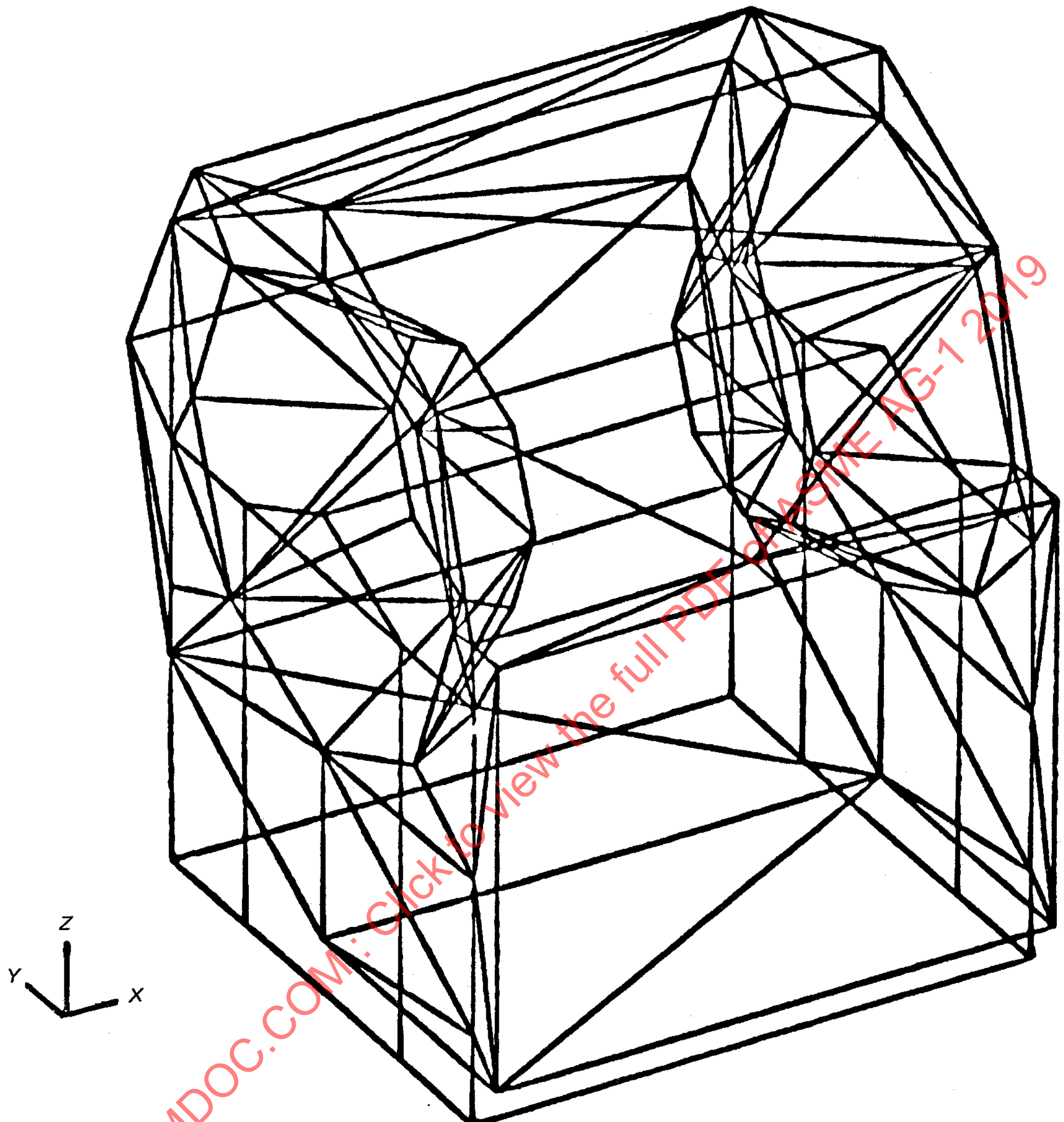


Figure AA-A-4300-1 Isometric View of a Typical I & C Cabinet Model

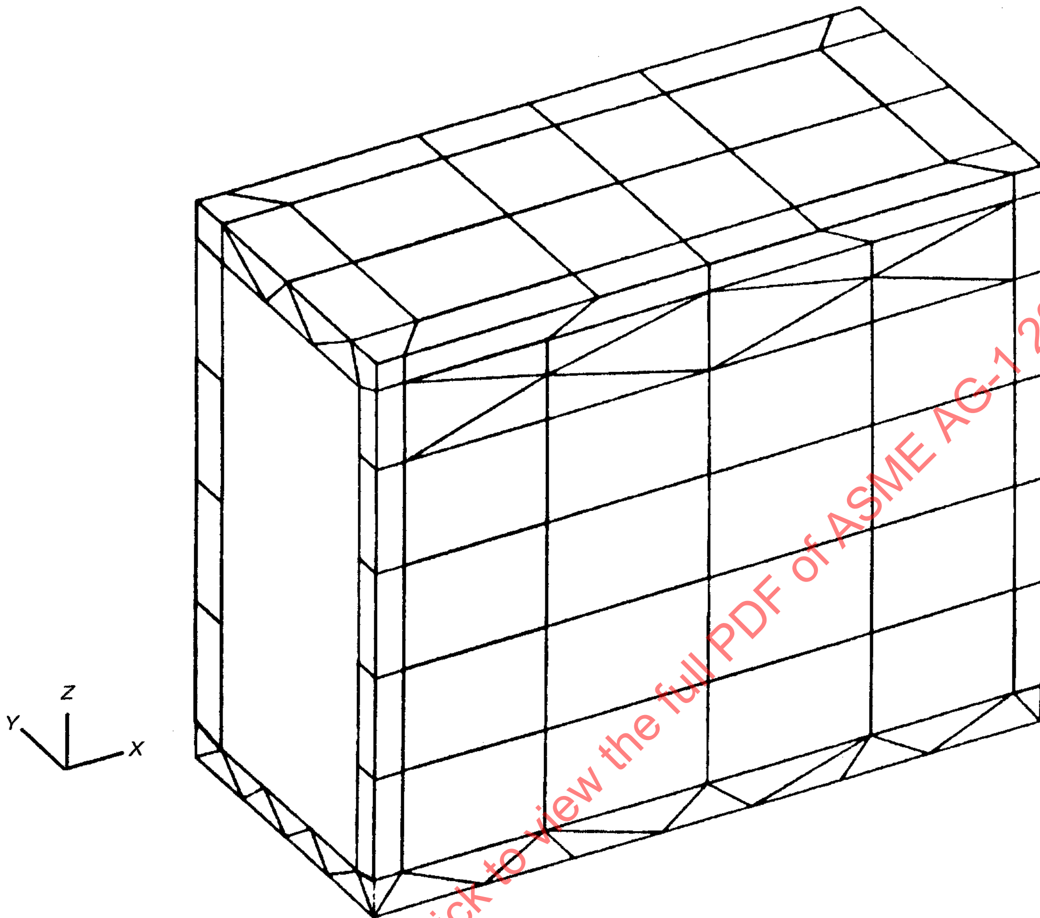


Figure AA-A-4400-1 Isometric View of a Typical Duct Support Model

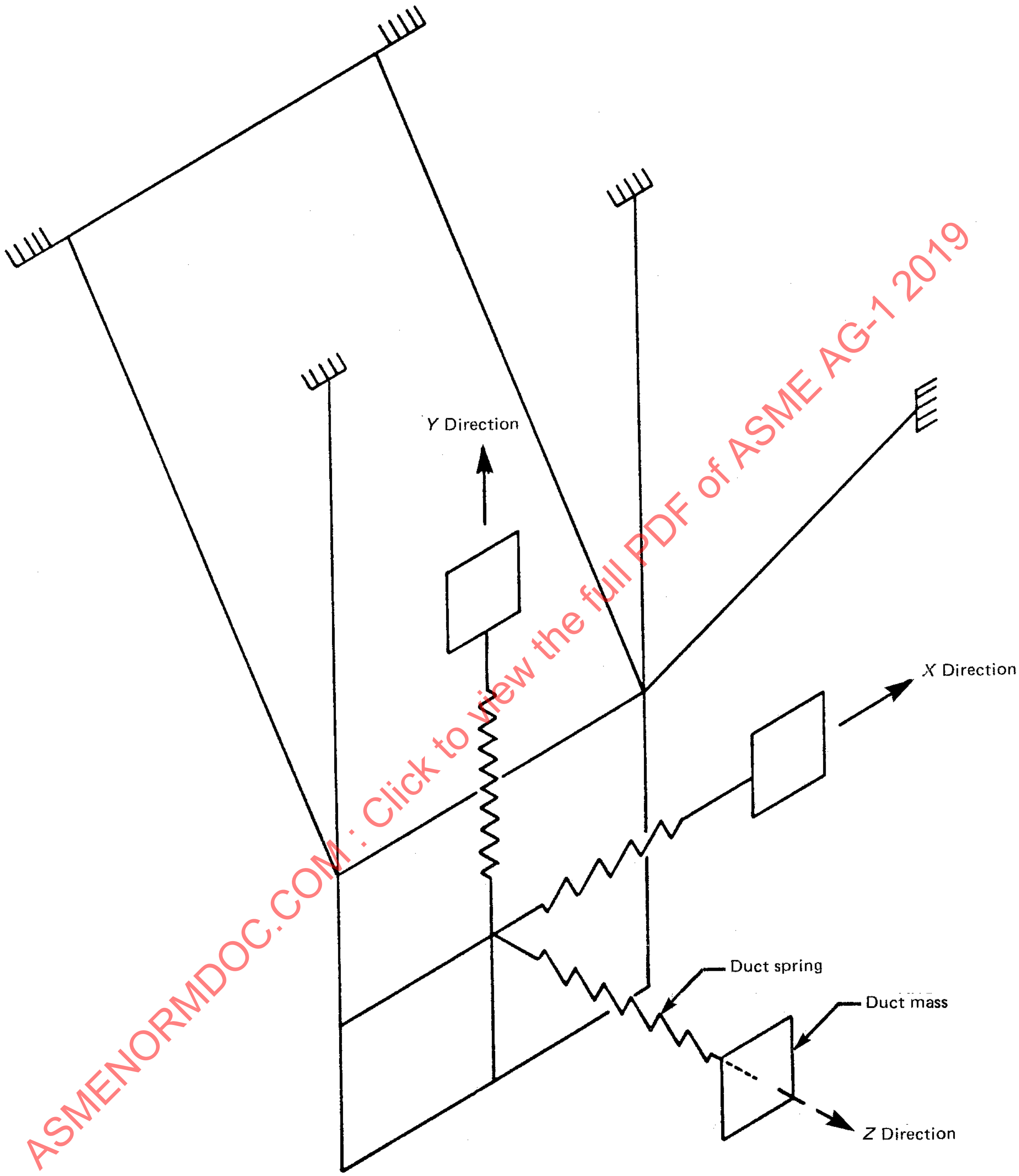
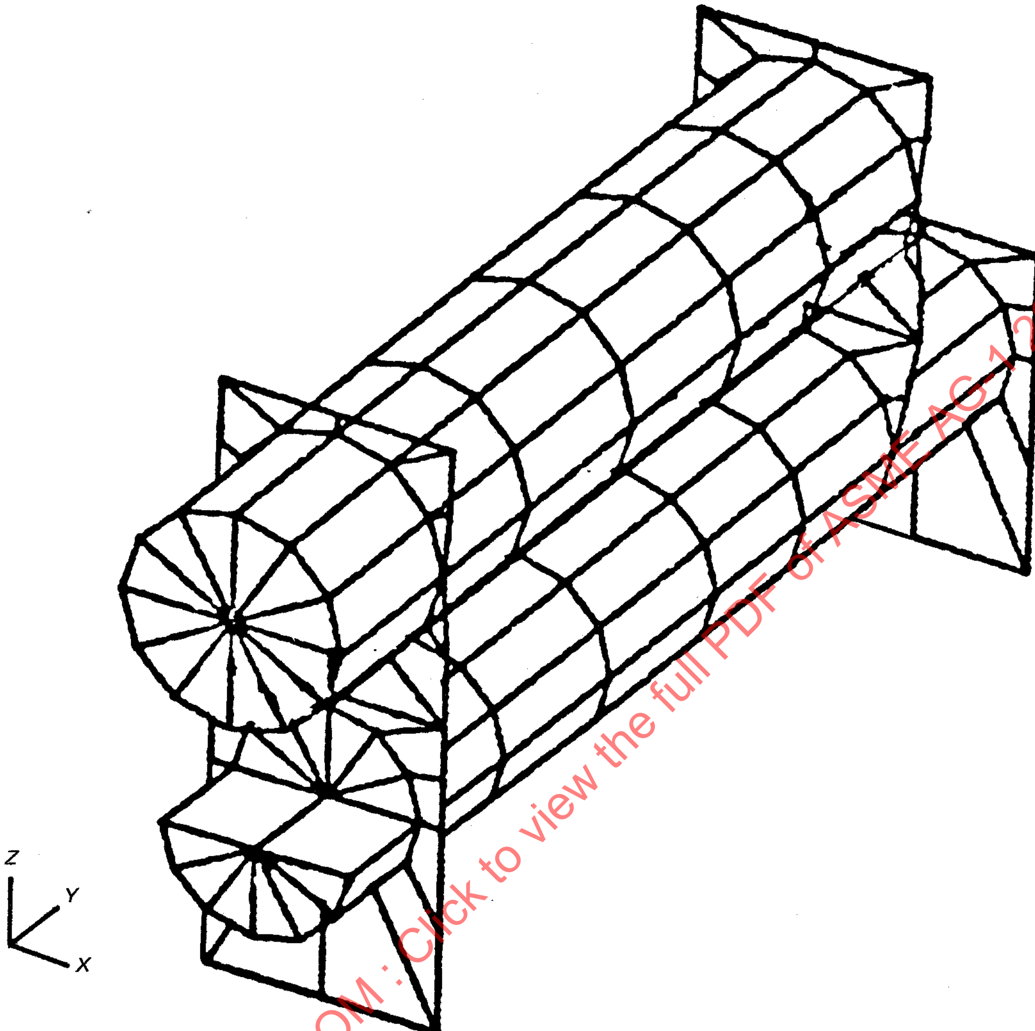


Figure AA-A-4500-1 Isometric View of a Typical Refrigeration Equipment Support



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 ASME BPVC, Section III, Nonmandatory Appendix N 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 twostep 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-4321-1 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-4323-1 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

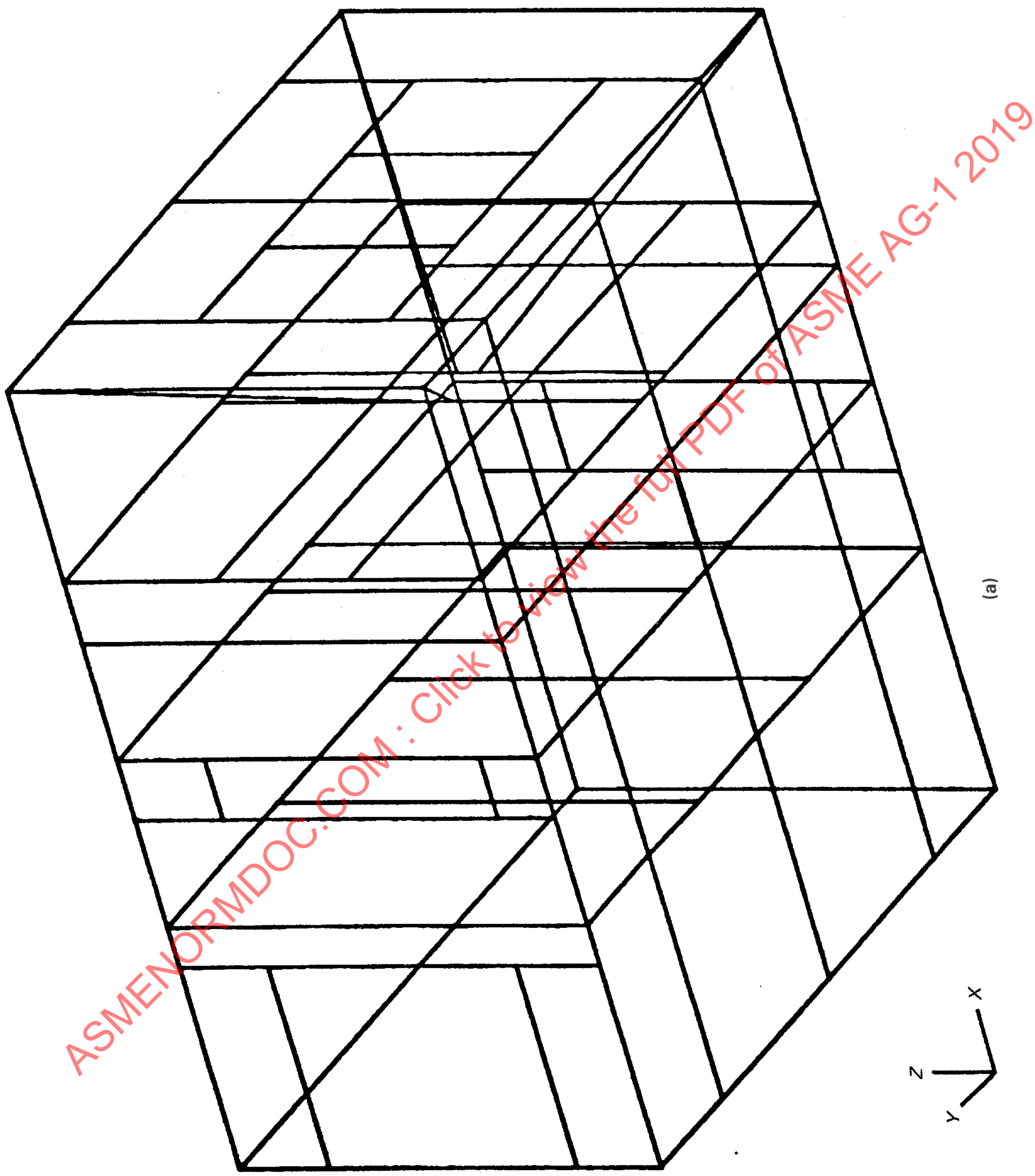
AA-A-7100 SCOPE

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

AA-A-7200 SAMPLE AHU ANALYSIS

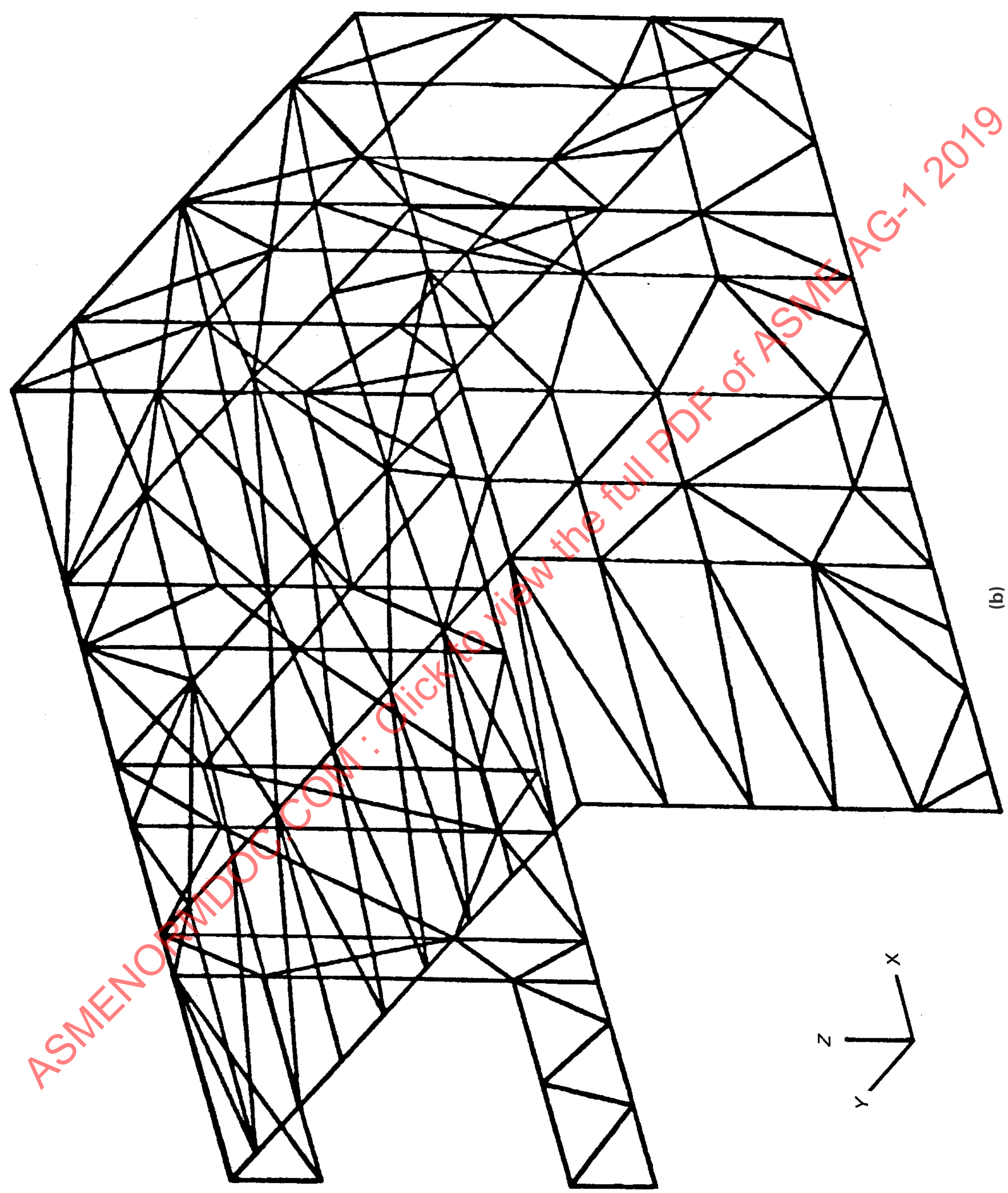
Computer generated plots of the mathematical model of a sample AHU are shown in Figure AA-A-7200-1, illustrations (a) and (b). Illustration (a) shows the structural framework, internal bracing, and duct attachment frames. Illustration (b) shows the triangular plate finite element mesh used to model the 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

Figure AA-A-7200-1 Computer Plots of Finite Element Model of Sample AHU (Perspective View of Tri-Plate Mesh)



(a)

Figure AA-A-7200-1 Computer Plots of Finite Element Model of Sample AHU (Perspective View of Tri-Plate Mesh) (Cont'd)



(b)

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-7300 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-7310 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 Figure AA-A-7310-1.

(19) **AA-A-7311 Baseplates.** Baseplates are modeled either as 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 Figure AA-A-7311-1.

AA-A-7312 Connections. If special joint fittings are used, joint flexibility members are included in the hanger model.

AA-A-7320 Analysis

AA-A-7321 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-7322 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-7321 and the average duct displacement.

AA-A-7323 Allowable Loads. For each load case of AA-A-7321, the maximum allowable load that satisfies the following criteria is determined:

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

(b) An interaction equation 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-7324 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 Figure AA-A-7324-1). 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-7325 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 Figure AA-A-7325-1).

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 equation relating hanger loads to allowable loads generated in AA-A-7323. The ductwork layout and system model may be adjusted until all hangers qualify.

The integrity of the duct itself is evaluated using member end loads from the system model. Interaction equations 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.

Figure AA-A-7310-1 Typical Duct Support As-Built (Dimensions and Member Sizes Not Shown)

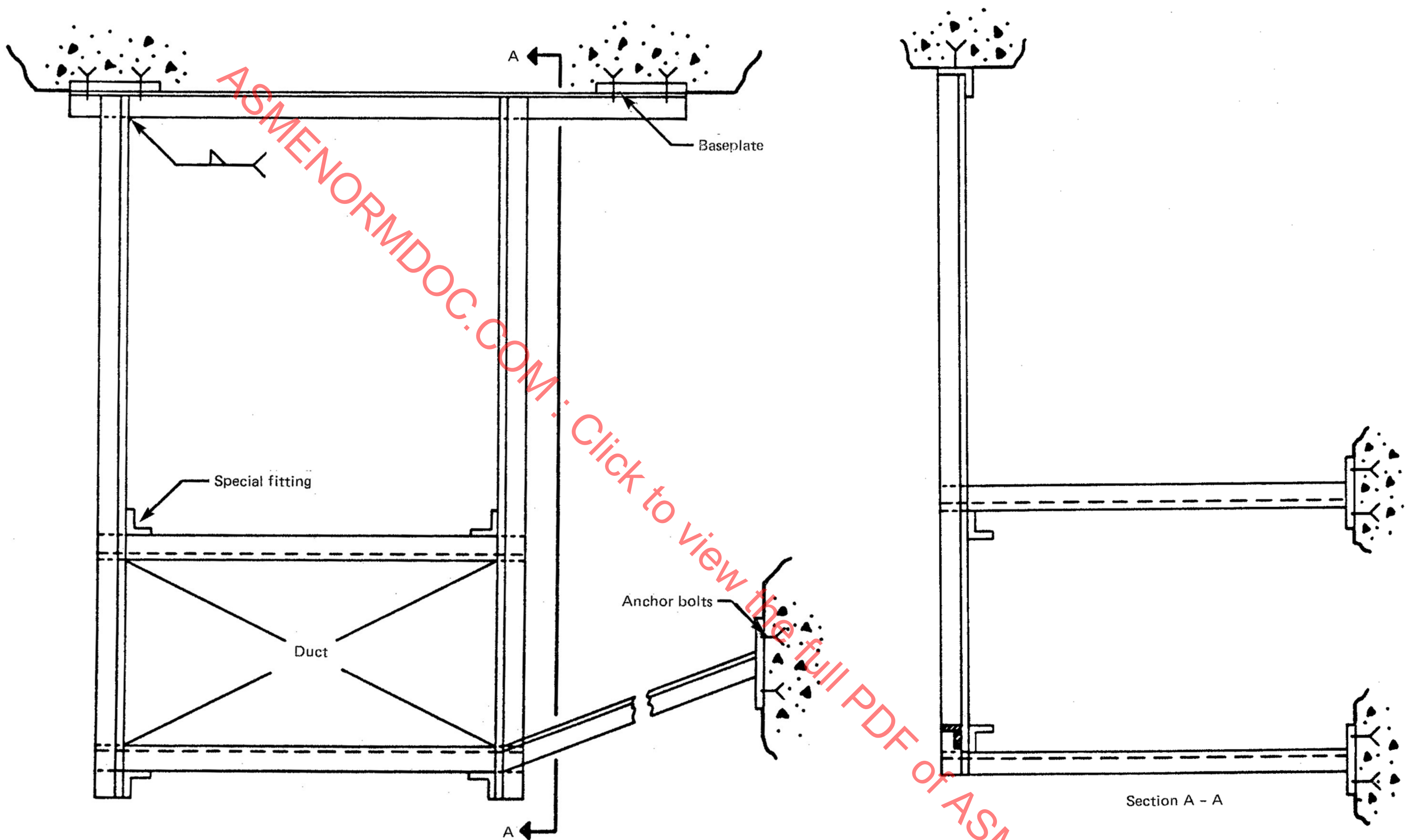


Figure AA-A-7311-1 Ductwork Support Baseplate Model

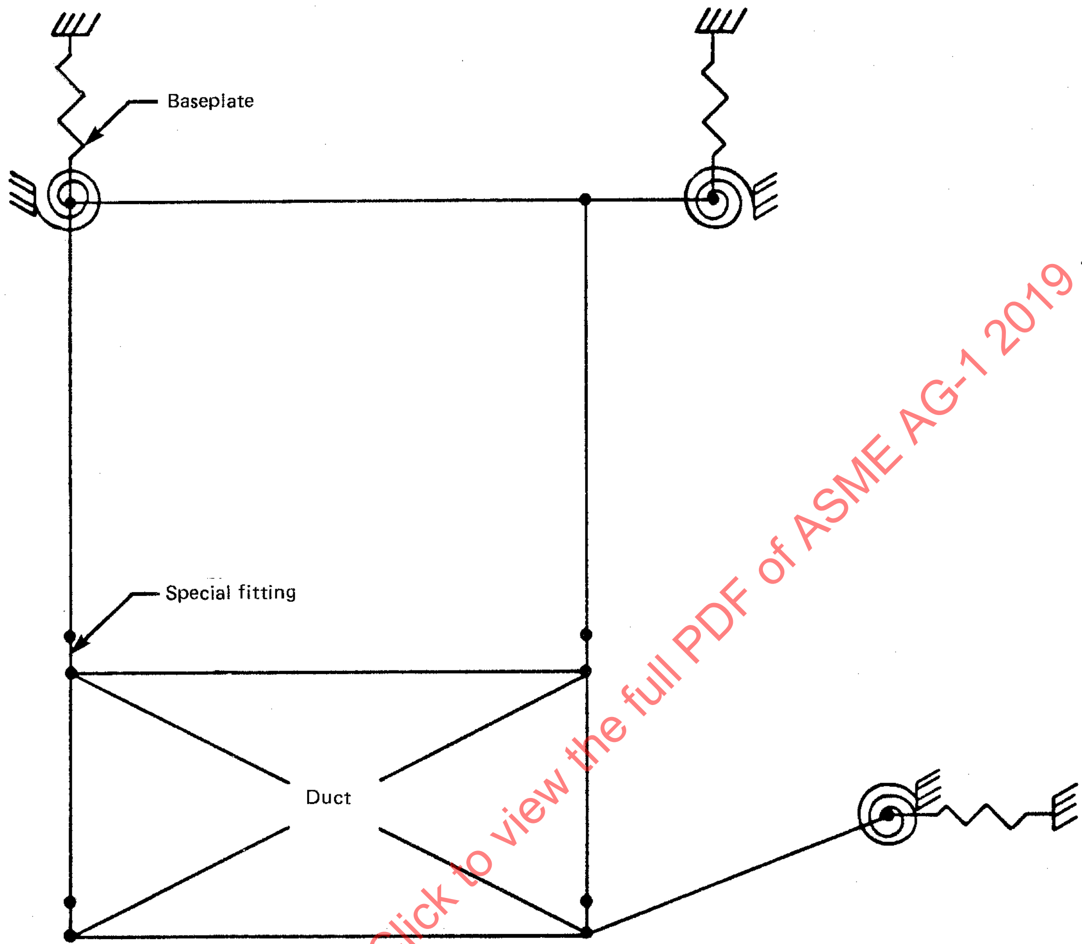


Figure AA-A-7324-1 Effective Duct Cross Section

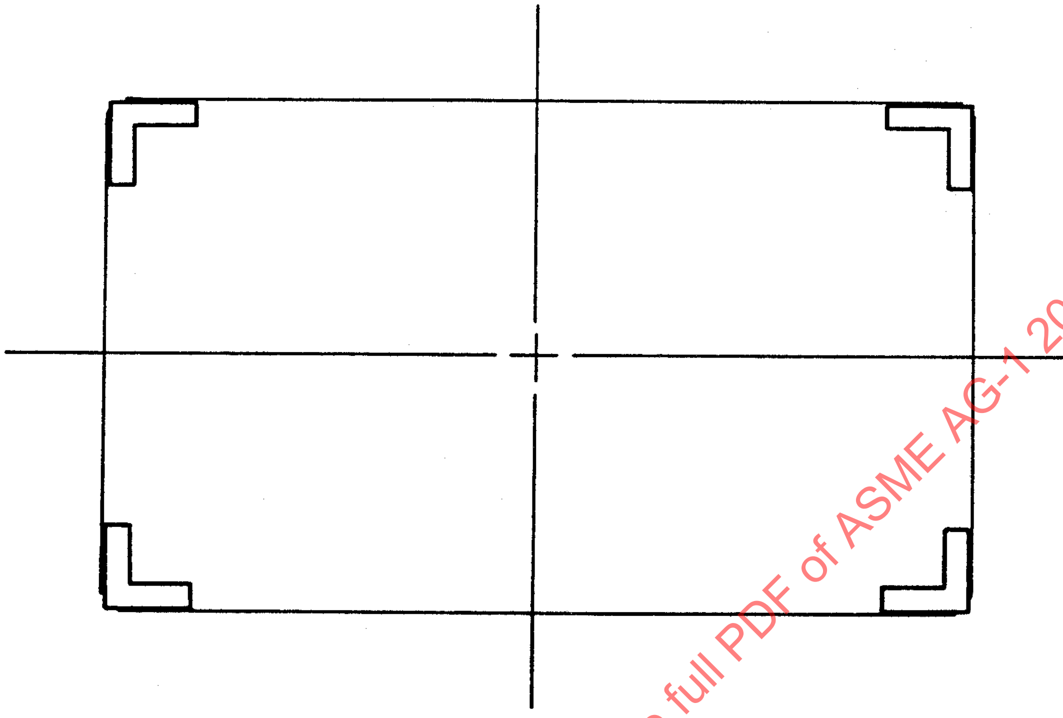
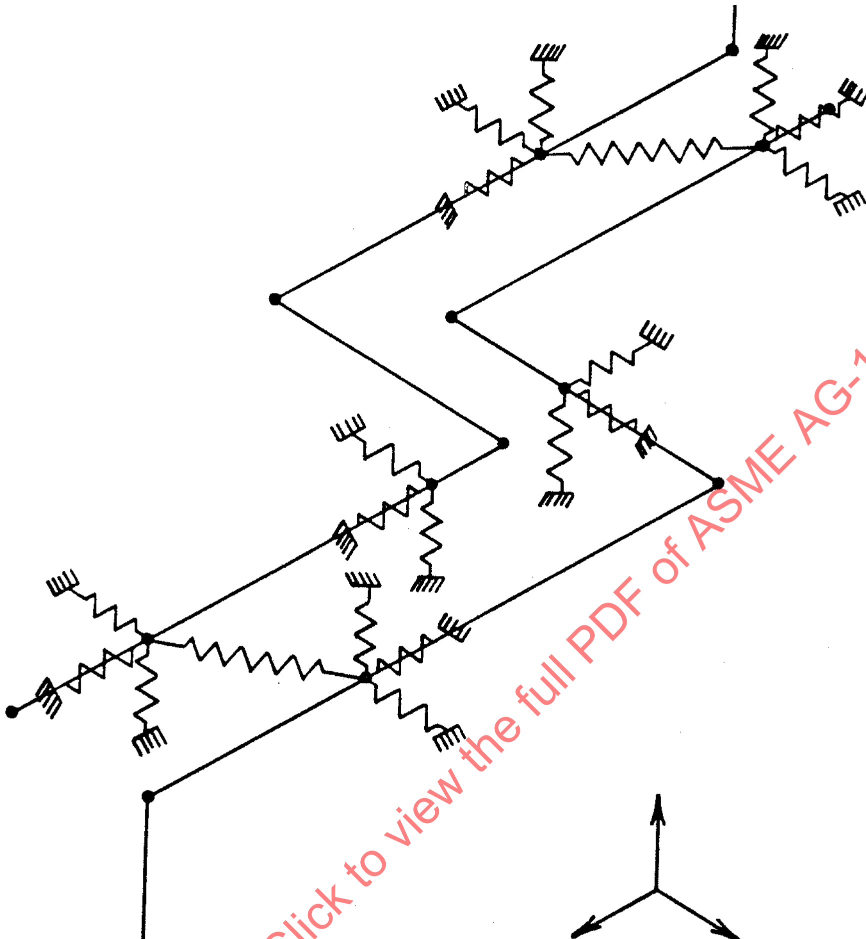


Figure AA-A-7325-1 Typical Duct System Model



NONMANDATORY APPENDIX AA-B
SEISMIC QUALIFICATION BY TESTING

ARTICLE AA-B-1000
TEST PLAN

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 gauges
(-c) load cells
(-d) stress coat
(-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 (3) 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 (3) 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 (3) will show the control capabilities of the bare test table. If a plot is made using a simulated test item as in (4), 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 successful 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

(19)

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

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

(b) equipment that is structurally simple

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

(d) 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

(19)

SECTION AB
SYSTEM DESIGN GUIDE

ARTICLE AB-1000
INTRODUCTION

AB-1100 SCOPE

This section provides supplementary guidance for the performance, design, installation, testing, and maintenance of air treatment systems in nuclear facilities. This section is not intended to replace or supersede any other section of this Code.

AB-1200 PURPOSE

The purpose of this section is to provide guidance for the performance, design, installation, testing, and maintenance of air treatment systems in nuclear facilities in accordance with the requirements of this Code and to capture the applicable system design information contained in ASME N509.

AB-1300 APPLICABILITY

The components and arrangements described in this section can be used in both pressurized water reactor (PWR) and boiling water reactor (BWR) nuclear air treatment systems.

AB-1400 DEFINITIONS AND TERMS

The definitions provided in this section supplement those listed in AA-1400 and in other sections of this Code.

air treatment system: the system that maintains temperature and humidity and removes contaminants from the air through the use of components such as moisture separators, heaters, HEPA filters, and carbon adsorbers.

boiling water reactor (BWR): a power plant that uses nuclear fission to produce steam to drive turbines and generate electrical power.

design basis accident (DBA): a postulated accident that a plant must be designed and built to withstand per 10 C.F.R. 100. For DBAs not covered by this definition, the Owner is responsible for defining the applicable DBA.

exfiltration: the movement of air out of a building.

leak detection and isolation system: the control and instrumentation system that detects and monitors leakage from the reactor coolant pressure boundary and initiates isolation of the leakage source.

light water reactor (LWR): a nuclear reactor such as a BWR or PWR that uses ordinary or "light" water as a coolant.

primary containment: the portion or portions of the containment system designed to withstand and/or control the pressures resulting from a postulated rupture of the reactor coolant pressure boundary and provide an essential leak-tight fission product barrier.

secondary containment: the portion of the containment system that encloses the primary containment and is designed to provide holdup, treatment, and a controlled release point for fission products that may escape primary containment.

system: the set of components required to perform a design function.

ARTICLE AB-2000
REFERENCED DOCUMENTS

The codes and standards listed below shall supplement those listed in Article AA-2000. Unless otherwise specified, the latest edition shall apply.

AMCA Publication 201, Fans and Systems
ANSI/AMCA Standard 99-10, Standards Handbook
Publisher: Air Movement and Control Association International, Inc. (AMCA), 30 West University Drive, Arlington Heights, IL 60004 (www.amca.org)

2014 ASHRAE Handbook—Refrigeration
Publisher: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle Northeast, Atlanta, GA 30329 (www.ashrae.org)

ASME B31.5, Refrigeration Piping and Heat Transfer Components
Publisher: The American Society of Mechanical Engineers (ASME), 2 Park Avenue, New York, NY 10016-5990 (www.asme.org)

NFPA 90A-2009, Installation of Air-Conditioning and Ventilation Systems

Publisher: National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471 (www.nfpa.org)

ANSI/SMACNA 006, HVAC Duct Construction Standards—Metal and Flexible
Publisher: Sheet Metal and Air Conditioning Contractors' National Association (SMACNA), 4201 Lafayette Center Drive, Chantilly, VA 20151-1219 (www.smacna.org)

ARTICLE AB-3000 FUNCTIONAL DESCRIPTION

This Article provides a brief description of the air treatment systems used at nuclear power facilities. The design requirements are specified or established by the license basis of each facility.

AB-3100 POWER GENERATION FACILITIES

Air treatment systems are used to maintain habitable conditions in critical areas under DBA conditions and limit exposure during normal plant operation. Both of these functions are designed to meet a facility's licensing requirements. The systems described herein are not intended for all nuclear facility air treatment systems.

AB-3110 Air Treatment Systems for DBA Requirements

Air treatment systems must operate under postulated DBA conditions. The stand-by gas treatment system (SGTS) is representative of similar filtration systems commonly used at BWR sites. It is an atmospheric cleanup system used in case of an accident in the containment building housing the reactor.

The SGTS is normally in standby mode. It is activated by a number of signals derived from plant parameters. Upon activation, the SGTS draws and filters air from the secondary containment atmosphere to create negative pressure surrounding the primary containment. This ensures that airborne radionuclides leaking from the primary containment are filtered before discharge to outdoor atmosphere via a vent stack, thus keeping radioactive releases below acceptable limits in accordance with regulations.

AB-3120 Normal Operation Systems

Air treatment systems filter potentially contaminated areas to limit the release of airborne contaminants to the atmosphere. These systems are usually designed to maintain the building at a slightly negative pressure to prevent exfiltration of contaminants at LWR sites. They are provided in the reactor, radwaste, turbine, fuel handling, and other auxiliary buildings. Another air treatment system is the containment ventilation and release system, which is designed to maintain a habitable environment for equipment maintenance and facilitate personnel entry into containment as required prior to and during unit shutdown.

ARTICLE AB-4000 TYPICAL AIR TREATMENT SYSTEM

AB-4100 SYSTEM FUNCTION

An SGTS incorporates some or all of the components that may be used in any other air treatment system. The safety significance is determined by the specific application and facility requirements. The SGTS treats air from the primary or secondary containment to reduce radioactivity prior to discharge to the outside atmosphere. This treated air must be within the limits specified in 10 C.F.R. 100. The signals that activate the SGTS include but are not limited to

(a) leak detection
(b) low reactor water level
(c) high drywell pressure
(d) high radiation on the reactor building refuel floor
(e) high radiation in the reactor building secondary containment exhaust

The SGTS maintains a negative pressure of 0.25 in. wg (0.06 kPa) or greater in the secondary containment relative to the outside atmosphere when the secondary containment is isolated within a specified time frame.

Other systems similar to the SGTS designed to clean a building's air may have positive or negative pressure requirements relative to the atmosphere or to other areas of the building.

AB-4200 SYSTEM BOUNDARIES

The boundaries include all components and areas between the entry and exit devices.

AB-4300 SYSTEM INTERFACES

The air treatment system interfaces with other plant systems. These may include typical controls, electrical power, fire protection, and building systems such as normal ventilation systems. These interfaces maintain the air treatment design requirements.

The SGTS has interfaces which the air treatment system may or may not incorporate, including but not limited to the following:

(a) logic and control system. Various controls are needed to initiate a secondary containment isolation and start the SGTS. Additional controls are needed to monitor the operating SGTS parameters such as temperature, flow, building negative pressure, damper positions, presence of fire in the filter train, etc.

(b) process radiation monitoring system. The normal operating reactor building HVAC (RBHVAC) system includes redundant safety-related radiation monitors that initiate the SGTS when radiation levels in the reactor and/or fuel handling building exhaust stream exceed predetermined postaccident set points.

(c) main control room panels. SGTS parameters are monitored remotely and the SGTS may be manually initiated from the main control room. Various dampers and/or valves may be manipulated from this location.

(d) radioactive drain system. The drain lines from the filter housing of the SGTS are connected to the high conductivity waste system.

(e) makeup water system for loop seals.

(f) electric power distribution system. The SGTS is fed power for running the fans, dampers, and logic and monitoring system equipment.

(g) atmospheric control system. This system provides a method for inerting and de-inerting the primary containment prior to and after power operations. The use of nitrogen ensures that hydrogen and oxygen concentrations are zero prior to an unanticipated occurrence.

(h) The fire protection system monitors the SGTS for smoke or fire and either sounds an alarm or automatically isolates the operating SGTS unit, initiating a fire suppression system or providing an alarm indication for such initiation.

(i) RBHVAC system. The RBHVAC shuts down and isolates the reactor building and initiates the SGTS and alignment.

(j) stack. The SGTS typically discharges to the plant ventilation stack.

AB-4400 SYSTEM DESIGN

A typical air treatment system will be in either standby mode or continuous operation. Depending on the design basis, redundancy and seismic consideration may be imposed upon the design. The system should incorporate some or all of the components described in AB-4410(a) through AB-4410(f) to accomplish its design function.

An SGTS typically consists of two 100% redundant independent trains powered by independent class 1E sources (commonly standby diesel generators). The SGTS is usually located in the reactor building, a seismic Category I structure, and is procured to seismic safety-related requirements. The ductwork (or piping) meets identical system requirements.

AB-4410 SGTS Typical Components

SGTS air-cleaning units typically include the following internal components:

(a) Prefilters are required in air-cleaning units when design inlet particulate concentrations may render the HEPA filter prematurely ineffective due to an unacceptable increase in pressure drop affecting design flow rate. On other air-cleaning units, prefilters are recommended only when it is desired to increase HEPA filter life.

(b) HEPA filters are required in all air-cleaning units when filtration of inlet particulate matter requires a minimum factory-tested efficiency of 99.97% on 0.3 µm challenge particles.

(c) Adsorbers are required when air-cleaning units are designed for removal of adsorbable elements and compounds.

(d) Moisture separators (demisters) are required when entrained water droplet concentration may be greater than 1 lb. (0.45 kg) of water per 1,000 cfm (1700 m^3/h) of airflow.

(e) Heaters should be used for air-cleaning units with adsorbers when the relative humidity of air to the adsorber must be controlled to less than or equal to 70%.

(f) Post filters should be provided to retain carbon fines when adsorbers are used in air-cleaning units. If the system design does not require a series of HEPA filter banks, the post filter may be a medium efficiency filter. If there is an upstream HEPA filter bank, the use of a HEPA filter downstream for carbon fine filtration will necessitate injection and sample manifold use during in-place leak testing.

Each filter train may include a moisture separator, heater, prefilter, HEPA filter, inlet space heater with fan, charcoal adsorber, fire protection, post filter, and adsorber cooling system.

AB-4420 SGTS Required Design Parameters

The following design parameters should be specified to meet the requirements of this section:

(a) volumetric airflow rate, cfm (m^3/h)
(1) minimum flow rate
(2) maximum flow rate
(3) design flow rate

(b) design pressures, in. wg (Pa)
(1) maximum operating pressure
(2) leak test pressure
(3) maximum design pressure
(4) structural capability pressure (usually determined by component designer)

(c) pressure-time transient (if applicable), in. wg/sec (kPa/sec)

(d) maximum and minimum gas temperature, °F (°C), and density, lb/ft^3 (kg/m^3)

(e) maximum inlet relative humidity, %

(f) entrained liquid water (mass flow rate), lb/min (kg/min)

(g) concentrations of specific contaminants in airstream

(h) required decontamination factors for each contaminant

(i) component radiation integrated life dose (rad) and maximum dose rate (rad/hr) *(j)* maximum dirty filter pressure differential, in. wg (kPa)

(k) structural loadings

(l) duct, fans, and housing maximum permissible leak rate, cfm (m^3/h), and associated operating pressure, in. wg (kPa)

(m) environmental design conditions including temperature, pressure, and relative humidity

(n) expected duration and environmental conditions of storage area

(o) particle size distribution and quantity of aerosols and contaminants under normal and accident conditions (if known)

(p) safety classification

(q) number of adsorber test canisters per adsorber bank

(r) heater capacity, watts, voltage, and temperature differential, if applicable

(s) fire suppression system requirements

(t) decay heat cooling air required, cfm (m^3/h)

AB-4500 SYSTEM OPERATION

A typical air treatment system may be in either standby mode or continuous operation. The operational characteristics should be derived from the specific design requirements of the system and facility.

For example, the SGTS is maintained in standby condition and is ready to function during abnormal plant operations. Both filter trains start automatically upon receipt of a loss of coolant accident (LOCA) signal, high drywell pressure signal, low reactor water level signal, or high radiation in the secondary containment or refueling floor ventilation exhaust signal. Either filter train can also be started manually from the main control room.

During accident operation, contaminated (or potentially contaminated) air is drawn into the SGTS and the air is cleaned and discharged via the plant ventilation stack.

AB-4510 Recommendation for Control of Heat of Radioactive Decay and Heat of Oxidation

When the system is shut down following an accident condition and the heat of radioactive decay or heat of oxidation or both may be significant, a means should be provided to remove this heat from the adsorbent beds to limit temperatures to prevent significant iodine desorption. For this purpose, a minimum circulatory airflow should be available for all operational modes of the air-cleaning unit and should be based on the maximum possible radioactivity loading on the adsorbent beds. Water deluge systems are not acceptable for this purpose.

AB-4600 SYSTEM INTERLOCKS AND ALARMS

System start is automatic on receipt of an accident signal (indicating a LOCA, fuel handing accident, etc.) or manual from the main control room. Interlocks between the operating and redundant filtration trains are provided to start the standby train on failure of the operating train or upon loss of power to the operating fan. There are alarms for high filter differential pressure (dp) and loss of airflow and there are filter dp and airflow indications for the proper functioning of the system in the main control room and/or on a local control panel, depending on the system design. Interlocks and alarms may ensure proper damper positions or alignment, fan status, system airflow, building dp, and functioning of support equipment (such as a cooling system). Interlocks and alarms are provided to protect the system from abnormal operating conditions and ensure that the design objectives of the system (i.e., internal temperature, humidity, pressure drop across filtration system components, electrical operating parameters for fan and heater) are met.

ARTICLE AB-5000 COMPONENT DESIGN

AB-5100 FILTER TRAIN COMPONENTS

AB-5110 Description

The filter train is a sequential collection of air cleaning and dehumidifying components enclosed by a housing that may provide connections to adjacent ductwork and piping. Each of these components may be used for moving, cleaning, heating, or dehumidifying the airstream. In order to properly design an air treatment system, the makeup of the process stream should be identified. The presence of other particulates, gases, and chemicals should be determined. All the contaminants, both particulate and gaseous, should be evaluated, including their concentration levels and particle sizes. Volatile organic compounds, entrained water, and acids may also affect the performance of various system components and should be addressed in the design of the system and its individual components. To properly design and size the system, the design flow should be considered as well.

AB-5120 Applications

This subarticle considers the design of and requirements for air treatment systems used to retain filters and/or adsorbers. Some systems may have only a single bank of HEPA filters with a bank of prefilters (to extend the life of the HEPA filter). Some systems may incorporate multiple banks of HEPA filters for redundancy. Radioactive gaseous (e.g., iodine) releases should be controlled, and this may require one or more banks of adsorbers. The adsorber bed design is based on residence time, iodine loading, and adsorbent efficiency. A bank of demisters may also be used, resulting in as many as six or more banks of components in series fabricated into a single filter housing. For more detailed design guidance and requirements for these components, see other applicable articles or paras. in this section and the applicable sections of this Code.

AB-5130 Cautions and Concerns

Air treatment system components should be designed to withstand the maximum pressure differential each component may experience due to normal operating pressure, test pressure, transient pressure conditions due to rapid closure of dampers, or anticipated system upsets that would render the system inoperable. The maximum design pressure should be equal to or greater than the maximum pressure differential after allowing for the venting effect of permanent openings and pressure relief devices in the system. The Designer should refer to Section AA and applicable individual Code sections for guidance. When testing the system, the commissioning agent should include the dirty dp drop across those sections where filters are not installed.

NOTE: Filters are usually installed after construction to prevent premature loading.

AB-5140 Recommendations for Installation

Air treatment systems should be set in place without filter elements installed. This is to prevent damage to the filtering elements and their clamping mechanisms during installation. Additionally, it is good practice to install an initial set of prefilter elements (excluding carbon adsorbers) immediately after installation. This initial filter set will remove construction debris. Prior to system start up, the initial construction filters should be discarded.

AB-5150 Recommendations for Maintainability

Air treatment systems should be designed for ease in maintenance, testing, and inspection.

(a) Air treatment systems that allow personnel entry should be either located at floor level or equipped with a permanent service gallery at least 4 ft (1.2 m) wide with permanent stairs or fixed ladders.

(b) Air treatment systems that do not allow personnel entry should be located at a height above the floor or work gallery level convenient for access, based on human factors and the design of the housing.

(c) The area in which the air treatment unit is located should be served by a clear aisle wide enough to accommodate servicing of internal components and equipment.

(d) A clear area adjacent to the housing door or hatch should be provided to allow servicing of the air treatment unit; a space at least 4 ft (1.2 m) wide by 7 ft (2.1 m) high is recommended. The clear work space may also serve as aisle space if it can be used while servicing the air treatment unit, or it may serve as the clear space for an adjacent air treatment unit.

(e) Clearance of 18 in. (0.45 m) is recommended above the housing to allow for installation and inspection. For systems containing Type III adsorbers, adequate clearance should be provided above the adsorber to easily allow proper filling and removal of the adsorber media.

(f) Internal elevated work galleries for personnel entry air treatment systems should be designed in accordance with OSHA (Occupational Safety and Health Act) requirements.

(g) Ducts should be equipped with low leakage access hatches at strategic points to allow for cleaning.

(h) In personnel entry systems, there should be a minimum of 3 ft (0.9 m) from mounting frame to mounting frame between banks of components to allow for ease of maintenance. If components will be replaced between mounting frames, the bank-to-bank dimension should be the maximum length of the component plus a minimum of 3 ft (0.9 m). When determining maintenance space, the designer should consider how susceptible to damage permanently installed testing manifolds are.

(i) Some design features that contribute to keeping maintenance exposures as low as reasonably achievable (ALARA) are

(1) location

(2) shielding

(3) use of techniques such as bag-in/bag-out to minimize airborne contamination

AB-5160 Recommendations for Fire Detection

A two-stage fire detection system should be installed for each adsorber unit. Detailed requirements for the instruments are contained in Section IA.

Temperature sensors should be installed upstream and downstream of the adsorber unit for the first stage alarm. Downstream temperature sensors should be designed to monitor temperature along the full length and at approximately the center of each adsorber bed. The fire detection system should sound an alarm upon detection of a temperature increase and be set to automatically trip fan(s) and isolate the air treatment unit when the temperature reaches about 165°F (74°C).

A carbon monoxide (CO) detector should be installed in the gas stream downstream of each adsorber unit for the second stage alarm, to ensure coverage of the total bed as well as localized hot spots that may occur within the bed. Locating the sensor within the adsorbent bed is not recommended. The CO detector system should sound an alarm for taking necessary actions, such as initiating fire control systems and isolating the system to contain the fire and minimize the release of potentially harmful contaminated gas and/or particulates to the environment.

AB-5170 Recommendations for Fire Protection

(a) Air treatment systems should be designed, fabricated, and installed to minimize the use of combustibles. Filter media, sealants, gaskets, and insulation should meet the requirements in applicable sections of this Code. Fire protection in or around housings should be designed to accomplish the following objectives:

(1) prevent fires from affecting the operation of the ventilation system

(2) protect the filtration function

(3) prevent the release of material that has accumulated on filters

(b) The potential for nozzle plugging or corrosion in housing deluge systems should be considered during design.

(c) General area sprinklers should be provided within all process areas.

(d) Process hazards inside and outside housings should be controlled.

(e) Plant fire protection procedures should include requirements to take appropriate action.

(f) Fire protection systems, when provided, may use water deluge, inert gases [e.g., halon, carbon dioxide (CO_2)], or other extinguishing agents as appropriate for the hazard.

(g) If water deluge systems are used, deluge nozzles should be permanently mounted within the housing and located to ensure that both deep-seated and surface fires can be extinguished. Nozzles should be piped to an accessible location outside the housing and provided with redundant leak-tight isolation outside screw and yoke valves and a connection suitable for manual attachment to the plant's fire protection system. Permanently connected fire protection systems are not recommended, but may be used in lieu of manual hose connections.

(h) If the fire hazard analysis requires that a fire protection system be provided for an air treatment unit, the fire protection system should be manually actuated. Automatic water deluge systems are not recommended because spurious actuation of automatic detection and protection systems may significantly degrade adsorber capability and damage the adsorber. If permanently connected fire protection systems are installed, provision should be made to activate an alarm upon initiation of flow of extinguishing agent (e.g., water, halon, carbon dioxide).

(i) If carbon does become wet, the wet carbon should be removed from the adsorber to prevent structural damage to the adsorber due to chemical interaction. Before placing the air-treatment unit back in service, the adsorber housing should be thoroughly dried and visually inspected for corrosion damage, and adsorber leak testing should be performed per Section TA and ASME N511.

See applicable sections of this Code and referenced standards for guidance on fire protection.

AB-5200 HEATERS

AB-5210 Description

Heaters are installed in filtration systems primarily to reduce the relative humidity of the air entering the carbon adsorber. Heaters are not typically required for filtration systems that do not utilize carbon adsorbers. For more detailed design guidance for this component, see Section CA.

AB-5220 Applications

The decision to use heaters in the system should be based on the requirements of test conditions for maintaining carbon efficiencies as defined in the design specification. If the heaters are credited for maintaining carbon efficiencies, heaters should be installed and designed to reduce the relative humidity of the incoming air to no greater than 70%. If the carbon efficiency is credited for relative humidity of incoming air at 95%, heaters are not required in the system. Their use may decrease the radioiodine removal performance of the carbon.

The heater should be sized for the maximum airflow for which the filtration system is designed. Depending upon the design airflow of the filtration unit, the heater should be designed with either single-stage or multiple-stage control. For smaller systems [i.e., 1,500 cfm (2 550 m^3/h) or less], a single-stage control system will usually be adequate. For larger systems that routinely see a significant variance in inlet conditions (e.g., airflow, humidity), a multistage silicon controller rectifier (SCR) may be more appropriate. For a single-stage on/off control system, the heater will typically be on at all times the system is in operation. An alternative is to have the heater turn on only when the relative humidity reaches the set point. For larger systems in which inlet conditions vary, the multistage SCR will turn the heater on or off in steps to match either the changes in airflow or the changes in inlet relative humidity.

AB-5230 Cautions and Concerns

Airflow distribution through the heater is very important. The heater should be installed in a location where there are minimal disturbances upstream and downstream of the heater. Heaters should not be installed in close proximity to other components that may be affected by the radiant heat from the heating elements.

AB-5240 Recommendations for Installation

The location of the heater relative to other filtration components is also important. Although both prefilters and HEPA filters are designed to withstand high levels of humidity, the heater should be located downstream of any moisture separators and immediately upstream of the particulate filters.

AB-5250 Recommendations for Maintainability

Adequate space both upstream and downstream of the heating coil should be provided for inspection. For insertion type heaters, adequate pull space should also be provided in the event the heater needs to be replaced.

AB-5260 Recommendations for Fire Protection

Where adequate airflow is provided and overtemperature switches are installed to prevent overheating of the temperature element, electric heaters should not require any additional fire protection.

AB-5300 FANS

AB-5310 Description

Fans are a critical component of any air treatment system, as they supply the energy to move gases through the system. For more detailed design guidance for this component, see Section BA. Additional detailed engineering information can be found in AMCA standards and publications.

AB-5320 Applications

The primary types of fans used in nuclear air handling applications are centrifugal and axial. Centrifugal fans have a radially outward flow path through the impeller while axial fans have airflow parallel to the shaft axis. Both centrifugal and axial fans are available with several different discharge designations, drive arrangements, fan bearing support configurations, motor locations, and intakes. ANSI/AMCA Standard 99-10 defines fan discharge designations, drive arrangements, and inlet box and motor positions.

AB-5330 Cautions and Concerns

A major challenge in designing the fan for an air treatment system is addressing the wide range of system resistance expected during normal operation. It is necessary to consider both clean filter operation (to ensure proper residence time is maintained in adsorbers) and dirty filter operation (to ensure the fan can operate safely at maximum system resistance) because of the anticipated extended operating times and particulate loading of the HEPA filters inside an air filtration system. System resistance curves generated by the Design Engineer should include losses from all ductwork, dampers, coils, housings, and filters (both clean and dirty) associated with operating the air treatment system. It is often necessary to perform several iterations of the system resistance curve, starting with preliminary information and concluding with final design information as it becomes available from suppliers.

Fan manufacturers typically rate fan performance at standard conditions (29.92 in Hg, 70°F, 0% humidity, which correlates to a density of 0.075 lbm/ft^3). It is the responsibility of the Owner's Design Engineers to determine the range of environmental conditions in which the air treatment system operates and clearly show that information in the design specification. Fans that operate in postaccident conditions may be subjected to elevated temperatures, pressures, and moisture. In design situations where large variations in postulated operating environments exist, sets of fan performance curves showing developed pressure, volumetric airflow, efficiency, and brake horsepower for each operating scenario should be generated. Even if systems are only operated postaccident, fan performance data for normal conditions is needed so system performance can be tested and validated as part of site acceptance and maintenance programs.

Many specific applications require accessories to allow the fan to function properly for the intended application. These items include but are not limited to

(a) backdraft dampers
(b) shaft seals
(c) inlet boxes
(d) shaft or inlet guards

For more detailed design guidance for these accessories, see Section BA.

AB-5340 Recommendations for Installation

Fans may be located on the upstream or downstream side of the air filtration equipment. Fans are usually located on the clean side of filtration and gas cleaning equipment to reduce the dust and contaminant loading on the fan wheel and casing. In typical HVAC applications, fans are located on the cool side of the process to prolong motor and bearing life.

It is important to note that placing the fan on the downstream side of the filtration equipment puts the filtration system under negative pressure, which provides a possibility for unfiltered inleakage to get into the system and be distributed by the fan. However, placing the fan on the upstream side of the filtration equipment puts the filtration system under positive pressure, which results in leakage out to the surrounding environment and may subject the fan to contaminated air. Although the benefits and detriments of each design depend on the application and location, a review of the end use configuration will typically determine which position is optimal. Nonmandatory Appendix SA-B contains tables that identify leakage classifications and duct configurations for systems relative to component placement. While Nonmandatory Appendix SA-B may be useful for sheet metal housings, some applications specify that housing must be leak tight. In those cases, the housing must be seal-welded and designed for the worst-case positive or negative pressure.

The following factors should be considered when selecting fan drives and arrangements:

(a) The fan must physically fit within the specified space, with proper distance from inlets or outlets to housing walls, ductwork transitions, or other system components that may affect fan operation. AMCA Publication 201 details proper fan inlet and outlet design parameters. Accessibility for maintenance should also be considered during the design phase.

(b) Direct-drive fans are preferred. Belt-driven fans allow more performance adjustability and may feature a smaller packaging space, but tend to require more maintenance than direct-driven fans. Using belts in a harsh environment is generally not recommended. If performance adjustability during operation is required, fans with adjustable blade pitch and/or variable speed drives offer alternatives to a belt-driven design.

(c) Placement of the fan components (i.e., bearings, motor, drive, and sheaves) relative to airstream and potential contaminants is critical for fan functional performance. Particulates may damage bearings or motors that are not completely sealed, and radioactive or toxic contaminants may make fan maintenance difficult due to radiation exposure to personnel. In addition, bearing placement may result in a large operating temperature difference, depending on proximity to the fan and airstream.

AB-5350 Recommendations for Maintainability

Fan maintenance procedures are based on several factors, including fan arrangement, room congestion, and equipment design and features. For example, belt-driven fans require periodic belt inspection, tensioning, and replacement to ensure reliability. The ability to inspect fan components without excessive equipment disassembly allows identification of potential problems before they occur.

When fan bearings are within a closed housing, extended lubrication lines may be used to perform preventive maintenance without entering the housing. However, the amount of grease consumed by the bearings should be considered relative to the grease line length. Long grease lines may extend the dwell time for the grease before it reaches the bearing, and this may result in separation of the oil and thickeners, thereby reducing the lubrication effectiveness. In addition, the lines require purging to remove air pockets upon initial installation. An alternative to grease lines for bearings that are inaccessible are mechanical automated greasers that can be mounted locally to the bearings. Many facilities also prefer to have accelerometers and temperature sensors mounted directly on bearing housings to monitor vibration and bearing life over operating time.

AB-5360 Recommendations for Fire Protection

Fans do not generally require any specific fire protection measures. However, their power source may be tied to control circuitry that secures their operation coincidental with a smoke alarm. Ensure that the fan motors are properly protected against overload conditions.

AB-5400 VALVES, PIPING, COOLING COILS

AB-5410 Description

Valves, piping, and coils may be used as part of housing drains, fire protection systems, or heating/cooling processes. Additional guidance can be found in ASME B31.1; ASME B31.5; ASME BPVC, Sections VIII and III, Division 1; and NFPA standards.

AB-5420 Applications

In an air treatment system, valves may be used to maintain an air pressure boundary, a water pressure boundary, or both. Article HA-4000 and Nonmandatory Appendix HA-B contain requirements on fire protection and housing drains that are applicable for design requirements.

In an air treatment system, piping may be used as part of either the fire protection system, the housing and condensate drain system, or the process flow system. Depending on the design and function, the piping may maintain an air pressure boundary or a water pressure boundary or both.

An air treatment system may also perform a conditioning function. In that case, coils may be used as an air-to-water heat exchanger (or air-to-refrigerant). Section CA contains requirements for coils.

AB-5430 Cautions and Concerns

Valves used for shut-off or isolation should be full port, globe style valves, suitable for system pressure and temperature design service conditions and plant design basis. The valve material should match that of the piping to which it is attached, unless consideration has been given to the corrosion potential between the dissimilar metals.

Piping for drain lines that are part of the pressure boundary of the air treatment unit and used for conveying water or air should be designed, fabricated, and tested in accordance with ASME B31.1, ASME B31.5, or ASME BPVC, Section III, as applicable.

Refrigerant piping should be designed, fabricated, and tested in accordance with ASME B31.5. Additional guidance is found in the 2014 ASHRAE Handbook—Refrigeration.

Piping for process flow should be designed, fabricated, and tested in accordance with ASME B31.1 or ASME BPVC, Section III, as applicable.

AB-5440 Recommendations for Installation

Valves and piping should be installed by qualified personnel to the applicable specification requirements.

Valves and piping should be located so as not to impede access for maintenance activities.

Manually operated valves should be located in readily accessible locations.

AB-5450 Recommendations for Maintainability

Valves and piping should be maintained in accordance with applicable facility procedures and commitments.

Isolation valves should be provided where beneficial to aid maintenance activities and component replacement.

Valves should be oriented to facilitate in-place maintenance activities.

Loop seals, when provided, should include provisions for filling.

AB-5460 Recommendations for Fire Protection

Piping and valves associated with fire protection systems should conform to the applicable NFPA standards. The Engineer specifying the equipment should determine which NFPA standards apply to the system being designed and require these in the design specification.

AB-5500 DUCT AND DAMPERS

AB-5510 Description

A ductwork system provides an enclosed passage through which air is transferred from point to point and does not typically include air treatment components such as filters or adsorbers. A damper is an operable device used to control pressure or flow by varying the air path area. Ductwork requirements are dictated by Section SA. Additional information can be found in SMACNA 006. Damper requirements are dictated by Section DA.

AB-5520 Applications

Ductwork is typically used for transporting air to and from the air treatment housing. Ductwork systems may contain features and accessories including plenums, extractors, grilles, diffusers, flexible connections, insulation, testing ports, and access panels. Duct supports transmit loads from the ductwork to appropriate load-bearing structures. Air ducts for air treatment systems are typically manufactured of coated carbon steel (often galvanized) or stainless steel.

Dampers may be used in an air treatment system for flow control, pressure control, fire control, balancing, isolation, backdraft prevention, or pressure relief. Dampers come in various configurations, illustrated in Figures DA-II-1000-1 through DA-II-1000-6.

AB-5530 Cautions and Concerns

This Code allows for various types of longitudinal seam design, including both welded and mechanical lock-type seams. Welded seam ductwork is generally preferred for air treatment systems carrying radioactive matter. Mechanical lock-type seams will usually require an elastomeric sealant for ductwork to meet leakage requirements. Any sealant used should be qualified for its applicable environment.

In leakage-critical applications, field connections to duct supports should not cause a pressure boundary breach.

Section DA and Mandatory Appendix DA-I should be used to quantify required damper leakage for a given application. For example, a flow control damper (with no isolation function) that also serves as ductwork air pressure boundary in a contaminated environment while carrying clean air under negative pressure may require a zero-leakage or low-leakage frame (Class A or Class B) with a seat leakage requirement of Class IV.

AB-5540 Recommendations for Installation

Ensure that access doors and/or panels are provided in the ductwork for surveillance of dampers or other equipment in the air treatment system requiring inspection and/or maintenance, as well as possible ductwork cleaning.

When using companion angle frames to connect ductwork sections, consider gasket material selection and design that allow consistent installation on all sections without relying on "skill of the craft" to determine acceptable leak-tight connections. One solution is to provide the gasket's nominal compression value in the form of thickness gauges to verify proper field installation. Another solution is to use a gasket that exhibits increasing compression force due to nonconstant cross section geometry and provide a fixed torque value for all companion frame fasteners. This allows the gasket to have initial soft compression that fills gaps from varying surface profiles, but then firms up as bolts are tightened, which allows consistent torque values while avoiding excessive gasket extrusion from the companion angle frame perimeter.

AB-5550 Recommendations for Maintainability

Ductwork systems typically require little maintenance, with the exception of occasional cleaning and the replacement of companion frame gaskets, access door and/or panel gaskets, or flexible connections.

AB-5560 Recommendations for Fire Protection

Ductwork and dampers do not typically require any special fire protection if no flammable particulate is being carried by the air. Fire damper construction is specified in Section DA.

AB-5600 INSTRUMENTATION

AB-5610 Description

All systems require some form of instrumentation. Instruments are used to monitor, control, and transmit alarms based on various system changes. For more detailed design guidance for this component, see Section IA.

AB-5620 Applications

The following are some of the applications for which instruments are used for measurement and monitoring:

(a) airflow
(b) fluid flow
(c) air temperature
(d) fluid temperature
(e) differential pressure
(f) pressure
(g) humidity
(h) vibration
(i) fire and/or smoke
(j) carbon monoxide

AB-5630 Cautions and Concerns

Instruments should be installed in locations that allow the devices to measure a representative sample of the condition within the air treatment system for which they are intended. Care should be taken not to install instruments in dead air spaces, in areas of nonuniform airflow, or in areas of extreme turbulence.

If possible, instruments should be installed from the outside of the housing through either a flanged or a threaded connection. This will make replacement easier in the event that the instrumentation fails.

Each instrument must be selected to operate properly within the environment in which it will be installed. The range and accuracy of the instrument should be selected to match the requirements of the value being measured. For example, a differential pressure gauge with an accuracy of 0.5% is not required when measuring the pressure drop across a HEPA filter.

AB-5640 Recommendations for Installation

See Table IA-C-1220-1 for guidelines for the type and location of the instruments used in an air treatment system.

AB-5650 Recommendations for Maintainability

Routine maintenance and calibration of instruments should be performed in accordance with the manufacturer's recommendation.

AB-5660 Recommendations for Fire Protection

Other than monitoring for a carbon bed fire, there are no specific recommendations regarding fire protection of instruments. However, instruments may be used to initiate action in the event of a fire. Examples are to trip the fan off in the event of a fire or to open or close certain dampers when smoke is detected.

AB-5700 HOUSINGS

AB-5710 Description

This section provides guidance for air treatment system housings, which are the portions of air treatment units that enclose air treatment components and provide connections to adjacent ductwork. For additional guidance, see Section HA.

AB-5720 Applications

Housings enclose and provide access to the different components of air treatment, air conditioning, or air handling units, such as HEPA filters, prefilters, adsorbers, moisture separators, cooling and heating coils, dampers, mounting frames, and fans. They also connect to adjacent ductwork, instrumentation, and ancillary systems.

AB-5730 Cautions and Concerns

Housings should be designed and constructed to withstand structural and pressure loadings according to Section HA.

For systems protected with water deluge fire protection systems, drains should be of a number and size that may readily remove water from the unit when the fire protection system is fully activated.

Drain lines should be welded to the unit housing and be of the same material alloy as the unit housing.

Loop seals should be used when moisture separators and/or condensing cooling coils are used. Loop seals should be properly designed considering their location and corresponding positive or negative pressure.

Each housing compartment should have floor drains that meet all allowable air leakage criteria. When piped to a common drain system, individual drain lines should include valves or be otherwise protected. There should be enough space from the housing to the valve to be able to manipulate it in case of a fire. Check valves are not recommended.

Drains should be protected against freezing, if applicable.

AB-5740 Recommendations for Installation

Filter housings should be located inside the building to minimize the spread of contamination.

Horizontal airflow with filter faces in a vertical position is recommended.

Layout of the housing and banks of components within the housing should provide for access to both sides of each bank of components for maintenance and testing and for uniform airflow through each bank of components.

Mounting frames for all components (moisture separators, prefilters, heaters, HEPA filters, adsorbers, and post filters) should be of all-welded construction and welded into the housing to prevent trapping of contamination between frame and housing.

Housings should be rigged into place without filter elements in place. This is to prevent damage to the filtering elements and their clamping mechanisms during installation.

AB-5750 Recommendations for Maintainability

Housings should be designed for ease in maintenance, testing, and inspection. Sufficient space should be provided for removal and replacement and maintenance of components.

AB-5760 Recommendations for Fire Protection

Fire protection requirements should be considered depending on the individual component requirement. Refer to HA-4248 for fire protection recommendations for systems.

ARTICLE AB-6000 INSTALLATION

AB-6100 SYSTEMS

Generally applicable criteria for the installation of assembled components and subassemblies as well as the field assembly of components is specified in AA-6600. This Code requires that the manufacturer provide detailed manuals for the operation, installation, and maintenance of all housing-related items. Certain sections refer to the requirements of NFPA 90A-2009 as well as those of AA-6600.

Additional guidance for the location and installation of nuclear air treatment systems and components may be found in DOE HDBK-1169-2003.

AB-6200 HOUSINGS

Access for maintenance, including periodic surveillance testing, should be considered when locating housings. There should be sufficient space adjacent to the housing to allow for change out of components and testing activities. All possible interferences to housing access (including piping, seismic supports, and ductwork) should be studied carefully during the housing layout process.

The general area surrounding the housing should be sufficient to allow it to be cordoned off as a contamination zone to facilitate the safe removal and replacement of filter elements and/or bulk activated carbon.

Housings should not be suspended in free overhead space or placed on the roof of buildings that do not have adequate roof access. Building roof locations are generally undesirable, but when such locations must be used, housings should be adequately protected from the environment. Negative-pressure, roof-mounted housings are susceptible to water intrusion during periods of rain and snow melt. Housings in outside locations may act as condensers in cold weather, depending on the relative humidity of the process stream they serve, and this can result in damage to filter components, especially carbon adsorbers.

In addition to adequate space adjacent to the housing, the provision of overhead clearance for bulk-loaded adsorber systems should be considered.

During housing layout, sufficient space should be provided for inlet and outlet duct transitions to assure adequate airflow distribution and proper fan performance.

AB-6300 COMPONENTS

Applicable criteria for the installation of assembled components and subassemblies as well as the field assembly of components is specified in AA-6600. This Code requires that the manufacturer provide detailed manuals for the operation, installation, and maintenance of all housing-related items. Additional guidance for component installation may be found in DOE HDBK-1169-2003.

Prior to component installation, housing mounting frames, clamping devices, and individual components should be thoroughly inspected for compliance to the design specifications.

HEPA filters and prefilters (as applicable) should be installed with pleats vertical to prevent sagging and damage over time.

Individual clamping of filter elements and modular adsorber elements should be provided for in the housing design. Common clamping of these components is discouraged.

Installation of adsorbent in bulk-loaded systems (Type Ill) should be performed in accordance with a procedure that assures the adsorbent is loaded at its maximum packing density.

ARTICLE AB-7000 TESTING

Article AA-5000 specifies generally applicable criteria for the inspection and testing of materials and equipment. Article TA-4000 specifies the field acceptance tests necessary to verify compliance with the Owner's design specifications.

Provisions for testing should be considered from the beginning of the design process and documented in a system test plan.

Adequate test ports, both in number and location, should be provided for in the design to facilitate the following:

(a) housing leak tests/structural capability tests
(b) mounting frame leak tests (if required)
(c) airflow capacity measurement
(d) airflow distribution measurement
(e) air/aerosol mixing measurement
(f) injection and sampling during the in-place leak test

All test, injection, and sampling ports should be clearly identified both on drawings and on equipment.

Depending on the outcome of certain acceptance tests, changes to test port location may be necessary. Therefore, consideration should be given to the provision of alternative test, injection, and sampling ports, especially when field modifications may require additional engineering analysis.

For systems not designed for personnel entry, access to internal system components is limited by the location and number of available test ports. Certain acceptance tests such as airflow distribution require access to each filter element. The low velocities internal to the housing typically permit measurement of the airflow distribution by a hot wire anemometer. However, the probe length of the hot wire anemometer limits access to filter elements. When laying out housing test ports, the limitations of available measurement equipment should be considered. For example, side-access test ports may be insufficient in a two-wide HEPA filter housing to accommodate limited probe length. In these cases, top-access test ports may be preferable.

Manufacturer-qualified injection and sampling manifolds should be clearly identified.

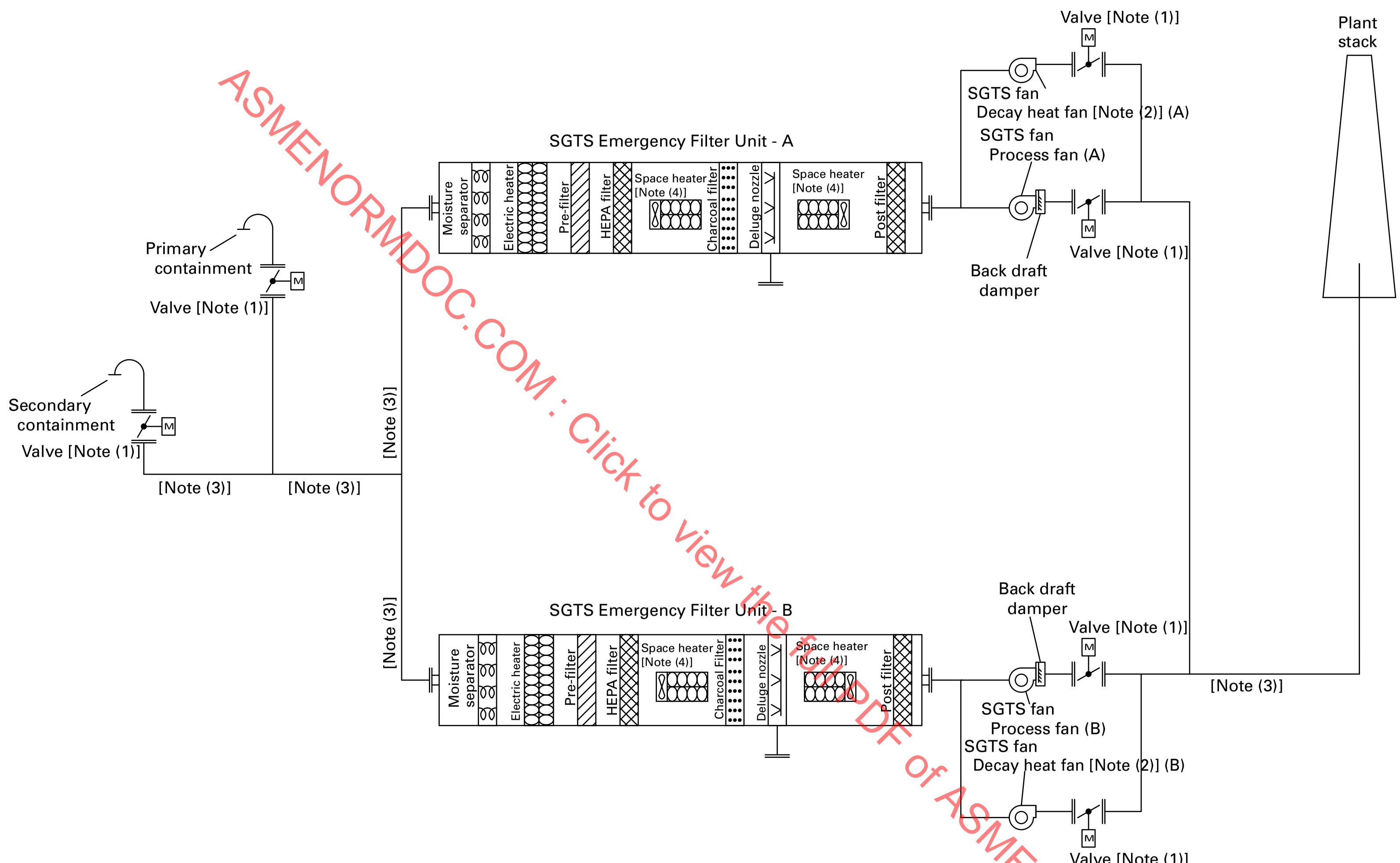
Where proper sampling manifold operation depends on sampling flow rate, or if any other restrictions for manifold use are specified by the manufacturer, this information should be clearly marked at the manifold sampling point on the housing.

ARTICLE AB-8000 TYPICAL STANDBY GAS TREATMENT FILTRATION SYSTEM

AB-8100 Air Treatment Systems for DBA Requirements

Air treatment systems shall operate under postulated DBA conditions. The SGTS is representative of similar filtration systems commonly used at BWR sites. It is an atmospheric cleanup system used in case of accident in the containment building housing the reactor. A typical SGTS is shown in Figure AB-8100-1.

Figure AB-8100-1 Typical Standby Gas Treatment Filtration System



NOTES:
(1) Valve actuators can be electric, pneumatic, or hydraulic.
(2) An optional decay heat fan or a bypass line between filter units for decay heat may be used.
(3) Process piping (exposed and/or buried).
(4) This is an optional component.

Division II
Ventilation Air Cleaning and Ventilation Air Conditioning

SECTION BA
FANS AND BLOWERS

ARTICLE BA-1000
INTRODUCTION

BA-1100 SCOPE

This section provides requirements for the performance, design, fabrication, installation, inspection, acceptance testing, and quality assurance for fan equipment used in air and gas treatment systems in nuclear facilities.

BA-1200 PURPOSE

The purpose of this section is to ensure that fan equipment is acceptable in all aspects of design and operation.

BA-1300 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.

BA-1400 DEFINITIONS AND TERMS (19)

axial fans: fans in which the airflow is parallel to the rotating shaft. The three groups of axial fans are propeller, tubeaxial, and vaneaxial.

blocked tight/shut off: a condition of fan operation accompanied by a complete closure of the inlet or outlet, permitting no airflow.

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: the speed that 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 (revolutions per minute) 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 airflow caused by change in direction or velocity of the airstream, or both, such as an unducted fan inlet or outlet.

fan: an air moving device 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 (AMCA International) standard configuration designation that indicates 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 airflow) 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): a fan or duct inlet opening made in the shape of a bell opening to streamline the inlet airflow, 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 recovers 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 (revolutions per minute) at which the supplied fan is to perform. This may be a range of speeds for variable frequency drives and variable speed drives.

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 is 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 is that point of an axial fan 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 is that point of a centrifugal fan 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 airflow.

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.

ARTICLE BA-2000 REFERENCED DOCUMENTS

The codes and standards listed below shall supplement those listed in Article AA-2000. Unless otherwise specified, the latest edition shall apply.

ABMA 9, Load Ratings and Fatigue Life for Ball Bearings
ABMA 11, Load Ratings and Fatigue Life for Roller Bearings
Publisher: American Bearing Manufacturers Association (ABMA), 330 N. Wabash Avenue, Suite 2000, Chicago, IL 60611 (www.americanbearings.org)

AMCA 99, Standards Handbooks
AMCA 201, Fans and Systems
AMCA 210, Laboratory Methods of Testing Fans for Rating
AMCA 300, Reverberant Room Method for Sound Testing of Fans
AMCA 301-2005, Methods for Calculating Fan Sound Ratings From Laboratory Test Data

Publisher: Air Movement and Control Association International, Inc. (AMCA International), 30 West University Drive, Arlington Heights, IL 60004-1893 (www.amca.org)

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 (www.ashrae.org)

ARTICLE BA-3000 MATERIALS

BA-3100 GENERAL

Materials for fan components and accessories shall be in conformance with the ASME or ASTM materials listed in Table AA-3100-1.

BA-3110 Material Stress Values

The ASME or ASTM designation in Table AA-3100-1 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 A370 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.

ARTICLE BA-4000 DESIGN

Design of fans shall be in accordance with the requirements of this section and of those portions of Section AA invoked in this section. 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

(19) **BA-4121 General.** Fans (including drivers, drives, bearings, and accessories) shall be designed to operate continuously, including while exposed to the environmental conditions caused by postulated accidents, for a period of 30 days, 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 are 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 airstreams
(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 and BA-4131.2 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 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-4142 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.

Table BA-4162-1 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-4143 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.

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-4162-1, 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 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 drivers, 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 ABMA 9 or ABMA 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.

Electric cables penetrating the fan housing shall meet the requirements of BA-5142.1 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 ABMA 9 or ABMA 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 able to be retained 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-4143.

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 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 design 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 this Section and of AA-5100, AA-5200, AA-5400, and AA-6430.

BA-5100 FAN INSPECTION AND TESTING

BA-5110 General Testing Requirements

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 yr 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 112 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 Semi-Reverberant 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.

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.

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-4143 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 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

First units of a design shall be given a complete test per IEEE 112. 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 112. Test data shall be documented.

ARTICLE BA-6000 FABRICATION AND INSTALLATION OF CENTRIFUGAL AND AXIAL FANS

Fabrication and installation shall be in accordance with the requirements of this section 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 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 this section 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.

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, and material lists

(c) welding procedures, applicable welding code, listed in AA-6300

(d) reports for tests and inspections required by Article 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 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 this section 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 ACCEPTABLE METHODS FOR MARKING ACCESSORIES

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

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 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 (19)

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 to change either 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 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 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 BA-B-1000-1 begins on the following page.

Table BA-B-1000-1 Division of Responsibility

BA-	Item	Responsible Party
3200	Limitations on materials	Engineer
3400	Certificate of conformance	Manufacturer
4110	Performance	Engineer
4110(a)	Fan type and blade shape	Engineer
4110(b)	Airflow	Engineer
4110(c)	Total pressure	Engineer
4110(d)	Maximum discharge velocity	Engineer
4110(e)	Air density at rating	Engineer
4110(f)	Maximum air density expected	Engineer
4110(g)	Operating temperature	Engineer
4110(h)	Details of intake and discharge transitions	Engineer/Manufacturer
4110(i)	Parallel fan operation	Engineer
4110(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
4151	Centrifugal fan support boundary	Engineer/Manufacturer
4151(a)	Size and type of anchorage	Engineer/Manufacturer
4151(b)	Anchorage loads	Manufacturer
4210	Fans	Engineer/Manufacturer
4211.1	Title and numbering	Engineer
4211.2	Duty cycle	Engineer
4211.3	Fan configuration	Engineer
4211.4	Environment	Engineer
4211.5	Limitations	Engineer
4212(a)	Flow rate	Engineer
4212(b)	Fan pressure	Engineer
4212(c)	Air density	Engineer
4212(d)	Air temperature	Engineer
4212(e)	Fan speed	Manufacturer
4212(f)	Fan power input	Manufacturer
4220	Drivers	Engineer/Manufacturer
4221(a)	Speed torque curve	Manufacturer
4221(b)	Inertia	Manufacturer
4221(c)	External forces	Manufacturer
4221(d)	Power source	Engineer/Manufacturer
4221(e)	Environmental	Engineer
4221(f)	Driver and fan orientation	Engineer/Manufacturer
4221(g)	Standards	Engineer
4221(h)	Heater requirements	Engineer
4221(i)	Air velocity over driver	Engineer/Manufacturer
4341(d)	Inspection panel requirements predetermined life	Engineer
4411	Rating calculations	Manufacturer

Table BA-B-1000-1 Division of Responsibility (Cont'd)

BA-	Item	Responsible Party
4412	Documentation of rating	Manufacturer
4421	Sound level data report	Manufacturer/Engineer
4431	Design verification stress report	Manufacturer
4432	Design verification test procedure	Manufacturer
4432	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
7000	Packaging, shipping, receiving, storage, and handling 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

ARTICLE DA-1000
INTRODUCTION

DA-1100 SCOPE

This section provides requirements for the performance, design, fabrication, installation, inspection, acceptance testing, and quality assurance for dampers and louvers used in air and gas treatment systems in nuclear facilities.

DA-1200 PURPOSE

The purpose of this section is to ensure that dampers and louvers are acceptable in all aspects of design and operation.

DA-1300 APPLICABILITY

DA-1310 Exclusion of Items

Valves whose design, manufacture, test, and installation are covered by ASME BPVC, 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-1320 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-1330 Boundary Limits

The requirements of this Code are limited to those parts that comprise a damper or louver assembly as defined in DA-1410. While general requirements are included for mating flanges and similar supports, the boundary limits are the damper or louver assembly, flange, or frame.

DA-1400 DEFINITIONS AND TERMS

DA-1410 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 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 that 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).

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.

louver: a fixed or adjustable device comprised of multiple blades that, when mounted in an opening, permits the flow of air but inhibits the entrance of other elements, such as rain or snow.

DA-1420 Function

back draft 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 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.

DA-1430 Configuration

See Mandatory 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-1440 Leakage and Blade Operating Positioning

fail-safe 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-1450 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-1460 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-1470 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 a sample from a typical production lot of the component.

DA-1480 Construction (19)

fire damper construction: construction suitable to pass the criteria of 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-1490 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

The codes and standards listed below shall supplement those listed in Article AA-2000. Unless otherwise specified, the latest edition shall apply.

AMCA 500-D, Laboratory Methods for Testing Dampers for Rating
AMCA 500-L, Laboratory Methods for Testing Louvers for Rating
Publisher: Air Movement and Control Association International, Inc. (AMCA International), 30 West University Drive, Arlington Heights, IL 60004-1893 (www.amca.org)

NFPA 90A, Standard for the Installation of Air-Conditioning and Ventilating Systems
Publisher: National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471 (www.nfpa.org)

UL 555, UL Standard for Safety Fire Dampers
UL 555C, UL Standard for Safety Ceiling Dampers
Publisher: Underwriters Laboratories, Inc. (UL), 333 Pfingsten Road, Northbrook, IL 60062-2096; Order Address: Comm 2000, 151 Eastern Avenue, Bensenville, IL 60106 (www.ul.com)

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 AA-3100-1.

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 the Owner's 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, 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 A370.

All other components used in the construction of the damper shall be provided with a manufacturer's certificate of conformance 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 designee in sufficient detail to provide a complete basis for design and manufacture in accordance with this Code shall include the following, as applicable:

(a) reference to this Code
(b) function, as defined in DA-1420
(c) configuration, as defined in DA-1430
(d) maximum allowable seat and frame leakage and the specific differential pressures, as defined in DA-1440 and Mandatory Appendix DA-I
(e) pressures, as defined in DA-1450
(f) temperatures, as defined in DA-1460
(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 fail-safe 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 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

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 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: the 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 Article 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 $\frac{1}{360}$ of the span in any direction, or $\frac{1}{8}$ in. (3.175 mm), whichever is less.

(b) Blade edge or centerline deflection under normal and upset plant conditions (Service Levels A and B) shall not exceed $\frac{1}{360}$ of the blade length (or diameter) or $\frac{1}{8}$ in. (3.175 mm), whichever is less.

(c) The blade edge and centerline 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. The actuator and associated linkage shall deliver to the damper or louver a minimum of 1½ 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 1½ 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 system 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 used 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, B, or C. Dampers requiring frame construction to Leakage Rate Class A or B (see Mandatory Appendix DA-I) shall be provided with stuffing boxes, gasketed cover plates, or other sealing devices to reduce frame leakage to less than or equal to that stated in the design specification. Frame Class C shall have no consideration of leakage.

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 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 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.

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.

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 the applicable AMCA standard per Article DA-2000. 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 Class A, B, or C

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. Frame Class C shall have no consideration of leakage.

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 that 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 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-5143 Seat Leakage Test for Leakage Class II or Class III Dampers or Louvers. Leakage data shall be based on tests performed in accordance with the applicable AMCA standard per Article DA-2000 or other approved methods.

DA-5144 Seat Leakage Test for Leakage Class IV Dampers and Louvers. Seat Leakage Class IV shall have no consideration of leakage.

DA-5145 Fire Damper Closure Test. The fire dampers shall be tested in accordance with AMCA 500-D using Figure 5.4, 5.5, or 5.7 for wall or floor transfer applications; and Figure 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 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.

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, STAMPING, AND MANUALS (19)

Article AA-9000 requirements for nameplates, stamping, 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 STAMPING (19)

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
SEAT AND FRAME LEAKAGE

Table DA-I-1000-1 Maximum Permissible Seat Leakage Rate, scfm/ft^2 (scmh/m^2), of Damper or Adjustable Louver Face Area at 1 in. wg (25.4 mm wg) Differential Pressure

Damper Blade Length or Diameter, in. (mm)	Leakage Class 0 (Zero Leakage)	Leakage Class I (Low Leakage)	Leakage Class II (Moderate Leakage) [Note (1)]	Leakage Class III (Normal Leakage) [Note (1)]	Leakage Class IV
Up to 12 (305)	Note (2)	Note (3)	15 (275)	60 (1 100)	Note (4)
Up to 24 (610)	Note (2)	Note (3)	10 (180)	40 (730)	Note (4)
Up to 36 (915)	Note (2)	Note (3)	8 (145)	32 (585)	Note (4)
Up to 48 (1 220)	Note (2)	Note (3)	8 (145)	32 (585)	Note (4)
Up to 60 (1 525)	Note (2)	Note (3)	6 (110)	27 (495)	Note (4)
Up to 72 (1 830)	Note (2)	Note (3)	5 (90)	25 (455)	Note (4)

NOTES:
(1) The total maximum permissible leak rate is determined by multiplying the above quantities by the damper area in square feet (square meters) times the square root of the specified blade design pressure in inches water gauge (millimeters water gauge divided by 25.4).
(2) Leakage shall be zero as determined by the bubble method damper leakage test per DA-5141.
(3) Low leakage is the greater of 1 scfm/ft^2 or 1 scfm (18.3 scmh/m^2 or 1.7 scmh) at the blade shutoff pressure differential in inches water gauge (millimeters water gauge).
(4) Leakage Class IV is for applications where leakage is of no consideration.

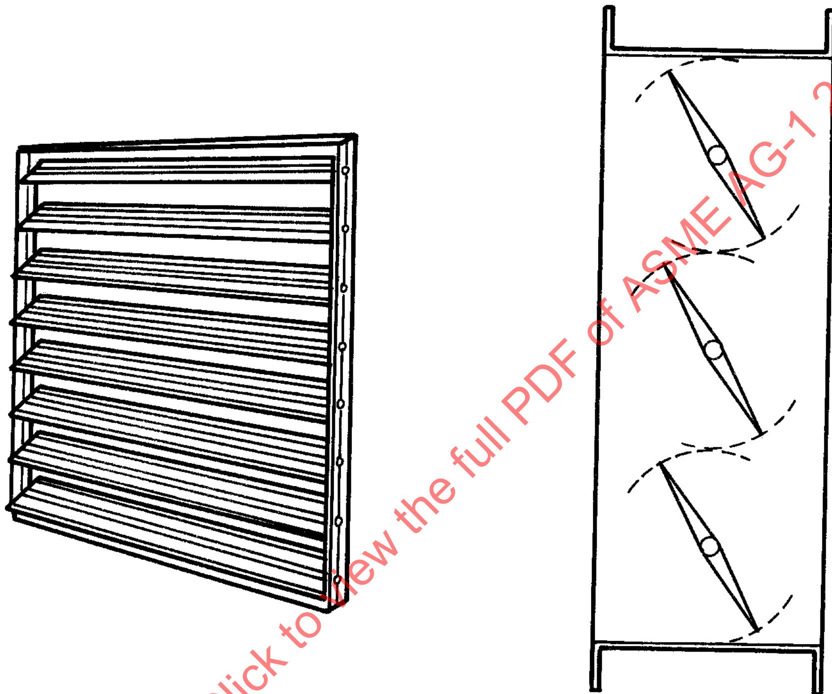
Table DA-I-1000-2 Maximum Permissible Frame Leakage Rate Classes at Frame Design Pressure

Leakage Rate Class	Permissible Leakage Rate
A	Zero leakage [Note (1)]
B	1 scfm (1.7 scmh) total leakage
C	No consideration of leakage

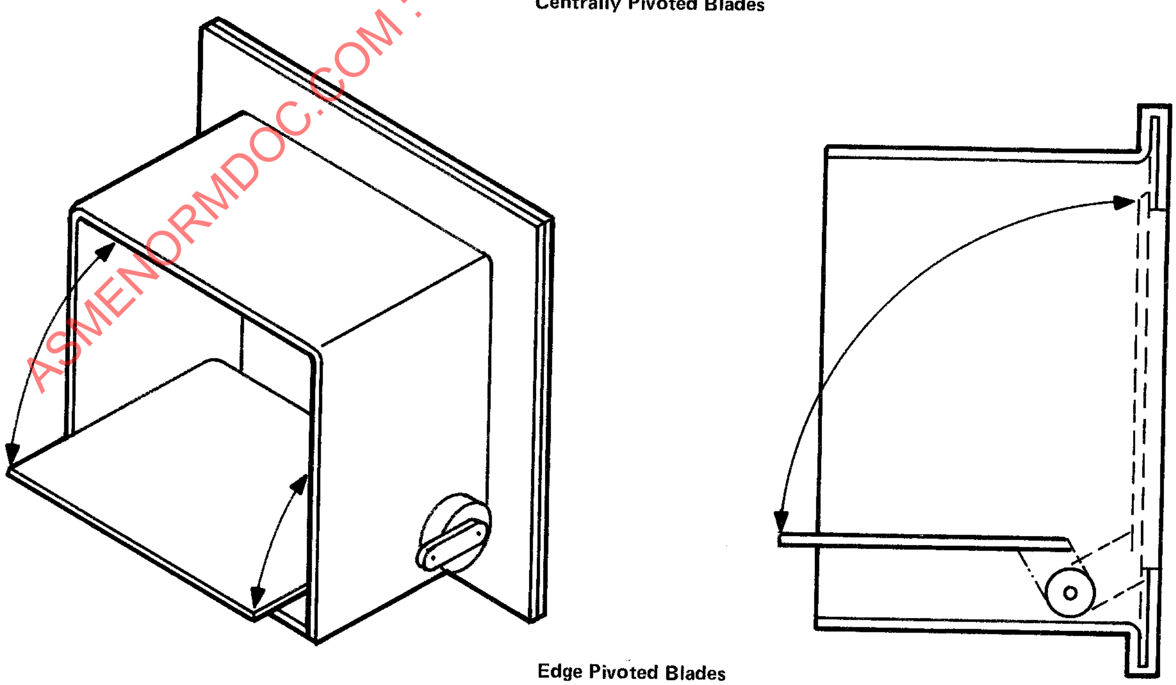
NOTE: (1) Leakage shall be zero as determined by the bubble method per DA-5130.

MANDATORY APPENDIX DA-II
DAMPER AND LOUVER CONFIGURATIONS

Figure DA-II-1000-1 Parallel-Blade Dampers

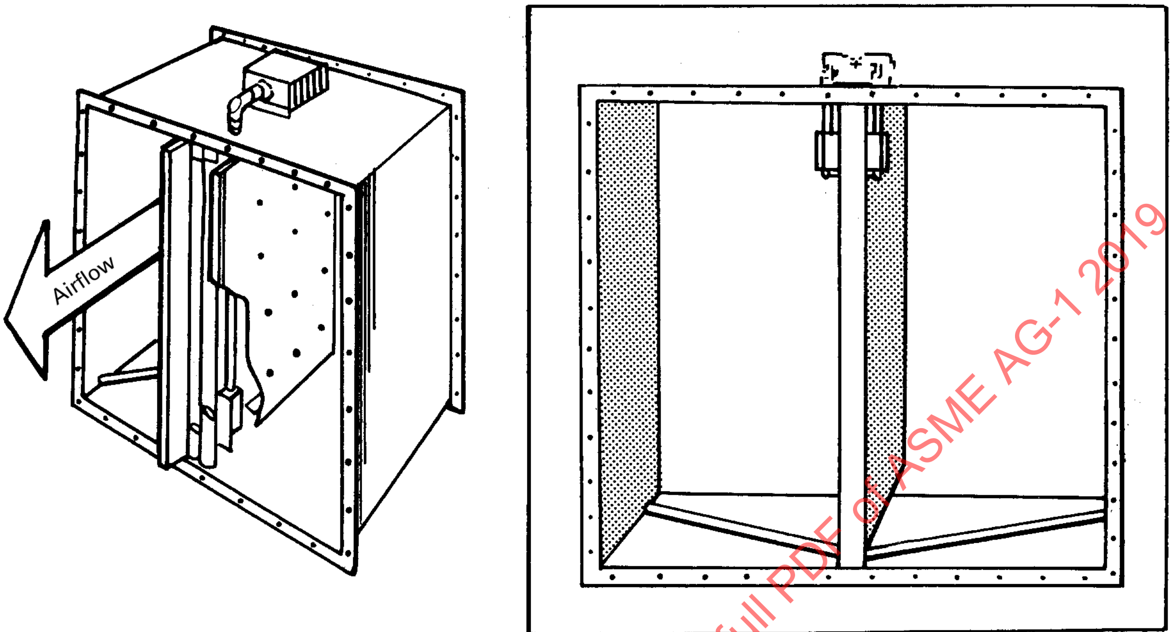


Centrally Pivoted Blades

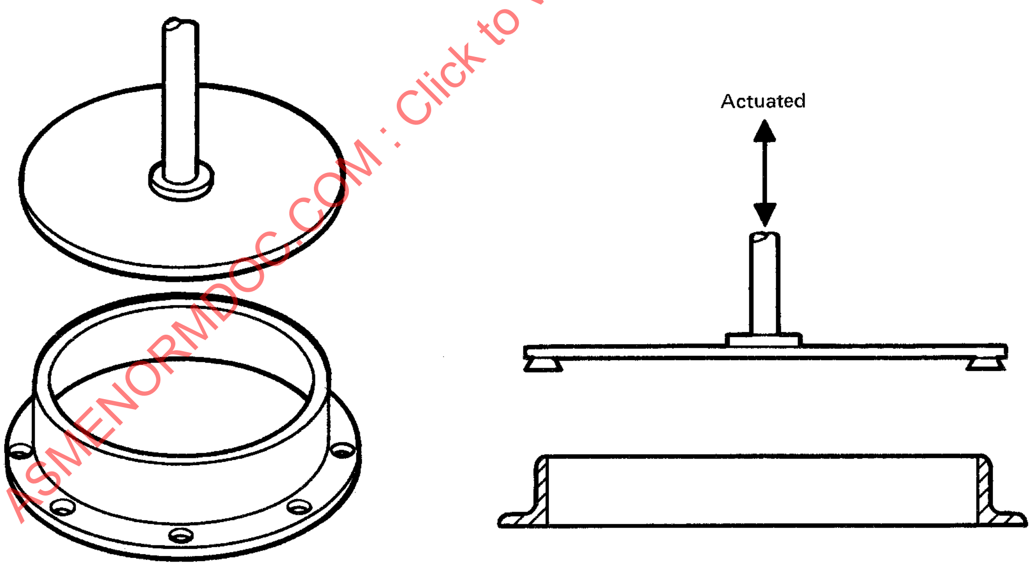


Edge Pivoted Blades

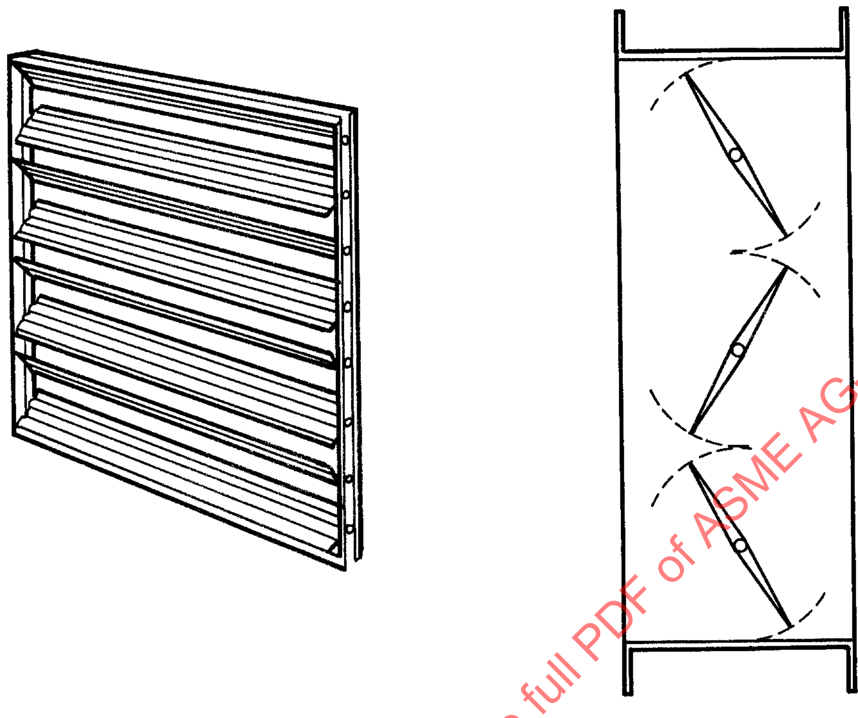
(19) **Figure DA-II-1000-2 Wing-Blade Damper**



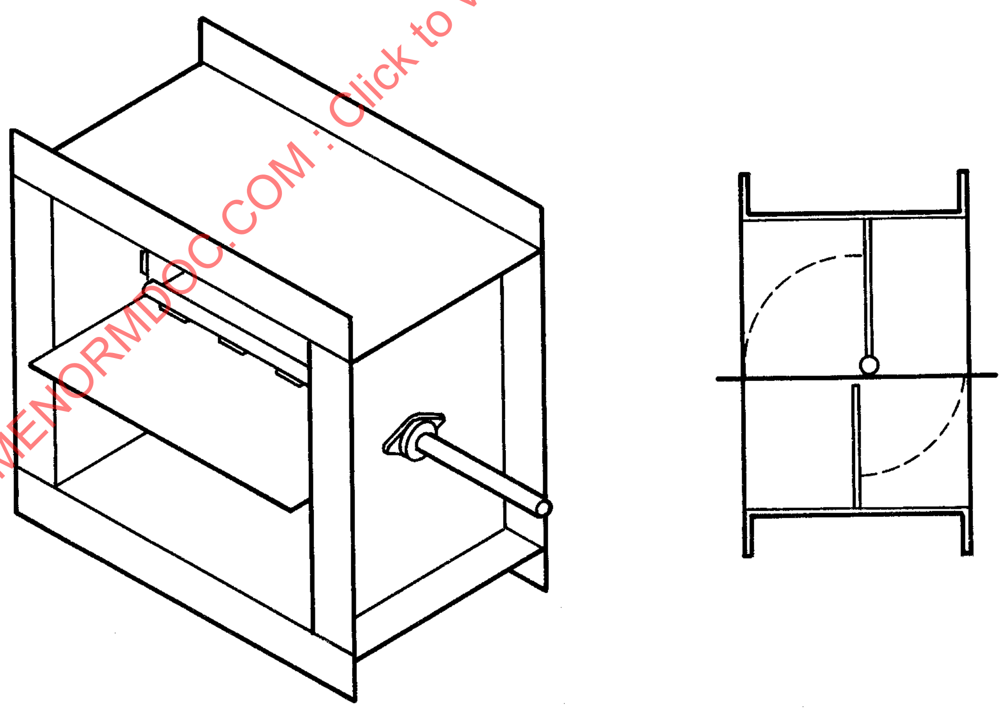
(19) **Figure DA-II-1000-3 Poppet Damper**



(19) **Figure DA-II-1000-4 Opposed-Blade Damper**



(19) **Figure DA-II-1000-5 Single-Blade Damper**



(19) **Figure DA-II-1000-6 Slide-Gate Guillotine Damper**

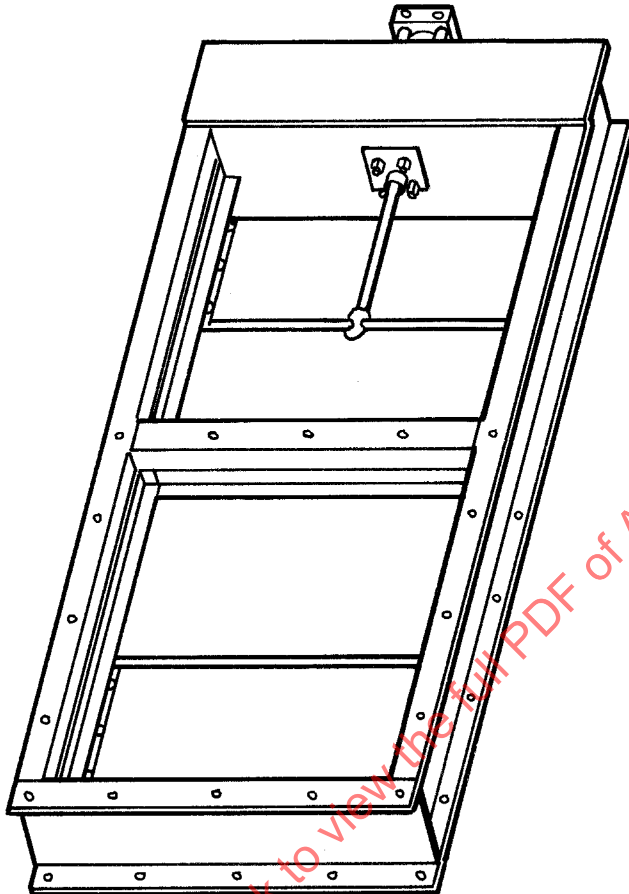


Figure DA-II-1000-7 Curtain-Type Dampers

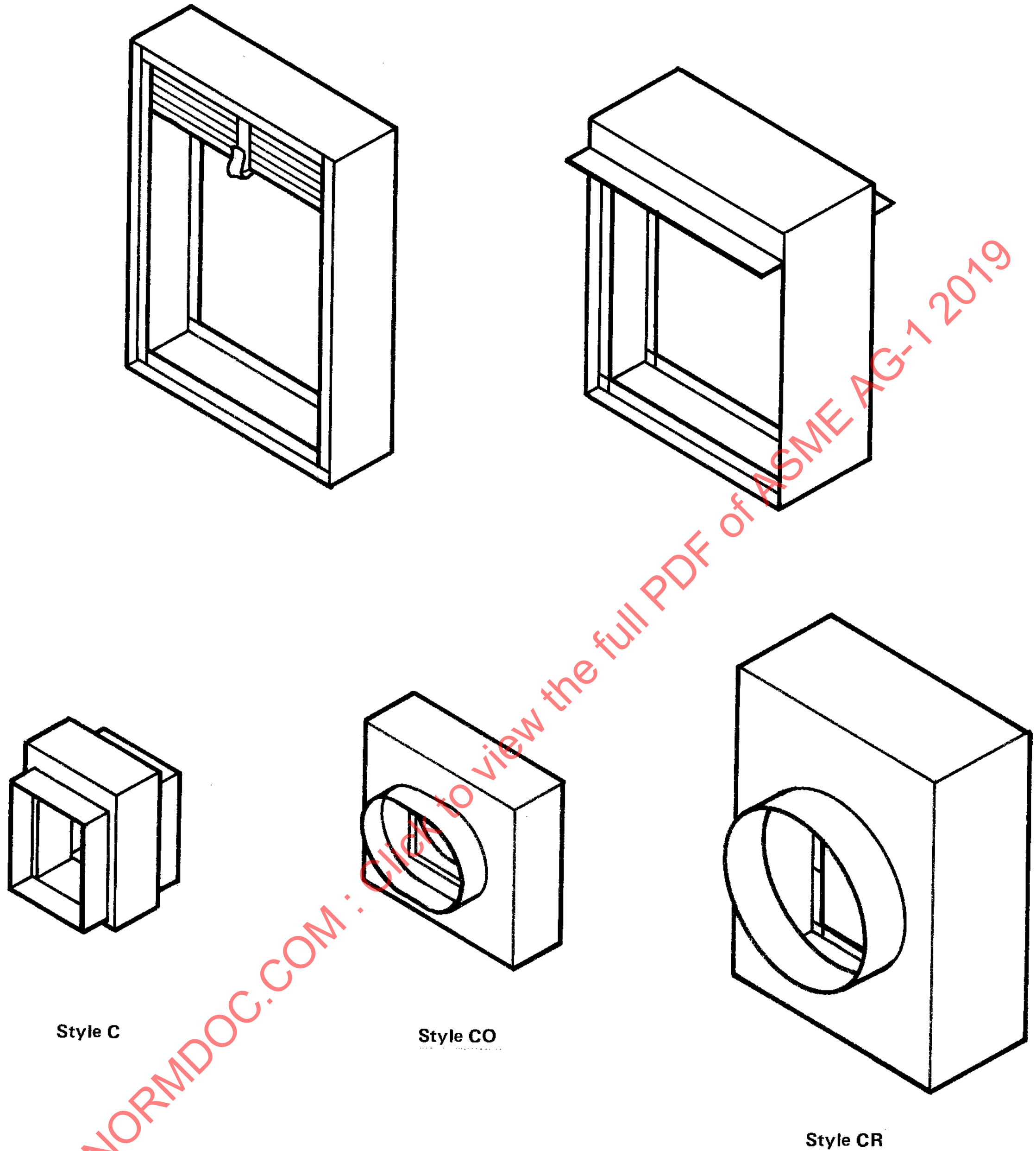
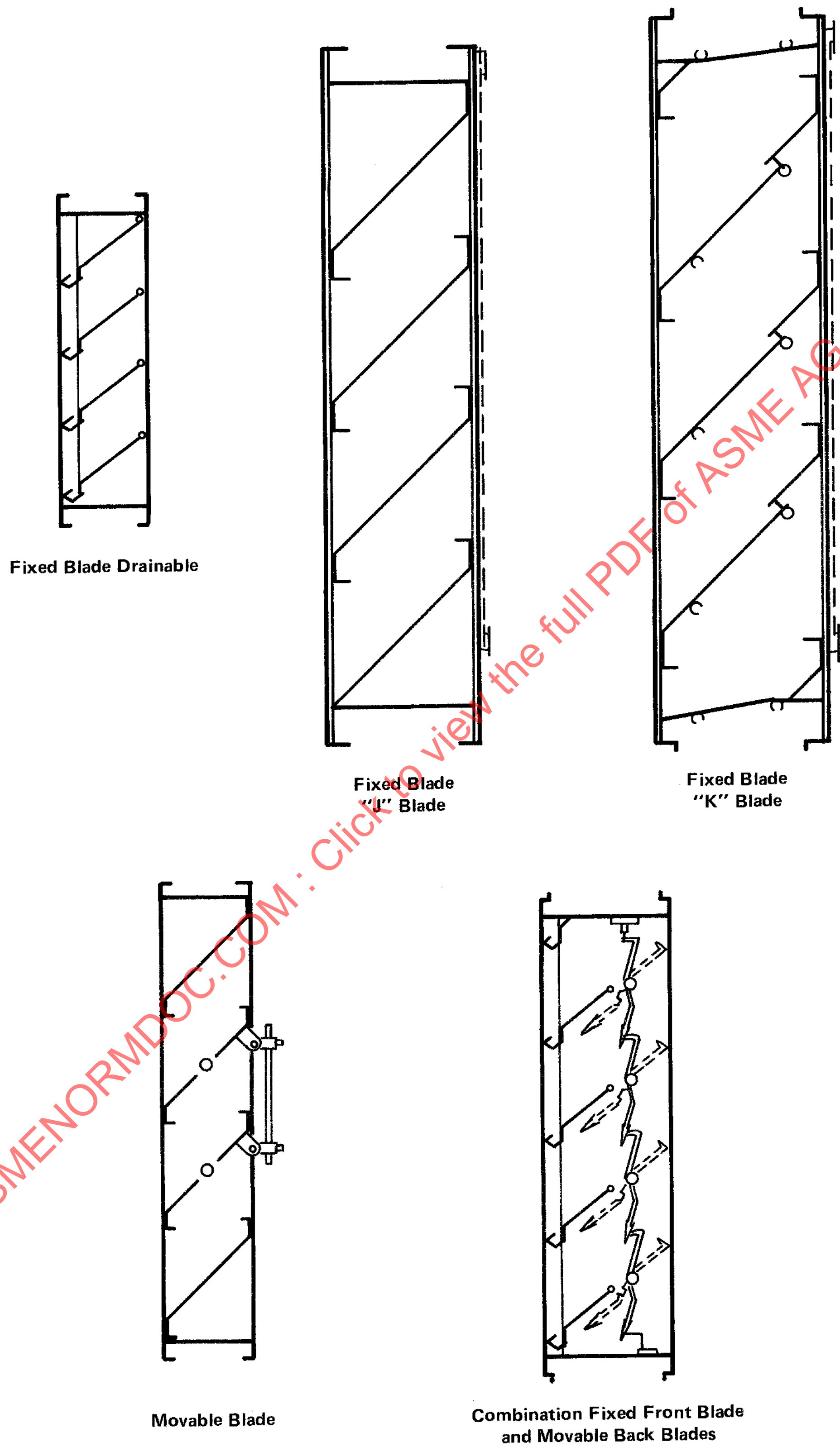


Figure DA-II-1000-8 Louver



NONMANDATORY APPENDIX DA-A
DIVISION OF RESPONSIBILITY

This 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-1000-1 begins on the following page.

(19)

Table DA-A-1000-1 Division of Responsibility

DA-	Item	Responsibility
3211	Fire hazard	Owner or designee
3211	Reduction of properties	Manufacturer
3212	Galvanic corrosion	Owner or designee
	With interface	Owner or designee
	With components	Manufacturer
3213	Prohibition of aluminum and zinc	Owner or designee
3220(a)	Fire hazard	Owner or designee
3220(b)	Degradation of properties	Manufacturer
3220(c)	Maintainability	Manufacturer
3230	Environmental conditions affecting material selection	Owner or designee
3300	CMTR	Manufacturer
3300	Allow certificate of conformance	Owner or designee
4110(b)	Damper function	Owner or designee
4110(c)	Damper configuration	Owner or designee
4110(d)	Allowable leakage	Owner or designee
4110(e)	Design pressures	Owner or designee
4110(f)	Design temperatures	Owner or designee
4110(g)	Volume flow rate	Owner or designee
4110(h)	Relative humidity	Owner or designee
4110(i)	Design pressure loss	Owner or designee
4110(j)	Entrained contaminants	Owner or designee
4110(k)	Normal blade position	Owner or designee
4110(k)	Fail-safe position	Owner or designee
4110(l)	Dimension and space for installation	Owner or designee
4110(m)	Mounting configuration and support	Owner or designee
4110(n)	Orientation and direction of airflow	Owner or designee
4110(o)	Blade orientation	Owner or designee
4110(p)	Operating time	Owner or designee
4110(q)	Actuator data	Owner or designee
4110(r)	Seismic requirements	Owner or designee
4110(s)	Allowable materials	Owner or designee
4110(t)	Special requirements	Owner or designee
4110(u)	Accessories required and mounting	Owner or designee
4110(v)	Loads, other than pressure loads	Owner or designee
4110(w)	Loading combinations and design transients	Owner or designee
4110(x)	Radiation dose rate	Owner or designee
4110(y)	Finish and coating requirements	Owner or designee
4110(z)	Fire resistance rating	Owner or designee
4120(a)	Mounting connection details	Manufacturer
4120(b)	Weight and center of gravity	Manufacturer
4120(c)	Service connections	Manufacturer
4120(d)	Pressure loss at rated flow	Manufacturer
4120(e)	Leakage	Manufacturer
4120(f)	Operating time	Manufacturer

Table DA-A-1000-1 Division of Responsibility (Cont'd)

DA-	Item	Responsibility
4120(g)	Materials of construction	Manufacturer
4120(h)	Bearing design life	Manufacturer
4120(i)	Seal design life	Manufacturer
4120(j)	Actuator torque	Manufacturer
4120(k)	Damper torque	Manufacturer
4120(l)	Actuator qualifications	Manufacturer
4120(m)	Verification reports	Manufacturer
4120(n)	Actuator position or orientation	Manufacturer
4120(o)	Fire resistance rating	Manufacturer
4120(p)	Replacement parts list	Manufacturer
4130	Gastight construction requirements	Owner or designee
4212	Damper/support boundary interface	Manufacturer
4212.1(a)	Design verification stress report (DVSR)	Manufacturer
4212.1(b)	Design verification test procedure (DVTP) and design verification test report (DVTR)	Manufacturer
4212.1(c)	Design verification by comparative evaluation report (DVCER)	Manufacturer
4220	Thermal expansion clearances	Manufacturer
4240	Requirement for interconnecting wiring and interfaces	Owner or designee
4315(a)	Actuator function	Owner or designee
4315(b)	Actuator power source	Owner or designee
4315(c)	Control signal characteristics	Owner or designee
4315(d)	Frequency of actuation	Owner or designee
4315(e)	Damper opening and closing time	Owner or designee
4315(f)	Environmental conditions	Owner or designee
4315(g)	Mounting location and space limitations	Owner or designee
4315(h)	Normal override requirements	Owner or designee
4315(i)	Accumulator sizing	Owner or designee
4315(j)	Qualification requirements	Owner or designee
4315(k)	Type of motion	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
5143	Approval of alternate test method	Owner or designee
6000	Finishing of materials	Owner or designee
6000	Structural support for dampers	Owner or designee
6100	Welding requirements	Owner or designee
7000	Packaging, shipping, receiving, storage, and handling	Manufacturer/Supplier/Contractor/Owner or designee
8000	Quality assurance	All parties
9000	Nameplates, stamping, and manuals	Manufacturer/Supplier/Contractor

SECTION SA DUCTWORK

ARTICLE SA-1000 INTRODUCTION

SA-1100 SCOPE

This section provides requirements for the performance, design, fabrication, installation, inspection, acceptance testing, and quality assurance for ductwork, including ductwork accessories, ductwork supports, and duct-mounted equipment, used in air and gas treatment systems in nuclear facilities.

SA-1200 PURPOSE

The purpose of this section is to ensure that ductwork, accessories, and ductwork supports are acceptable in all aspects of design and operation.

SA-1300 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 Figure SA-1300-1.

(19) SA-1400 DEFINITIONS AND TERMS

The definitions and terms described below are specific to this section. For other definitions and terms, see AA-1400.

accessories: components of a duct system (e.g., turning vanes, diffusers, and gaskets) that are required to make the system operate in accordance with design.

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.

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 and/or directing airflow.

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.

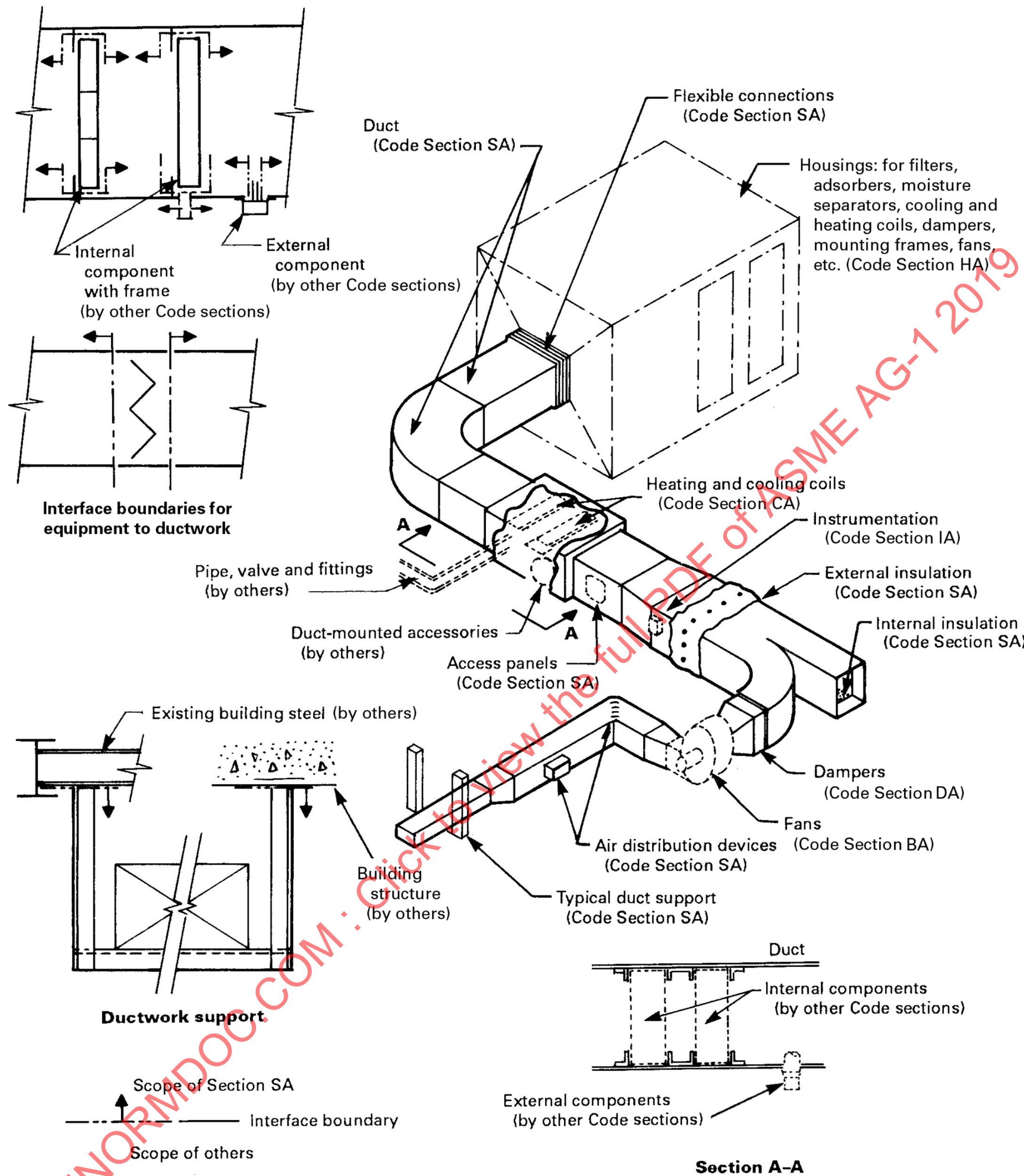
insulation, internal: a material attached to the internal duct surface that has heat transfer resisting properties.

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 still 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.

Figure SA-1300-1 Ductwork and Ductwork Support — Interface Boundary



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.

splitter damper: a manually positioned single-blade damper located at duct branch connections for diverting airflow into the branch duct.

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.

ARTICLE SA-2000 REFERENCED DOCUMENTS

The codes and standards listed below shall supplement those listed in Article AA-2000. Unless otherwise specified, the latest edition shall apply.

AISC 348, Specification for Structural Joints Using High-Strength Bolts
Publisher: American Institute of Steel Construction (AISC), 130 East Randolph Street, Suite 2000, Chicago, IL 60601 (www.aisc.org)

AMCA 201, Fans and Systems
Publisher: Air Movement and Control Association International, Inc. (AMCA International), 30 West University Drive, Arlington Heights, IL 60004-1893 (www.amca.org)

ASHRAE 70, Method of Testing the Performance of Air Outlets and Air Inlets
ASHRAE Handbook: Fundamentals
Publisher: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329 (www.ashrae.org)

Industrial Ventilation: A Manual of Recommended Practice
Publisher: American Conference of Governmental Industrial Hygienists (ACGIH), 1330 Kemper Meadow Drive, Cincinnati, OH 45240 (www.acgih.org)

National Fire Codes, 1991 Edition
NFPA 90A, Standard for the Installation of Air-Conditioning and Ventilating Systems
Publisher: National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471 (www.nfpa.org)

SMACNA 1520, Round Industrial Duct Construction Standards
SMACNA 1922, Rectangular Industrial Duct Construction Standards (Inch-Pound Version)
SMACNA 1943, Rectangular Industrial Duct Construction Standards (SI Version)
SMACNA 1958, HVAC Systems Duct Design
SMACNA 1966, HVAC Duct Construction Standards: Metal and Flexible
Publisher: Sheet Metal and Air-Conditioning Contractors' National Association (SMACNA), 4201 Lafayette Center Drive, Chantilly, VA 20151-1209 (www.smacna.org)

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 critical attributes. 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 components used in the construction of ductwork shall be provided with a manufacturer's certificate of conformance 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 AA-3100-1. Substitute materials shall be equivalent to or exceed the requirements of Table AA-3100-1, as determined by the Owner or designee.

Materials selected shall be evaluated for suitability with service conditions and compatibility with other materials used in duct construction.

The ASTM numbers in Table AA-3100-1 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.

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).* These loads and terms are as defined in AA-4211.

(b) Constraints of Free End Displacement Loads (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) Live Loads (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).

(d) Normal Operating Pressure Differential (NOPD). This is as defined in 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 (see AA-4211). NOPD and SOPT may be positive or negative pressures. Worst case shall be considered in design.

(e) Seismic Loads (SL). These loads are the result of the envelope of the operating basis earthquake (OBE) and the safe shutdown earthquake (SSE).

(f) Hydrostatic Loads (HY) 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. HY shall be added to the DW case as applicable.

(g) Design Pressure Differential (DPD). These are the dynamic external pressure loads resulting from a design basis accident (DBA), intermediate break accident (IBA), or small break accident (SBA). Generally, ductwork should be routed outside the local pipe break affected area. If ductwork is subjected to these loads, the design specification (SA-4600) shall address the station specific design requirements considering a Service Level D load combination.

(h) Component Load (CL). CL shall be added to the DW case as part of normal loads (N) when determining ductwork support load combinations as defined in AA-4212. For other component load criteria, see the following sections and other applicable Division II Code sections:

(1) Article BA-4000, for fans and blowers
(2) Article CA-4000, for conditioning equipment
(3) DA-4210, for dampers and louvers
(4) HA-4200, for housings
(5) Article IA-4000, for instrumentation and controls
(6) Article RA-4000, for refrigeration equipment
(7) FA-4300, for moisture separators
(8) FB-4300, for medium efficiency filters
(9) FC-4300, for HEPA filters
(10) FD-4300, for Type II adsorber cells
(11) FE-4400, for Type III adsorber cells
(12) FG-4200, for mounting frames
(13) FH-4300, for Type IV adsorber cells
(14) FK-4300, for special HEPA filters

SA-4212 Ductwork Load Combinations. The applicable component loading shall be combined in accordance with Table AA-4212-1.

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 L, NOPD, SL shall also be used for duct supports. The definition of loads per AA-4211 for DW, EL, and ADL shall also be used for duct supports. HY and CL 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 AA-4211 is not typically a significant load for supports and may be neglected.

SA-4216 Ductwork Support Load Combinations. The applicable support loading shall be combined in accordance with Table AA-4212-1.

SA-4220 Stress Criteria

Detailed stress analysis of the ductwork and ductwork supports shall be prepared in accordance with 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-4230 for various service level conditions.

SA-4232 Deflection Limits for Panels, Flanges, and Stiffeners. The requirements of AA-4230 apply.

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 the welding procedure qualifications/prequalifications of AA-6300.

Attachments may be either the welded or the 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) Van Stone 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. (100 mm) on center unless otherwise specified by the design specification. The adequacy of bolt spacing greater than 4 in. (100 mm) 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 (3735 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 AA-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

(19) 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 (19)

Construction of access doors and panels and their frames shall be selected to meet the allowable leakage determined in SA-4500. Sealing surfaces between the doors and panels and their frames 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 that ensures leakage requirements are met and provides a uniform gasket compression of 50% ± 20% of nominal gasket thickness.

Door hinges shall be designed to minimize damage to compression seals due to friction and shear forces during opening and closing of the doors.

Hinges and latches, etc., shall be designed such that lubrication materials shall not enter the interior of the ductwork.

See SA-C-1210 for additional guidance on the design of access doors.

SA-4440 Ports for Testing and Maintenance

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 test port penetrations shall be sealed by welding, sealant, adjustable compression seal, or gland type seals. Gland type seals include, but are not limited to, nonmetallic materials.

SA-4450 Miscellaneous

SA-4451 Drains (19)

(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) Drain lines shall be valved, sealed, trapped, or otherwise protected to prevent the following adverse conditions:

(1) air bypass around filtration components

(2) a negative impact on cooling/heating coil capacity

(3) transfer of contaminated (radioactive or otherwise) air through the piping to a protected environment (either into or out of ductwork)

(d) For additional guidance on the design of drains, see 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 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 applicable standards.

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..

(19) **SA-4455 Fire Detectors.** If required to be installed in the duct, fire protection instruments shall meet the reliability and sensitivity requirements of the system specification. The carbon monoxide (CO) or carbon dioxide (CO_2) or smoke detector or a combination thereof shall be placed at a location downstream of the adsorber at which adequate air mixing has been verified. Smoke detectors are to be used only when high efficiency filters are not installed downstream of the adsorber.

Single-point temperature sensors are not considered an adequate method of detecting an adsorber fire and shall not be used as the sole means of fire detection.

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-1400

(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 Owner or designee shall evaluate each system to establish the allowable leakage to ensure its design ventilation, temperature, and contamination control function are achievable.

SA-4532 Allowable Leakage Determination. The following criteria shall be used 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. The following portions of air cleaning, air cooling, and ventilation systems need not be subjected to quantitative measurement of leakage unless otherwise required by the design specification (however, the system shall be pressurized to NOPD to locate and seal all audible leaks): (19)

(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 modes are not credited to meet off-site dose limits

(c) systems that provide air cooling or heating function only, located entirely in a clean interspace

Other exceptions to quantitative measurement of leakage requirements shall be technically justified and specifically documented with basis by the Owner or designee.

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) NOPD and 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 evaluation by the Owner or designee, it shall be performed in accordance with SA-5300 and Section TA.

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 function: identify the function 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.

(g) fire protection requirements

(h) material certification requirements

(i) tolerance requirements

(j) dust components and interface with other components

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 Owner or designee. 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 using gaskets 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 Owner or designee.

(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 scfm (sL/s)

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 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 used 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. (19)

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 AA-6300.

Welding and brazing performed in accordance with this section shall meet the requirements of AA-6300 and AA-6400.

SA-6200 FABRICATION PROCESSES

(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) Methods of cutting, forming, or bending coated material shall be designed to minimize the potential for damage to coatings.

(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 $\frac{1}{8}$ 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

(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 AISC 348.

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 AISC Specification for the Design, Fabrication and Erection of Structural Steel for Buildings.

(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

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-6400-1.

(b) Circular ducts, measured by outside circumference or two interior diameters at 90 deg (±5) to each other, shall conform to Table SA-6400-2.

(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-6400-3.

(d) The tolerances given in Tables SA-6400-1, SA-6400-2, and SA-6400-3 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.

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

SA-7100 GENERAL

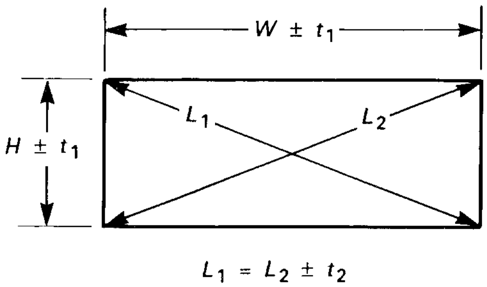
Packaging, shipping, receiving, storage, and handling requirements shall be in accordance with Article AA-7000 and this section.

SA-7200 PACKAGING

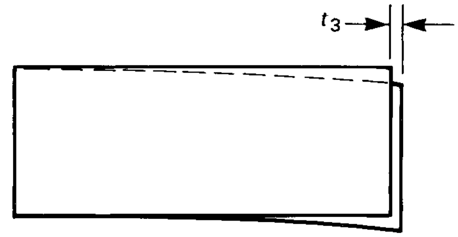
Ductwork and accessory item packaging requirements are dependent upon the protection level as described by AA-7230. Additional clarification or exceptions are provided below.

(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.

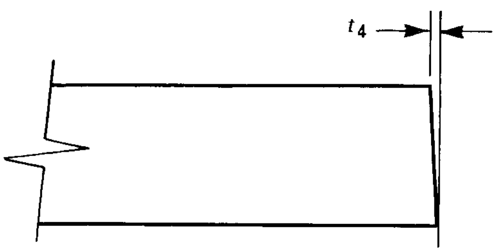
Table SA-6400-1 Rectangular Ducts: Maximum Allowable Tolerances



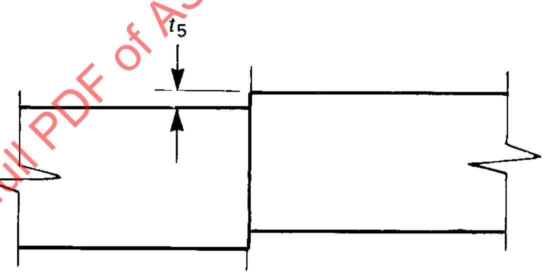
Cross Section
Parallelism/Squareness



Twist
Per 5 ft (1.5 m) Joint



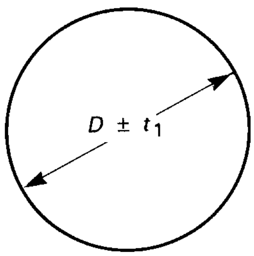
Joint Flange
Squareness



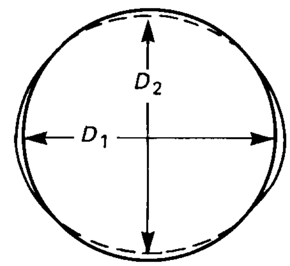
Joint Connection
Maximum Offset

	Maximum Allowable Tolerances, in. (mm)				
W* or *H	t_1	t_2	t_3	t_4	t_5
Less than 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)

(19) **Table SA-6400-2 Circular Ducts: Maximum Allowable Tolerances**

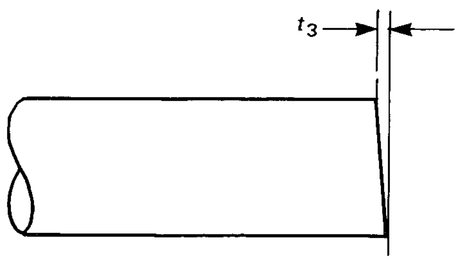


Diameter

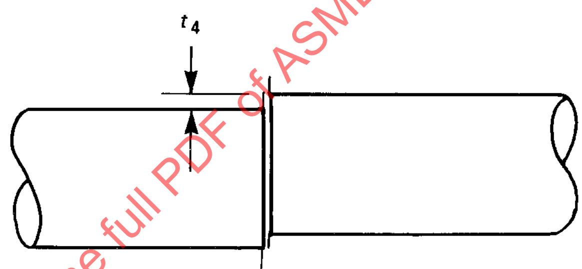


$D_2 = D_1 \pm t_2$

Out-of-Round



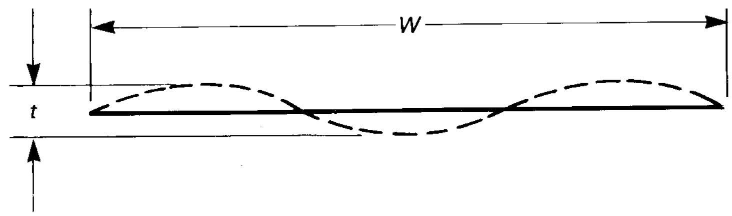
Joint End Squareness



Joint Connection Offset

Diameter	Maximum Allowable Tolerances, in. (mm)			
	t_1	t_2	t_3	t_4
Less than 12	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)

(19) **Table SA-6400-3 Flatness of Surface: Maximum Allowable Waviness Tolerance**



Maximum Allowable Waviness Tolerance	
t = waviness tolerance of flat surfaces between duct edges and adjoining stiffeners. It shall not exceed 125% of allowed manufacturer's tolerance as specified by:	
Cold-rolled steel sheet	ASTM A568
Cold-rolled steel plate	ASTM A6, Table A-1.13
Hot-rolled steel sheet	ASTM A568
Hot-rolled steel plate	ASTM A6, Table A-1.14
Galvanized steel sheet	ASTM A653, Supplementary Requirement S1.3

(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

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 per AA-7230.

(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-9210, and AA-9220. 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-9200 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-9210 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 unreadable.

SA-9220 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-9230 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 Appendix defines primary responsibility for individual sections of this Code section.

Table SA-A-1000-1 Division of Responsibility

SA-	Item	Responsible Party
3100	Certification of material	Manufacturer/Supplier
3200	Material substitution	Manufacturer/Supplier/Contractor/Owner or designee
3300	Material testing	Manufacturer/Supplier
4210	Load criteria	Owner or designee
4220	Stress criteria	Owner or designee
4230	Deflection criteria	Owner or designee
4240	Other criteria	Owner or designee
4320	Duct joints and seams	Contractor/Engineer
4410	Flexible connections	Manufacturer/Contractor/Owner or designee
4420	Gaskets	Manufacturer/Contractor/Owner or designee
4430	Access doors and panels	Manufacturer/Contractor/Owner or designee
4440	Provisions for testing and maintenance	Manufacturer/Contractor/Owner or designee
4450	Miscellaneous	Manufacturer/Contractor/Owner or designee
4530	Pressure boundary leakage evaluation	Owner or designee
4540	Leakage testing	Owner or designee/Contractor
4600	Design specification	Owner or designee
5120	Responsibility for procedures	Manufacturer/Contractor/Owner or designee
5200	Visual inspection	Contractor/Manufacturer/Owner or designee
5320	Systems completeness	Owner or designee/Contractor
5330	Allowance for testing system leakage rates by sections	Owner or designee/Contractor
5340	Testing procedures	Owner or designee/Contractor
5350	Documentation	Contractor
5361	Acceptance criteria — quantitative leakage tests	Contractor/Owner or designee
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 or designee
8000	Quality assurance	All parties
9000	Nameplates and stamping	Manufacturer/Supplier/Contractor

NONMANDATORY APPENDIX SA-B PROCEDURES TO DETERMINE ALLOWABLE LEAKAGE FOR DUCTWORK

(19) ARTICLE SA-B-1000 INTRODUCTION

(19) SA-B-1100 PURPOSE

The purpose of this Appendix is to provide additional guidance for determining 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 C.F.R. 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 C.F.R. 20, Appendix B, Table 1.

This section provides procedures to determine the maximum duct out-leakage based on the maximum permissible concentration (MPC) as determined by 10 C.F.R. 20 §103, paras. a and b.

SA-B-1220 Procedure to Determine Allowable Leakage by Maximum Permissible Concentration Method

(19) **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 in a clean interspace, under positive pressure in either normal or transient conditions.

(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 Figure SA-B-1221-1 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. The nomenclature is as follows:

A = duct surface area, ft^2 (m^2)
AC = room ventilation rate, air changes per hour or $60qv/H\ell w$ ($3.6qv/H\ell w$)
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/s/m^2)
ℓ = room length, ft (m)
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

(U.S. Customary Units)

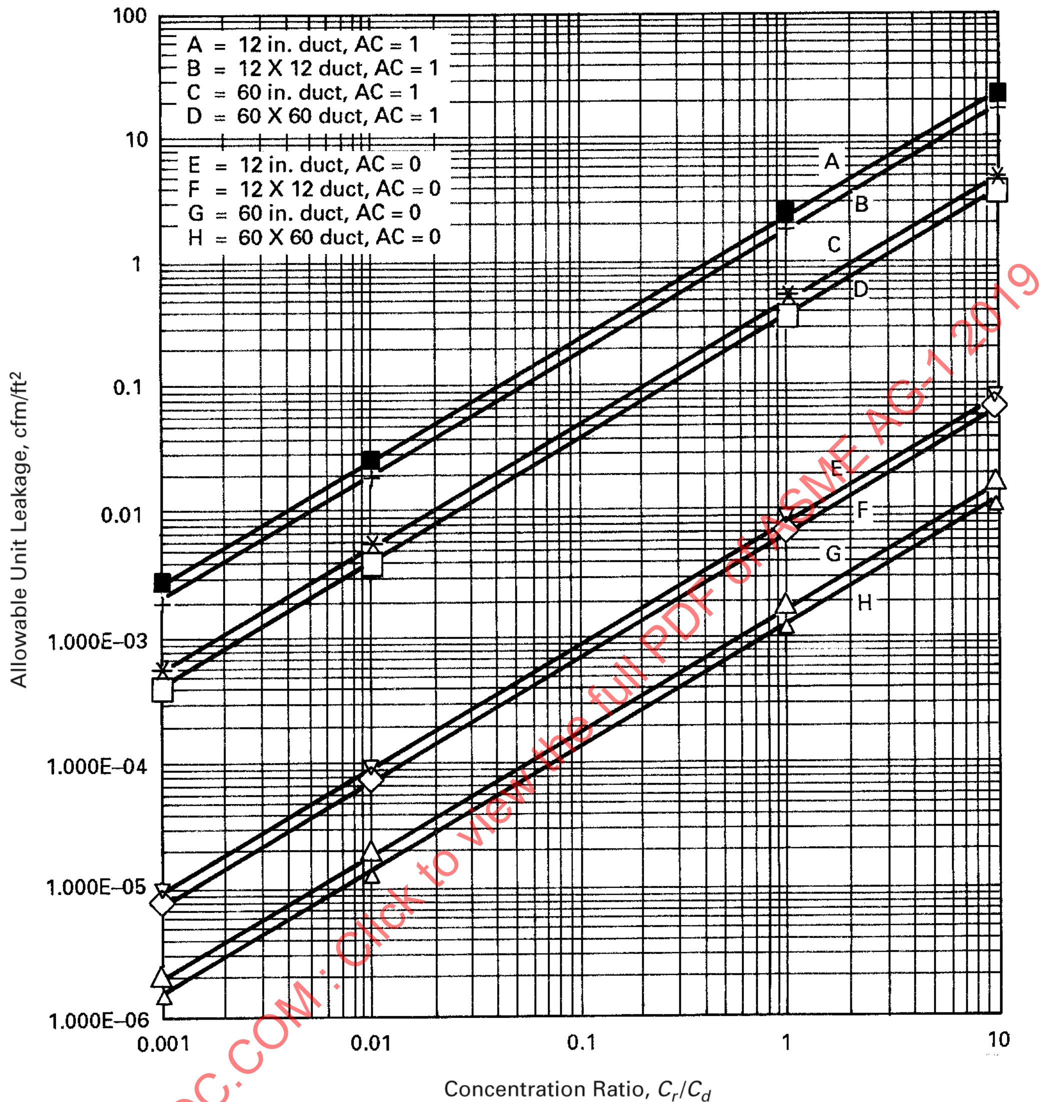
$$G = 1.7 \times 10^6 C_d LA \tag{1}$$

(SI Units)

$$G = 3.6 \times 10^6 C_d LA$$

Equilibrium concentration in the room that results from outleakage is

Figure SA-B-1221-1 Allowable Unit Leakage From Duct or Housing to Occupied Space



GENERAL NOTES:

(a) Based on 10 C.F.R. 20, Appendix B, para. B.2.1(d), eq. (B-1), and a room that is 25 ft^2 × 20 ft high. For other duct (and room) lengths and heights, prorate chart values by

$$L = L_{\text{chart}} \times \frac{\text{duct length}}{25} \times \frac{\text{room height}}{20}$$

(b) Contamination assumed to mix uniformly in space.

(c) I-131 assumed to be contaminating nuclide.

(d) Allowable unit leakage applies to maximum operating pressure, $P_{d,}$ as defined in 10 C.F.R. 20, para. 4.6.3.

(U.S. Customary Units)

$$C_r = \frac{G}{28{,}320\ V_r\left(\lambda + \dfrac{60qv}{V_r}\right)} \tag{2}$$

(SI Units)

$$C_r = \frac{G}{1 \times 10^6 V_r\left(\lambda + \dfrac{3.6qv}{V_r}\right)}$$

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

(U.S. Customary Units)

$$A = \frac{\ell_d}{6}(h + b) \tag{4}$$

(SI Units)

$$A = \frac{\ell_d}{500}(h + b)$$

Substituting eqs. (1), (3), and (4) into eq. (2) and transposing, the general equation for a rectangular duct is

(U.S. Customary Units)

$$L = \left(\frac{C_r}{C_d}\right)\frac{H\ell w}{10\ell_d(h+b)}\left(\frac{0.693}{T^{1/2}} + \overline{AC}\right) \tag{5}$$

(SI Units)

$$L = \left(\frac{C_r}{C_d}\right)\frac{138H\ell w}{\ell_d(h+b)}\left(\frac{0.693}{T^{1/2}} + \overline{AC}\right)$$

Assuming that the duct cross section is square ($b = h$) and that the room is square ($w = \ell$), eq. (5) reduces to

(U.S. Customary Units)

$$L = \left(\frac{C_r}{C_d}\right)\frac{1}{20}\frac{H\ell^2}{h\ell_d}\left(\frac{0.693}{T^{1/2}} + \overline{AC}\right) \tag{6}$$

(SI Units)

$$L = \left(\frac{C_r}{C_d}\right)\frac{69H\ell^2}{h\ell_d}\left(\frac{0.693}{T^{1/2}} + \overline{AC}\right)$$

Further assuming that the room height is 20 ft (6.1 m)

(U.S. Customary Units)

$$L = \left(\frac{C_r}{C_d}\right)\frac{\ell^2}{h\ell_d}\left(\frac{0.693}{T^{1/2}} + \overline{AC}\right) \tag{7}$$

(SI Units)

$$L = \left(\frac{C_r}{C_d}\right)\frac{420\ell^2}{h\ell_d}\left(\frac{0.693}{T^{1/2}} + \overline{AC}\right)$$

If the contaminating nuclide is I-131 ($T^{1/2}$ = 193.6 hr) and ℓ = 25 ft and ℓ_d = 25 ft (7.6 m)

$$L = \left(\frac{C_r}{C_d}\right)\frac{25}{h}(0.00358 + \overline{AC}) \tag{8}$$

For a sealed room, $\overline{AC} = 0$

(U.S. Customary Units)

$$L = \left(\frac{C_r}{C_d}\right)\frac{1}{11.17h} \tag{9}$$

(SI Units)

$$L = \left(\frac{C_r}{C_d}\right)\frac{11.43}{h}$$

For a room with $\overline{AC} = 1$

(U.S. Customary Units)

$$L = \left(\frac{C_r}{C_d}\right)\frac{25.09}{h} \tag{10}$$

(SI Units)

$$L = \left(\frac{C_r}{C_d}\right)\frac{3\,202}{h}$$

For a round duct, eq. (6) is replaced by

(U.S. Customary Units)

$$A = \pi\left(\frac{D}{12}\right)\ell d \tag{11}$$

(SI Units)

$$A = \pi\left(\frac{D}{1\,000}\right)\ell d$$

and general eq. (7) becomes

(U.S. Customary Units)

$$L = \frac{1}{15.7}\left(\frac{C_r}{C_d}\right)\left[\frac{H\ell w}{\ell_d D}\left(\frac{0.693}{T^{1/2}} + \overline{AC}\right)\right] \qquad (12)$$

(SI Units)

$$L = 88.4\left(\frac{C_r}{C_d}\right)\left[\frac{H\ell w}{\ell_d D}\left(\frac{0.693}{T^{1/2}} + \overline{AC}\right)\right]$$

Where N nuclides are present in the duct, it can be shown that

(U.S. Customary Units)

$$L = \frac{H\ell w}{10\ell_d(h+b)} \frac{\sum_{n=1}^{N} C_r n/\mathrm{MPC}n}{\sum_{n=1}^{N} \frac{C_d n/\mathrm{MPC}n}{0.693/T^{1/2}/2n + \overline{AC}}} \qquad (13)$$

(SI Units)

$$L = \frac{138H\ell w}{\ell_d(h+b)} \frac{\sum_{n=1}^{N} C_r n\ /\ \mathrm{MPC}n}{\sum_{n=1}^{N} \frac{C_d n\ /\ \mathrm{MPC}n}{0.693\ /\ T^{1/2}\ /\ 2n + \overline{AC}}}$$

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

(U.S. Customary Units)

$$L = \frac{H\ell w\overline{AC}}{10\,\ell_d\,(h+b)} \frac{\sum(C_r n\ /\ \mathrm{MPC}n)}{\sum(C_d n\ /\ \mathrm{MPC}n)} \qquad (14)$$

(SI Units)

$$L = \frac{138H\ell w\overline{AC}}{\ell_d\,(h+b)} \frac{\sum(C_r n\ /\ \mathrm{MPC}n)}{\sum(C_d n\ /\ \mathrm{MPC}n)}$$

Since the ratio

$$\sum_{n=1}^{N} (C_r n/\mathrm{MPC}n)$$

represents the fraction of maximum permissible dose for the stated period of exposure, usually a 40-hr week, and $C_r n/\mathrm{MPC}n$ 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 multinuclide duct leakage as well. Finally, the ratio

$$\sum_{n=1}^{N} (C_r n/\mathrm{MPC}n)$$

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 (airflow rate/room volume) required to maintain minimum MPC based on as low as reasonably achievable (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 by subtracting item (b) or item (c) from item (d).

(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 equation:

$$L_t = L_o(P_t/P_o)^{1/2} \qquad (15)$$

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)

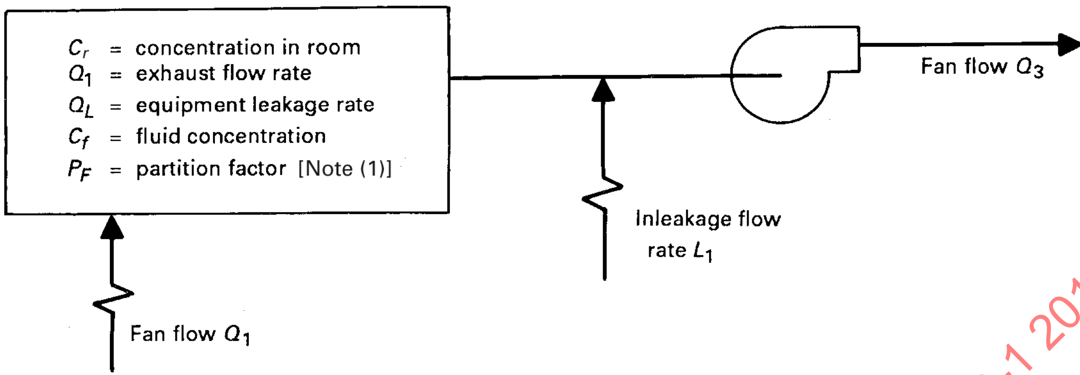
P_o = operating pressure, in. wg (kPa)

P_t = test pressure, in. wg (kPa)

(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 Figure SA-B-1222-1.

Figure SA-B-1222-1 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.

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 Figure SA-B-1410-1, has a rated flow of 10,000 cfm (4 720 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 × 6.1 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

(U.S. Customary Units)

$$L = \left(\frac{C_r}{C_d}\right)\frac{H \ell w}{10\,\ell_d (h+b)}\left(\frac{0.693}{T^1\!/_2} + \overline{AC}\right)$$

$$= 0.0032 \times \frac{20 \times 25 \times 25}{10(50)(30+12)} \times \left(\frac{0.693}{193.6} + 1\right)$$

$$= 0.0019 \text{ cfm / ft}^2 \text{ or } 0.002 \text{ cfm / ft}^2$$

(SI Units)

$$L = \left(\frac{C_r}{C_d}\right)\frac{138 H \ell w}{\ell_d (h+b)}\left(\frac{0.693}{T^1\!/_2} + \overline{AC}\right)$$

$$= 0.0032 \times \frac{138(6.1 \times 7.6 \times 7.6)}{(15.2)(762+305)} \times \left(\frac{0.0693}{193.6} + 1\right)$$

$$= 0.0096 \text{ L/s/m}^2 \text{ or } 0.010 \text{ L/s/m}^2$$

where

$T^1\!/_2$ = 193.6 hr

(b) **Given:** A cubicle containing a normally operating pump with a leak rate of 1 gal/hr (3.8 L/h) at a concentration of 0.15 Ci/cc. (The MPC I-131 is 9 × 10^{-9} Ci/cc.)

Determine:

(1) The required minimum room ventilation rate to maintain ⅓ 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. (305 mm × 305 mm) ductwork outside of the cubicle.

Solution:

Consider a case with the following parameters:

allowable C_r = ⅓MPC
= ⅓ 9×10^{-9} Ci/cc
= 3×10^{-9} Ci/cc

C_f = 0.15 μCi/cc (I-131)

P_F = 0.0075 (Reference NUREG-0017, Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from PWRs, para. 2.2.5.2, April 1976)

qL = 1 gal/hr × 1 hr/60 min × 3,785 cc/gal for U.S Customary units
= 3.8 L/h × 1 h/60 min × 1 000 cc/L for SI units
= 63 cc/min

To meet C_r under the above conditions

$$Q_1 = qL \times C_f \times P_F / C_r$$
$$= 63 \text{ cc/min} \times 0.15 \text{ Ci/cc} \times 0.0075/(3 \times 10^{-9} \text{ Ci/cc})$$
$$= 2.363 \times 10^7 \text{ cc/min}$$

(U.S. Customary Units)

$$Q_1 = 2.363 \times 10^7 \text{ cc/min} \times (1 \text{ ft}/30.48 \text{ cm})^3$$
$$= 834 \text{ cfm}$$

(SI Units)

$$Q_1 = 2.363 \times 10^7 \text{ cc/min} \times (1 \text{ L}/1\,000 \text{ cc}) \times (1 \text{ min}/60 \text{ s})$$
$$= 394 \text{ L/s}$$

If the fan is sized to handle 1,500 cfm (708 L/s) for this system, then the allowable clean inleakage, Q_i, is

(U.S. Customary Units)

$$Q_i = 1{,}500 \text{ cfm} - 834 \text{ cfm} = 666 \text{ cfm}$$

(SI Units)

$$Q_i = 708 \text{ L/s} - 394 \text{ L/s} = 314 \text{ L/s}$$

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.) To meet this criterion, the following flow rate, Q_1, is required:

(U.S. Customary Units)

$$Q_1 = 50 \text{ ft/min} \times 25 \text{ ft}^2$$
$$= 1{,}250 \text{ cfm}$$

(SI Units)

$$Q_1 = 0.254 \text{ m/s} \times 2.3 \text{ m}^2 \times (1 \text{ L} / 0.001 \text{ m}^3)$$
$$= 584 \text{ L/s}$$

The allowable clean air inleakage is then 1,500 cfm − 1,250 cfm = 250 cfm (708 L/s − 584 L/s = 124 L/s). The unit duct leakage is therefore equal to

(U.S. Customary Units)

$$L = \frac{250 \text{ cfm}}{\text{duct length} \times \text{duct perimeter}}$$
$$= \frac{250 \text{ cfm}}{\frac{(50)2(30) + 2(12)}{12}}$$
$$= 0.7 \text{ cfm/ft}^2$$

(SI Units)

$$L = \frac{124 \text{ L/s}}{\text{duct length} \times \text{duct perimeter}}$$
$$= \frac{124 \text{ L/s}}{\frac{(15.2)2(762) + 2(305)}{1\,000}}$$
$$= 3.8 \text{ L/s/m}^2$$

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.

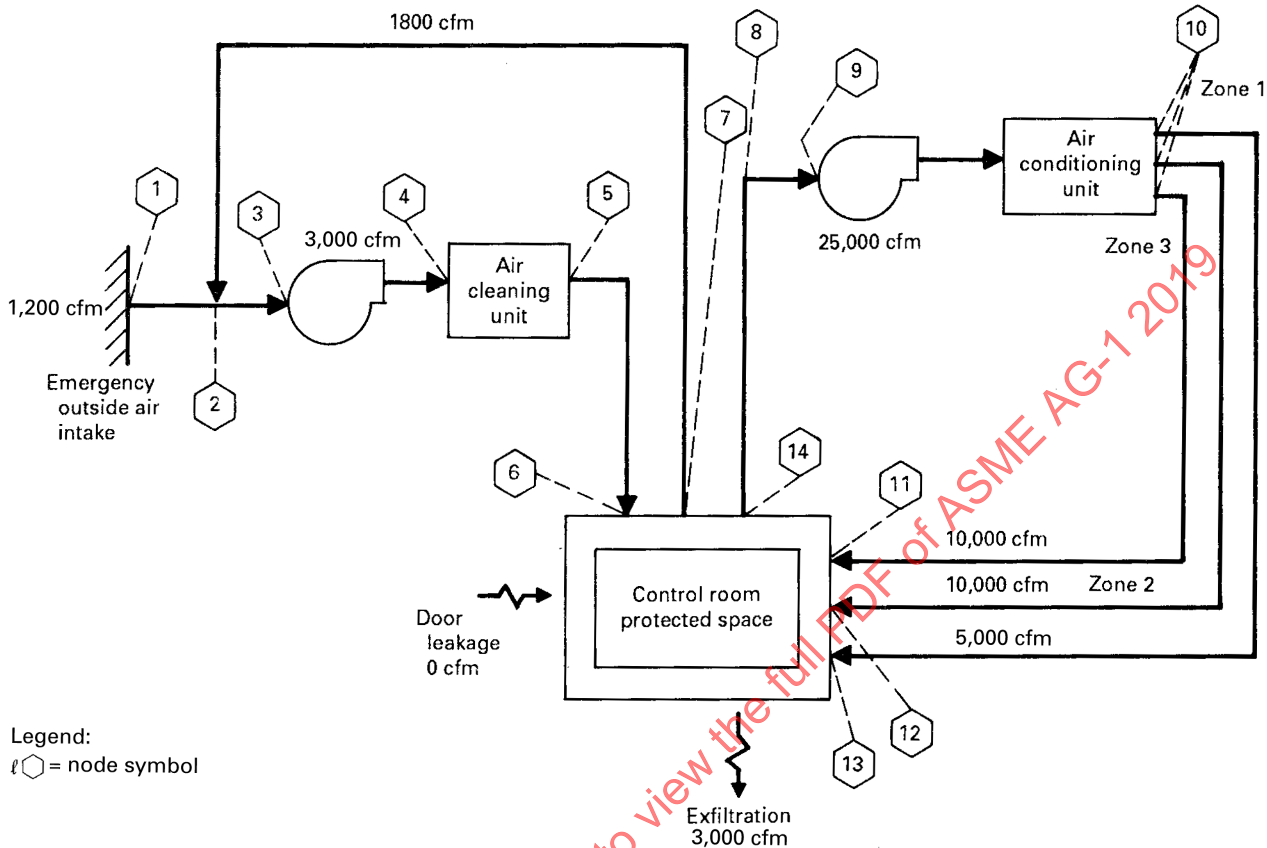
SA-B-1232 Determination of IPF

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[1] is defined as follows:

[1] Murphy and Campe, "Nuclear Power Plant Control Room Ventilation System Design for Meeting GDC-19," 13th AEC Air Cleaning Conference.

Figure SA-B-1232.1-1 Control Room System Flow Diagram



GENERAL NOTE: See Tables SA-B-1234-1 and SA-B-1234-2 for duct lengths, duct pressures, and leakage.

$$\text{IPF} = \frac{\text{dose without protection}}{\text{dose with protection}}$$

NOTE: "Dose" refers to the level of exposure to radioactive iodine.

The value of the IPF for the configuration shown by Figure SA-B-1232.1-1 is determined by the following:

$$\text{IPF} = \frac{F_1 + nF_2 + F_3}{F_1(1 - n) + F_3} \tag{16}$$

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)

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 Figure SA-B-1232.2-1:

$$\text{IPF} = \frac{F_5{}' + nF_2 + F_3}{F_1(1 - n) + F_3} \tag{17}$$

where

$$F_1{}' = F_1 + (L_f - L_o1), \text{ cfm (L/s)} \tag{18}$$

$$F_5{}' = F_5 + (L_o2 - L_u) - F_3, \text{ cfm (L/s)} \tag{19}$$

$$F_1 = F_5 + (L_o1 - L_f) + (L_o2 - L_u) - F_3, \text{ cfm (L/s)} \tag{20}$$

where

F_5 = control room boundary exfiltration, cfm (L/s)

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)

NOTE: $(L_o1 - L_f) + (L_o2 - L_u)$ represents the additional make-up air required to maintain control room pressurization due to air conditioning duct and housing leakage.

(19) **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 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 10 C.F.R. 50 (2019), Appendix A, Criterion 19 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, and L_u such that the IPF is achieved.

(g) Determine unit leak rate by dividing allowable leak rates from (f) by surface areas from (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 has an air cleaning and cooling system. (19) Figure SA-B-1232.2-1 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-1234-1 and SA-B-1234-2.

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 Figure 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.

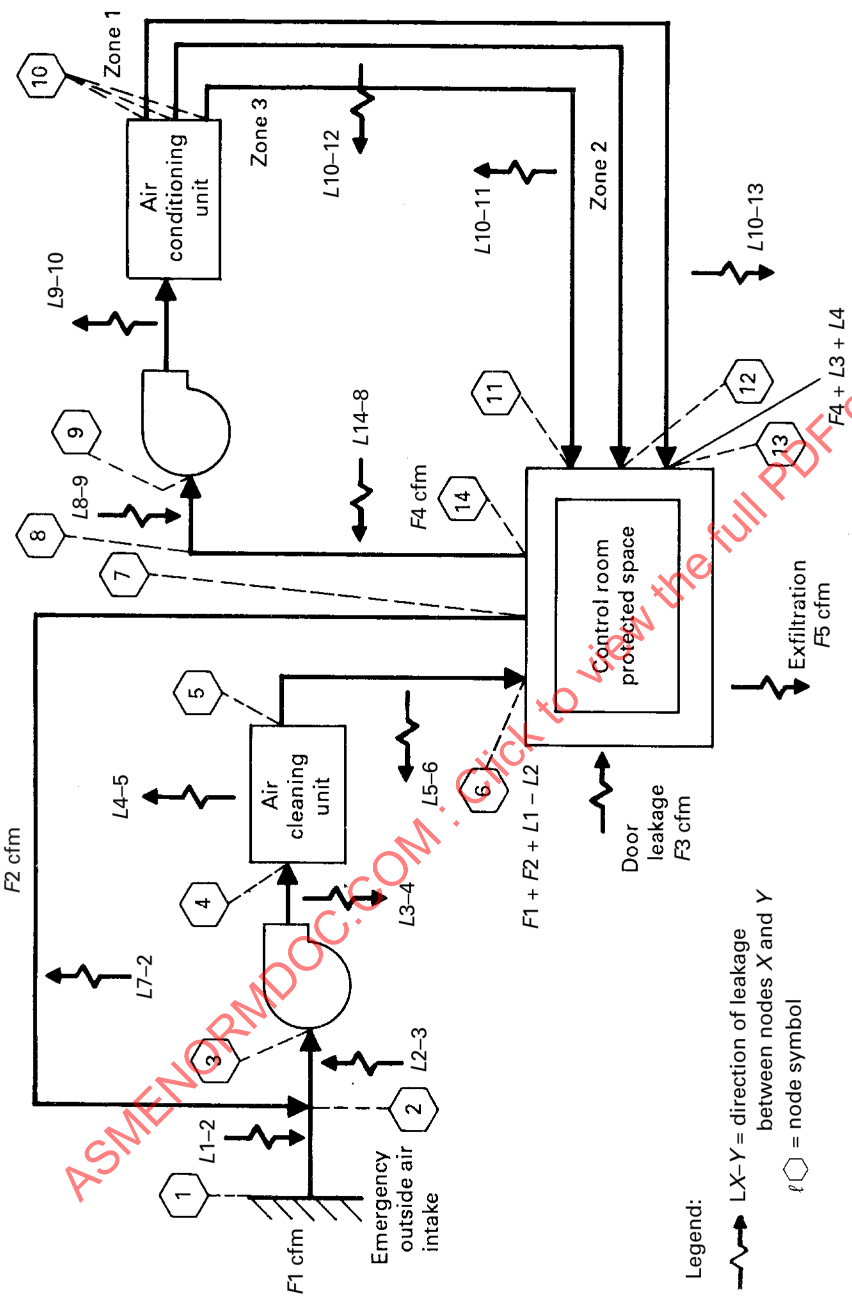
The leakage classes of the air conditioning units are leakage Class I for the negative pressure return air duct (because any inleakage would be unfiltered), and leakage Class II for the positive pressure supply duct (assuming control room pressure boundary requirements can be maintained).

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

Figure SA-B-1232.2-1 Control Room System Flow Diagram With Leakage Paths



GENERAL NOTE: See Tables SA-B-1234-1 and SA-B-1234-2 for duct lengths, duct pressures, and leakage.

Table SA-B-1234-1 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) [Note (1)]	−1.0 (−0.25)	II
2–3	16 O.D. (406)	20 (6.1)	84	(7.9) [Note (1)]	−2.0 (−0.50)	II
3–4	22 × 12 (559 × 305)	5 (1.5)	28	(2.6) [Note (2)]	+10.0 (2.5)	I
4–5	36 × 84 (914 × 2 134)	40 (12.2)	842	(78.2) [Note (3)]	+10.0 (2.5)	I
5–6	22 × 12 (559 × 305)	50 (15.2)	283	(26.3) [Note (2)]	2.0 (0.50)	II
7–2	12 O.D. (305)	75 (22.9)	236	(21.9) [Note (1)]	1.0 (0.25)	I

NOTES:

(1) Square meters calculated using $A = \pi \frac{D}{1{,}000} Id$.

(2) Square meters calculated using $A = \frac{Id}{500}(h + b)$.

(3) Straight conversion, square feet to square meters.

Table SA-B-1234-2 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 (1 524 × 762)	50 (15.2)	750	(69.5) [Note (1)]	−2.0 (−0.50)	I
8–9	60 × 30 (1 524 × 762)	25 (7.6)	375	(34.7) [Note (1)]	−3.0 (−0.75)	I
9–10	72 × 96 (1 829 × 2 438) [Note (2)]	10 (3.0)	376	(34.9) [Note (3)]	+5.0 (+1.2)	I
10–11	40 × 20 (1 016 × 508)	40 (12.2)	400	(37.2) [Note (1)]	+4.0 (+1.0)	II
10–12	40 × 20 (1 016 × 508)	40 (12.2)	400	(37.2) [Note (1)]	+4.0 (+1.0)	II
10–13	26 × 12 (660 × 305)	40 (12.2)	250	(23.5) [Note (1)]	+4.0 (+1.0)	II

NOTES:

(1) Housing dimensions.

(2) Housing calculated using $A = \frac{Id}{500}(h + b)$.

(3) Straight conversion, square feet to square meters.

concentration within the control room as a result of filtration and recirculation.

For this example, the IPF is determined using eq. (16):

$$\mathrm{IPF} = \frac{F_1 + nF_2 + F_3}{F_1(1 - n) + F_3}$$

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 air lock vestibules, and a filter efficiency of 99% gives

(U.S. Customary Units)

$$\mathrm{IPF} = \frac{1{,}200 + (0.99)(1{,}800) + 0}{(1{,}200)(1 - 0.99) + 0} 248.5$$

(SI Units)

$$\mathrm{IPF} = \frac{566 + (0.99)(850) + 0}{(566)(1 - 0.99) + 0} 248.7$$

For this particular example, a minimum IPF of 150 is required to meet the dose requirements of 10 C.F.R. 50 (2019), Appendix A, 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)

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 (0.127 L/s/m^2). This results in

(U.S. Customary Units)

$$L_f = 451 \text{ ft}^2 \times 0.025 \text{ cfm/ft}^2 = 11.3 \text{ cfm}$$
$$L_o1 = 1{,}153 \text{ ft}^2 \times 0.025 \text{ cfm/ft}^2 = 28.8 \text{ cfm}$$

(SI Units)

$$L_f = 41.9 \text{ m}^2 \times 0.127 \text{ L/s/m}^2 = 5.32 \text{ L/s}$$
$$L_o1 = 107.1 \text{ m}^2 \times 0.127 \text{ L/s/m}^2 = 13.6 \text{ L/s}$$

Air cleaning system net leakage = $L_o1 - L_f$, as follows:

(U.S. Customary Units)

$$28.8 \text{ cfm} - 11.3 \text{ cfm} = 17.5 \text{ cfm exfiltration}$$

(SI Units)

$$13.6 \text{ L/s} - 5.32 \text{ L/s} = 8.28 \text{ L/s exfiltration}$$

For air conditioning systems, assume the leak rate to be 0.07 cfm/ft^2 (0.36 L/s/m^2)

(U.S. Customary Units)

$$L_u = 1{,}125 \text{ ft}^2 \times 0.07 \text{ cfm/ft}^2 = 78.8 \text{ cfm}$$
$$L_o2 = 1{,}426 \text{ ft}^2 \times 0.07 \text{ cfm/ft}^2 = 99.8 \text{ cfm}$$

(SI Units)

$$L_u = 104.5 \text{ m}^2 \times 0.36 \text{ L/s/m}^2 = 37.6 \text{ L/s}$$
$$L_o2 = 132.5 \text{ m}^2 \times 0.36 \text{ L/s/m}^2 = 47.7 \text{ L/s}$$

Net air conditioning system leakage = $L_o2 - L_u$, as follows:

(U.S. Customary Units)

$$99.8 \text{ cfm} - 78.8 \text{ cfm} = 21 \text{ cfm exfiltration}$$

(SI Units)

$$47.7 \text{ L/s} - 37.6 \text{ L/s} = 10.1 \text{ L/s exfiltration}$$

With air lock vestibules, $F_3 = 0$; inserting into eqs. (18) and (19) gives the following:

$$F'_1 = F_1 + (L_f - L_o1)$$
$$F'_5 = F_5 + (L_o2 - L_u) - F_3$$

(U.S. Customary Units)

$$F'_1 = 1{,}200 + (11.3 - 28.8) = 1{,}182.5 \text{ cfm}$$
$$F'_5 = 1{,}000 + (99.8 - 78.8) - 0 = 1{,}021 \text{ cfm}$$
$$\text{IPF} = \frac{1{,}021 + (0.99 \times 1{,}800) + 0}{(1{,}182.5)(1 - 0.99) + 0} = 237$$

(SI Units)

$$F'_1 = 566 + (5.32 - 13.6) = 557.7 \text{ L/s}$$
$$F'_5 = 472 + (47.7 - 37.6) - 0 = 482.1 \text{ L/s}$$
$$\text{IPF} = \frac{482.1 + (0.99 \times 850) + 0}{(557.7)(1 - 0.99) + 0} = 237$$

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_o2 = 50 cfm (23.6 L/s)
L_u = 200 cfm (94.4 L/s)

the IPF would become

(U.S. Customary Units)

$$F'_1 = 1{,}200 + (50 - 30) = 1{,}220 \text{ cfm}$$
$$F'_5 = 1{,}000 + (50 - 200) = 850 \text{ cfm}$$
$$\text{IPF} = \frac{850 + (0.99)(1{,}800)}{(1{,}220)(0.01)} = 215.7$$

(SI Units)

$$F'_1 = 566 + (23.6 - 14.2) = 575.4 \text{ L/s}$$
$$F'_5 = 472 + (23.6 - 94.4) = 401.2 \text{ L/s}$$
$$\text{IPF} = \frac{401.2 + (0.99)(850)}{(575.4)(0.01)} = 216.0$$

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-1310-1 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 non-air 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 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 (19)

There may be a desire to establish bench mark leakage rates for various leakage classes or types of construction, or both, 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 the Owner's designee should randomly select sections of ducts or individual housings to leak test in situ. Selection of duct sections may be based on 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 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 in Figures SA-B-1410-1 through SA-B-1410-3.

Table SA-B-1310-1 Maximum Allowable Leakage Factors for Air Cleaning Effectiveness

Leakage Class [Note (1)]	ESF Duct [Note (2)]	Housing	Total [Note (3)]	Non-ESF Duct [Note (2)]	Housing	Total [Note (3)]
I	0.10	0.10	N/A	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

$$L_s = \frac{a}{A} \times \frac{P \times Q}{100}$$

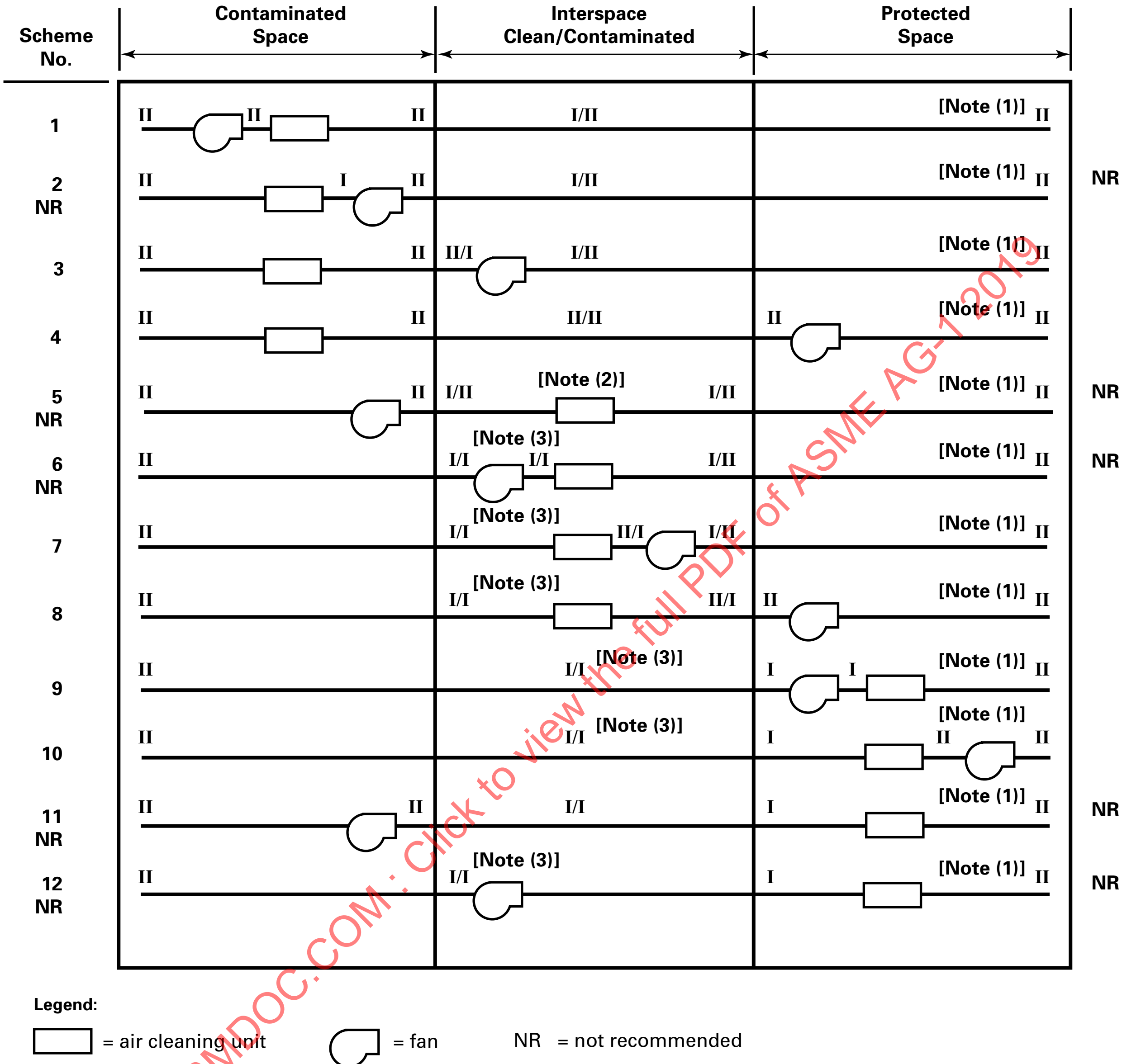
where

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)
P = maximum allowable leakage factor (from Table SA-B-1310-1)
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 (not applicable for Leakage Class I ESF duct systems). 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.

Figure SA-B-1410-1 Single-Pass Air Cleaning System Configuration



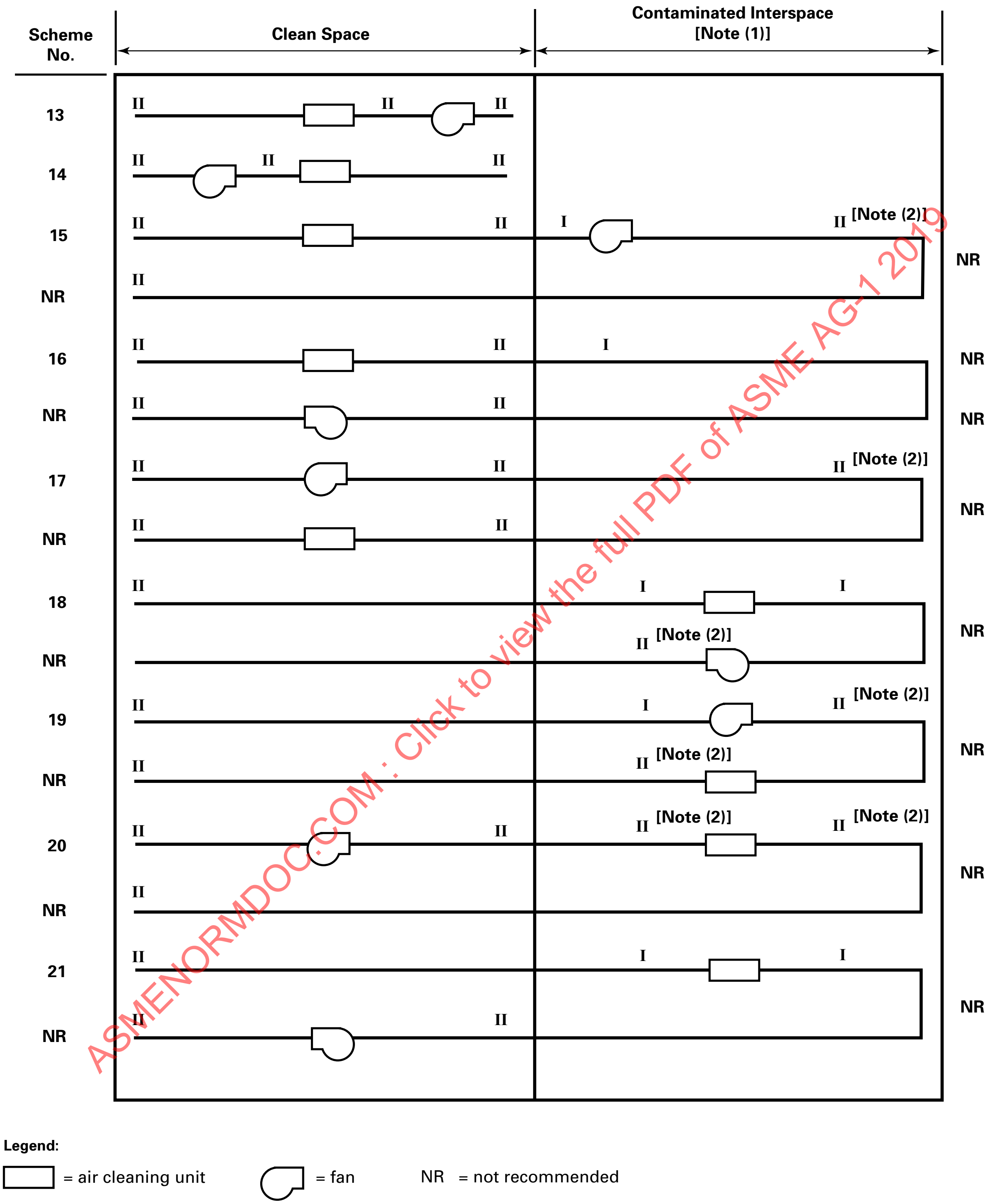
NOTES:

(1) All ducts under positive pressure that discharge into the plant stack for high-level release credit shall be leakage Class I.

(2) 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.

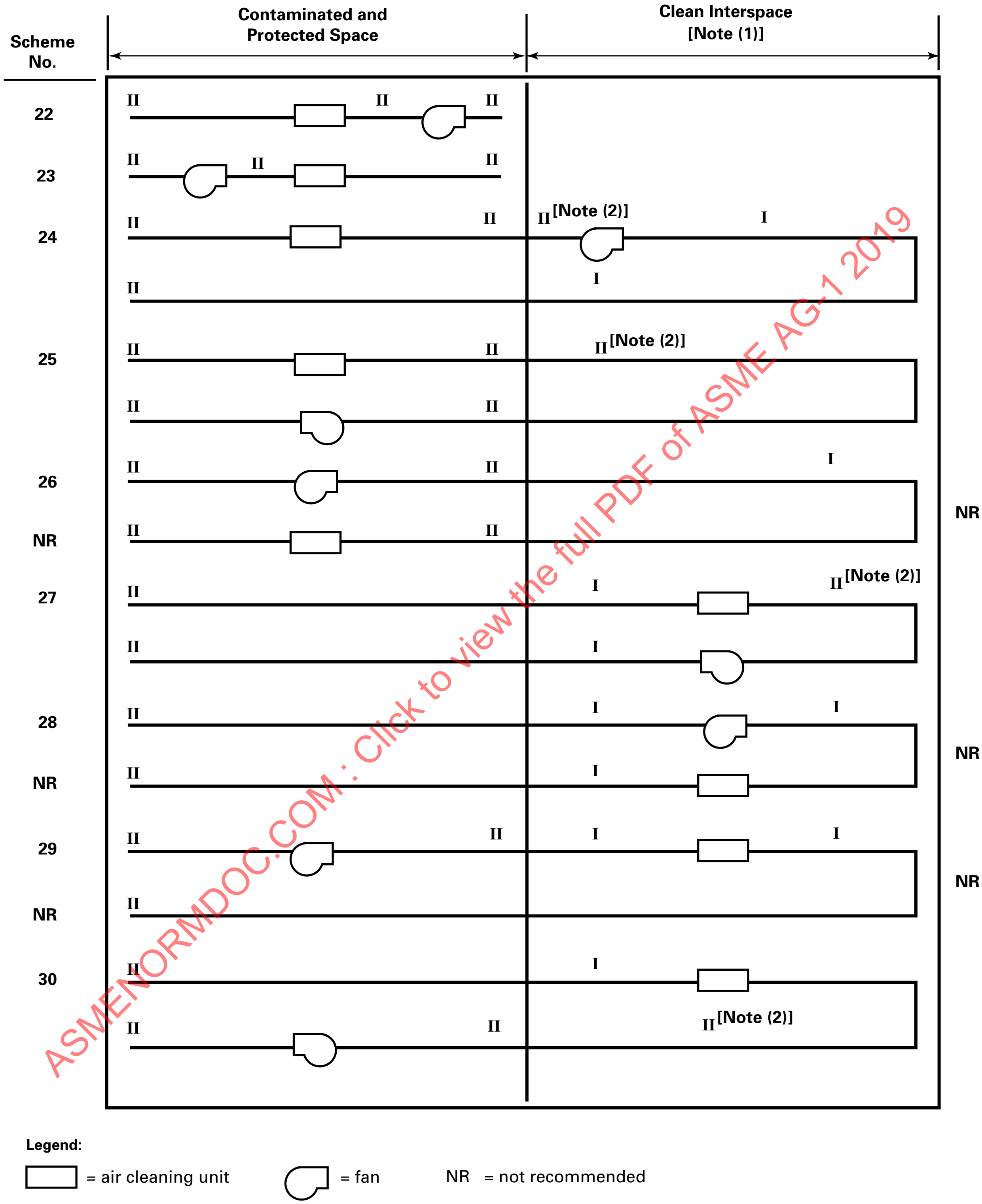
(3) Noted duct sections that pass through a clean interspace and that are under a negative pressure for all modes of operation may be leakage Class II.

Figure SA-B-1410-2 Recirculating Air Cleaning System Configurations



NOTES:
(1) Contamination level of fluid within ductwork is less than 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.

Figure SA-B-1410-3 Recirculating Air Cleaning System Configurations



NOTES:
(1) Contamination level of fluid within ductwork is greater than 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
(19) FUNCTIONAL DESIGN

(19) SA-C-1100 INTRODUCTION

Procedures and data for sizing of ductwork to provide the desired air quantities and distribution are presented in the ASHRAE Handbook: Fundamentals and in SMACNA 1958. Principles of room-air distribution and duct system layout are also described in those publications. Exhaust system concepts are described in ACGIH Industrial Ventilation.

SA-C-1200 GENERAL

(19) SA-C-1210 Access Doors

(a) Seals

(1) Gaskets should be installed on the door and a "knife-edge" sealing surface for the gasket should be provided. Gasket should be neoprene or silicone rubber with a recommended durometer of 30 to 40 in Shore A scale. Spacing shall enable a compression that ensures leakage requirements are met and provides a uniform gasket compression of 50% ± 20% of nominal gasket thickness.

(2) The gasket should be installed in as few pieces as possible to minimize number of joints. Gasket joints should be dovetailed 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 the 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.

Traps or loop seals when used should be designed for the maximum operating (static) pressure the duct 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 used, 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 used, 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 leakage criteria derived in SA-4532.

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

(19) **Table SA-C-1300-1 Duct Construction Standards**

SMACNA Manuals	Maximum Design Static Pressure, in. wg	
	Positive	Negative
HVAC Duct Construction Standards	10 (2.5 kPa)	3 (0.75 kPa)
Rectangular Industrial Duct Construction Standards	30 (7.5 kPa)	30 (7.5 kPa)
Round Industrial Duct Construction Standards	30 (7.5 kPa)	30 (7.5 kPa)

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.

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 (19)

Table SA-C-1300-1 lists standards that may be used in the mechanical design of ductwork. SMACNA HVAC Duct Construction Standards contain design data for both maximum design static pressures 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 performance, design, fabrication, installation, inspection, acceptance testing, and quality assurance for housings and housing supports used in air and gas treatment systems in nuclear facilities.

HA-1200 PURPOSE

This purpose of this section is to ensure that housings and housing supports are acceptable in all aspects of design and operation.

HA-1300 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 Figures HA-1300-1, HA-1300-2, and HA-1300-3. 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-1400 DEFINITIONS AND TERMS

The definitions and terms described below are specific to this section. For other definitions and terms, see AA-1400.

Figure HA-1300-1 Housing, Air Cleaning Unit: Walk-In Type

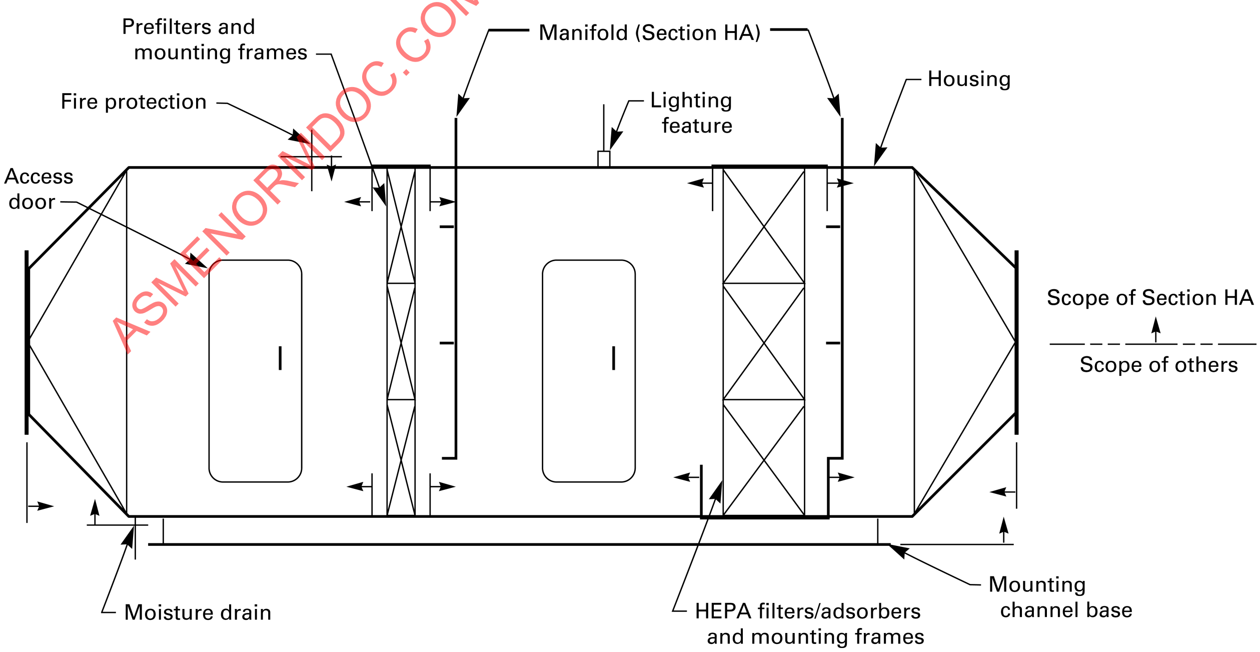


Figure HA-1300-2 Housing, Air Cleaning Unit: Side-Access Type

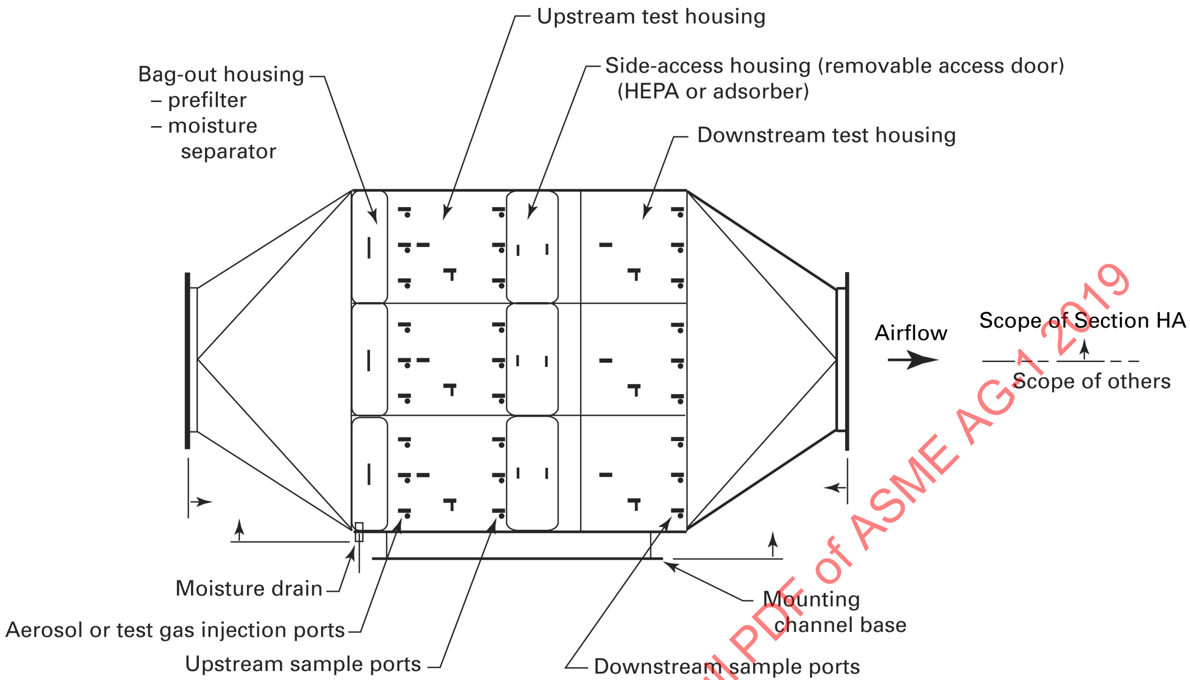
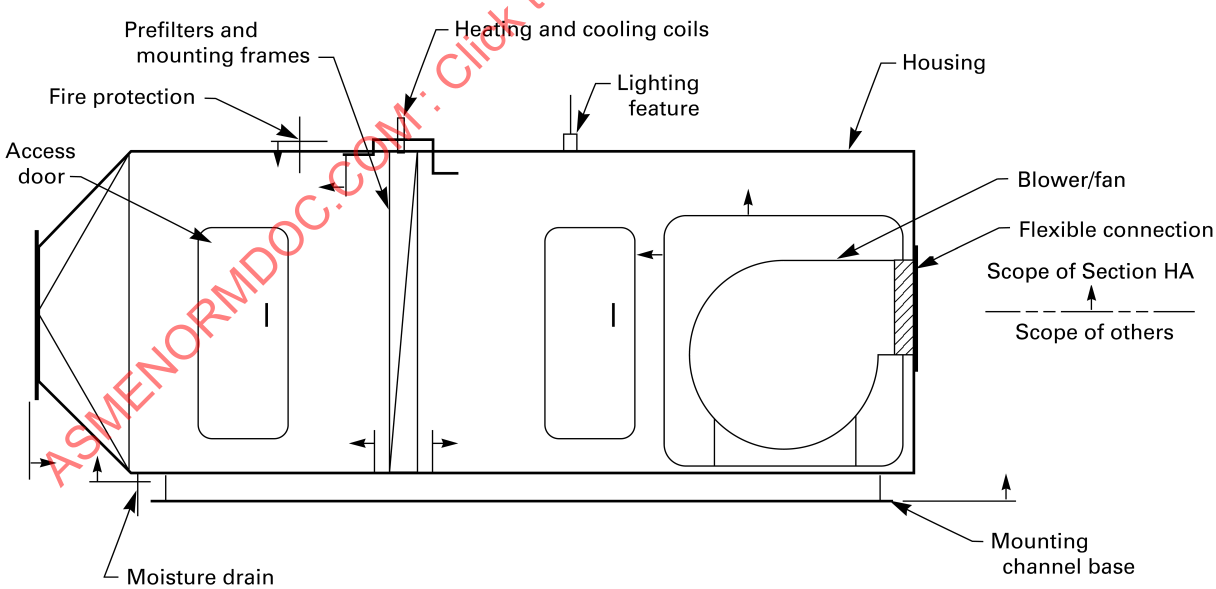


Figure HA-1300-3 Housing, Air Conditioning Unit: Walk-In Type



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.

(19)

ARTICLE HA-2000 REFERENCED DOCUMENTS

The codes and standards listed below shall supplement those listed in Article AA-2000. Unless otherwise specified, the latest edition shall apply.

AISI S100, North American Specification for the Design of Cold-Formed Steel Structural Members
Publisher: American Iron and Steel Institute (AISI), 2000 Town Center, Southfield, MI 48075 (www.steel.org)

AMCA 201, Fans and Systems
Publisher: Air Movement and Control Association International, Inc. (AMCA International), 30 West University Drive, Arlington Heights, IL 60004-1893 (www.amca.org)

ASHRAE Handbook: Fundamentals
Publisher: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329 (www.ashrae.org)

ASTM D2240-2005, Standard Test Method for Rubber Property — Durometer Hardness
ASTM D5144-2008, Standard Guide for Use of Protective Coating Standards in Nuclear Power Plants
Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 (www.astm.org)

IES Lighting Handbook, eighth edition, 1993
Publisher: Illuminating Engineering Society (IES), 120 Wall Street, New York, NY 10005 (www.ies.org)

Industrial Ventilation: A Manual of Recommended Practice, 23rd edition
Publisher: American Conference of Governmental Industrial Hygienists (ACGIH), 1330 Kemper Meadow Drive, Cincinnati, OH 45240 (www.acgih.org)

NFPA 90A-2009, Standard for the Installation of Air Conditioning and Ventilating Systems
Publisher: National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471 (www.nfpa.org)

SMACNA 1520, Round Industrial Duct Construction Standards
SMACNA 1922, Rectangular Industrial Duct Construction Standards (Inch-Pound Version)
SMACNA 1943, Rectangular Industrial Duct Construction Standards (SI Version)
SMACNA 1966, HVAC Duct Construction Standards: Metal and Flexible
Publisher: Sheet Metal and Air-Conditioning Contractors' National Association (SMACNA), 4201 Lafayette Center Drive, Chantilly, VA 20151-1209 (www.smacna.org)

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 AA-3100-1. Substitute materials shall be equivalent to or exceed the requirements in Table AA-3100-1. 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.

HA-3120 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 D5144. 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 conformance covering the ASME, ASTM, or other material specification, grade, and class, if applicable.

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. (19)

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, operating basis earthquake (OBE), and safe shutdown earthquake (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.

hydrostatic load (HY): the load 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, and shall be added to the DW case as applicable.

live load (L): the load that includes a construction main load 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

Table HA-4212-1 Load Combinations

Service Level	Load Combination
A	$N + T + L + \mathrm{CL} + W$
B	Not required, see Level C
C	$N + T + L + \mathrm{CL} + \mathrm{SL} + \mathrm{ADL}$
D	If DPD Applicable, $N + \mathrm{DPD} + \mathrm{SSE} + \mathrm{ADL}$

component included in the housing. See applicable Division II component sections for all component NOPDs.

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 system operational pressure transient (SOPT) and NOPD.

seismic loads (SL): loads that are the result of the envelope of the OBE and the 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 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: as 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-4300
(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-4212-1.

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 (19)

The allowable stresses for housing sheet metal material and cold-formed members shall be as defined in AISI S100. 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.

For plate- and shell-type housing components, such as the housing sheet steel, the stress criteria shall be in accordance with AA-4321. For linear-type components, such as the housing stiffeners comprising shapes or plates, the stress criteria shall be in accordance with AA-4331.

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-4230.

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 the 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 the welding procedure qualifications/prequalifications of AA-6300.

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 for Buildings.

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.

(19) **HA-4248 Fire Protection.** Fire protection requirements shall be specified by the Owner or designee commensurate with system-specific requirements.

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 and panels and door frames shall be selected to meet the allowable leakage determined in HA-4500. Sealing surfaces between doors and panels and their frames 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 HA-B-1210 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 [a minimum of 20 in. wide by 50 in. high (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 (19)
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 given in the design specification and guidance provided by the IES Lighting Handbook.

HA-4440 Miscellaneous

HA-4441 Drains. Consideration shall be given to drains depending on requirements, services, or components within each compartment. 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 HA-B-1220.

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.

(19) **HA-4444 Fire Detection.** If required to be installed in the housing, fire detection instruments shall meet the reliability and sensitivity requirements of the system specification. Fire detection instruments shall be either thermistors or carbon monoxide (CO) or carbon dioxide (CO_2) or smoke detectors or a combination thereof. The active element(s) of any such system shall be placed as follows:

(a) for carbon media beds, thermistor 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.

(b) the CO or CO_2 or smoke detector or a combination thereof shall be placed at a location downstream of the adsorber at which adequate air mixing has been verified. This location may be outside the housing in the downstream duct. If smoke detectors are used, high efficiency filters shall not be located between the carbon adsorbers and the smoke detectors.

Single-point temperature sensors are not considered an adequate method of detecting an adsorber fire and shall not be used as the sole means of fire detection.

HA-4500 PRESSURE BOUNDARY LEAKAGE

HA-4510 General

Pressure boundary leakage shall be controlled to ensure satisfactory environmental conditions.

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 used 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 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. For typical system configurations, see Figures SA-B-1410-1 through SA-B-1410-3.

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, as follows:

(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, as follows:

(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

(19) ### HA-5310 Allowance for Housing 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 type that enables visual inspection of the sealing mechanism between mating housing sections.

(b) Assembled joints using gaskets shall be visually inspected to ensure uniformity of gasket compression.

(c) The reduced allowable leakage, L_r, of housing sections shall be as follows:

$$L_r = L_s - R$$

$$R = \left(C_j / C_T\right) L_s$$

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-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, 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

(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.

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 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 HA-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 used 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 AA-6300.

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 AISC 325.

HA-6214 Joining Parts. Parts that are to be joined may (19)
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 the AISC Specification for the Design, Fabrication and 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.

(19) **HA-6312 High-Strength Bolts.** High-strength bolts, used in making bolted structural joints, shall be installed in accordance with the requirements of AISC 348.

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 $^1/_{16}$ 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

The tolerance on each knife-edge shall be plane within $^1/_8$ 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-7220 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-7520 and HA-7530.

HA-7520 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-7530 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 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-9200 STAMPING AND MARKING

Stamping and marking, as used herein, provides a means of maintaining identification of finished products for the purpose of retaining traceability of material.

HA-9210 Housings

Housings shall be provided with nameplates, in accordance with AA-9200, that 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-9220 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 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-1000-1 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 or 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

(19) ## ARTICLE HA-B-1000 GUIDELINES

(19) ### HA-B-1100 INTRODUCTION

Procedures and data for sizing of housings to provide the desired air quantities and distribution are presented in the ASHRAE Handbook: Fundamentals and in SMACNA 1958. Principles of room-air distribution and duct system layout are also described in those publications. Exhaust system concepts are described in ACGIH Industrial Ventilation.

Guidance for design, construction, and testing of housings is provided by ERDA-76-21, Nuclear Air Cleaning Handbook — Design, Construction, and Testing of High Efficiency Air Cleaning Systems for Nuclear Application, by C. A. Burchsted, J. E. Kahn, and A. B. Fuller, and additional guidance provided herein.

HA-B-1200 GENERAL

(19) #### HA-B-1210 Access Doors

(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 durometer of 30 to 40 on the Shore A scale, per ASTM D2240, *Standard Test Method for Rubber Property — 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 misfit 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-1220 Drains (19)

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 around filtration components.

(b) negative impact on cooling/heating coil capacity

(c) transfer of contaminated (radioactive or otherwise) air 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 used, 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 back up 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 used, 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
(19) TEST MANIFOLDS

(19) HA-C-1100 INTRODUCTION

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-1200 MANIFOLD REQUIREMENTS FOR IN-PLACE TESTS

HA-C-1210 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-1220 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-1230 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 Figures HA-C-1230-1 through HA-C-1230-5.

HA-C-1240 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-1250 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.

HA-C-1300 CONSIDERATIONS FOR USE OF PERMANENTLY INSTALLED MANIFOLDS

HA-C-1310

Permanently installed manifolds, which have passed Nonmandatory Appendix HA-D acceptance testing, provide a quick and simple means to repeat leak tests.

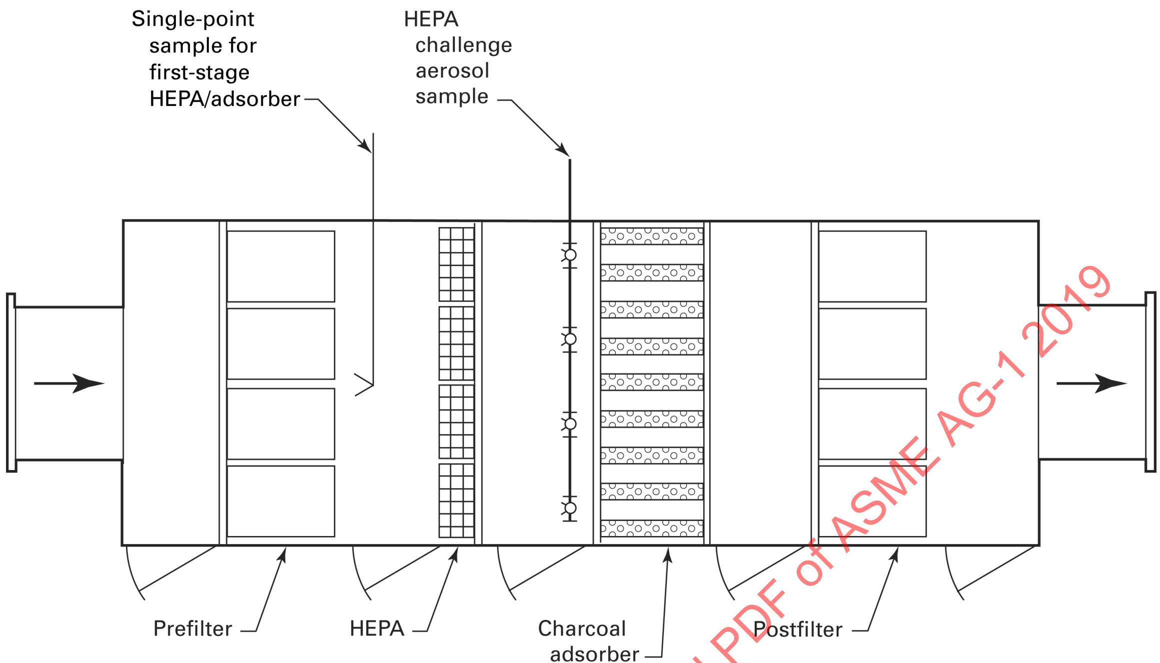
HA-C-1320

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-1330

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.

Figure HA-C-1230-1 Common Configurations Requiring Test Manifolds (Plan A)



Plan A: Ducted Inlet/Outlet HEPA/Adsorber Configuration

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.

HA-C-1340

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-1350

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-1400 INJECTION MANIFOLDS

HA-C-1410

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-1420

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 Figures HA-C-1230-2 and HA-C-1230-3.

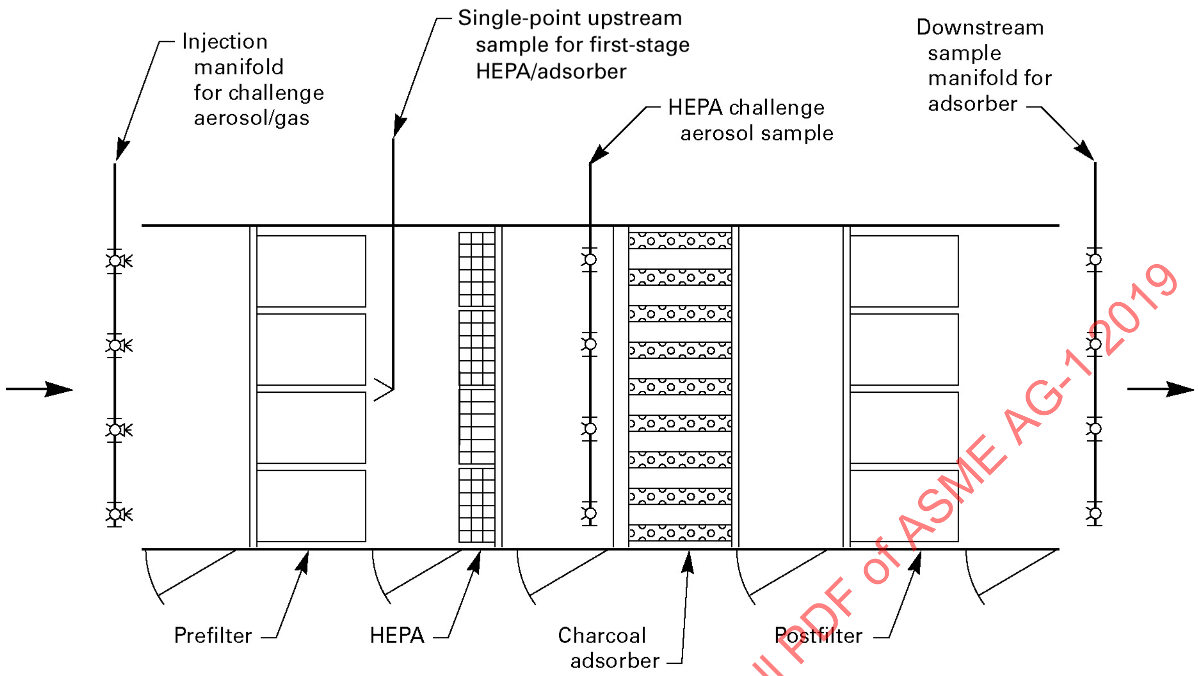
The HEPA-HEPA configuration requires a wider distribution of injection and sampling because of the low velocity and laminar flow.

The distance between the component banks should be considered when designing the manifold.

HA-C-1430 (19)

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 the recommendations of HA-C-1440 through HA-C-1490 are critical.

Figure HA-C-1230-2 Common Configurations Requiring Test Manifolds (Plan B)



Plan B: Unducted Inlet/Outlet HEPA/Adsorber Configuration

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.

HA-C-1440 General Rules Applicable to All Injection Manifolds

HA-C-1441 The total area of the exit holes are typically 1¼ times the cross section of the pipe in which the holes are located.

HA-C-1442 Headers should have a cross section 1¼ times the sum of the cross sections of all branches. {Four branches, each 1 in. (0.8 in.^{2}) [25.4 mm (516 mm^2)], results in a header of 1.25 × 4 × 0.8 in.^{2} = 3.9 in.^{2}, or a 2¼-in. diameter header [1.25 × 4 × 516 mm^2 = 2 580 mm^2, or a 57.3-mm diameter header].}

HA-C-1443 Paragraphs HA-C-1441 and HA-C-1442 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-1444 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-1445 The low point of each branch should have a screw cap to allow the leg to be drained if necessary.

HA-C-1446 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-1447 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.

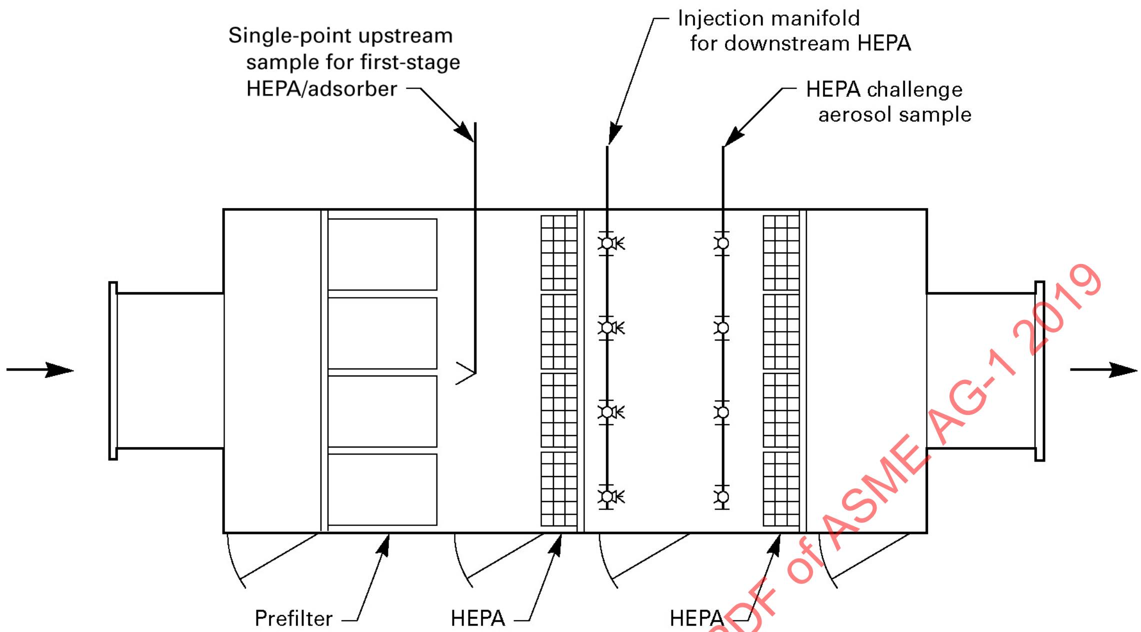
HA-C-1448 The existing high velocity areas, or turbulence, within the air cleaning unit should be used to enhance mixing, and therefore, simplify the manifold design.

HA-C-1449 The inlet to the injection manifold should be at a location accessible for connecting the generator.

HA-C-1450

The location of permanent manifolds should be checked for possible interference with component change out and other maintenance access requirements.

Figure HA-C-1230-3 Common Configurations Requiring Test Manifolds (Plan C)



Plan C: Ducted Inlet/Outlet HEPA/HEPA Configuration

GENERAL NOTES:
(a) Injection of challenge aerosol/gas is in inlet duct.
(b) Downstream challenge aerosol/gas sample point may be located in outlet duct.

HA-C-1460

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 Figure HA-C-1230-3.

HA-C-1470

The design of an aerosol injection manifold is dependent on the bank and housing configuration.

HA-C-1480

Unique injection manifold designs shall be qualified by testing to ensure meeting the air-aerosol mixing uniformity test of TA-4600.

HA-C-1490

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

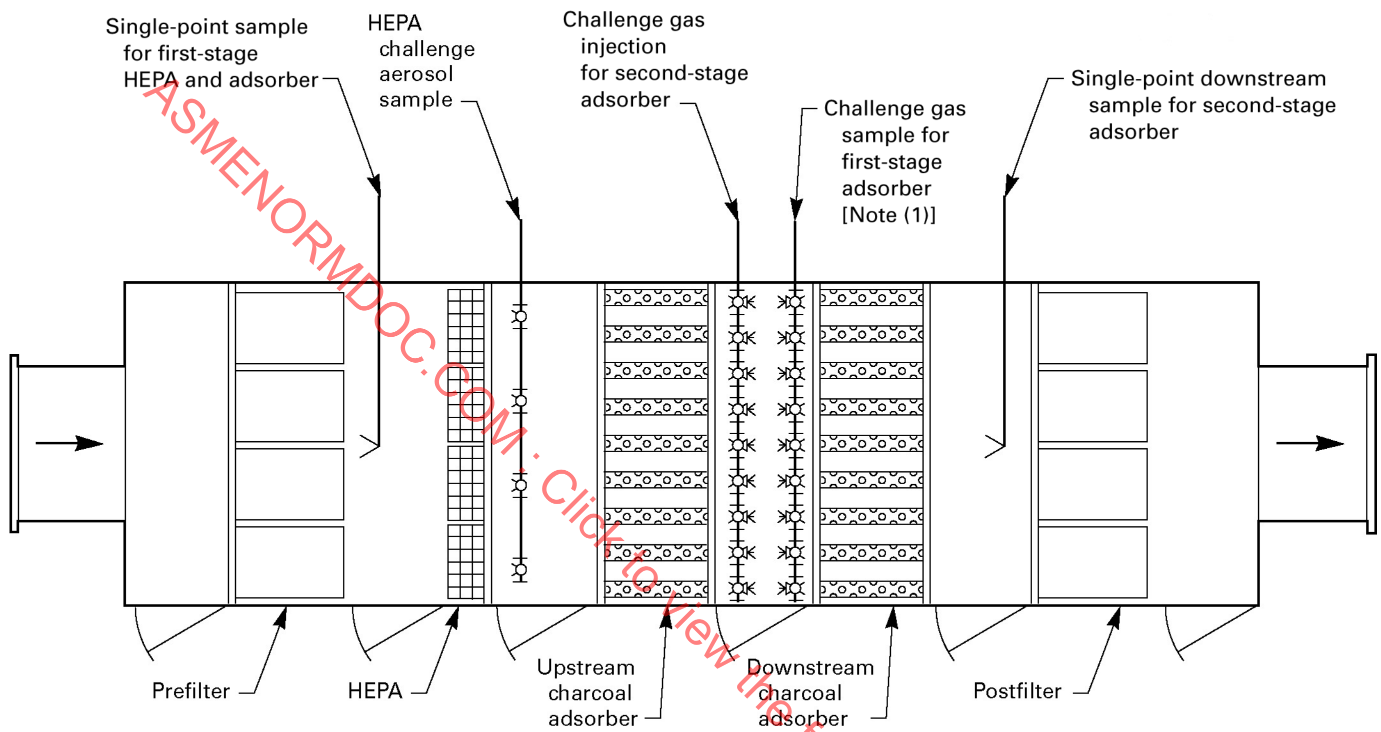
HA-C-1500 SAMPLE MANIFOLDS

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-1510

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.

Figure HA-C-1230-4 Common Configurations Requiring Test Manifolds (Plan D)

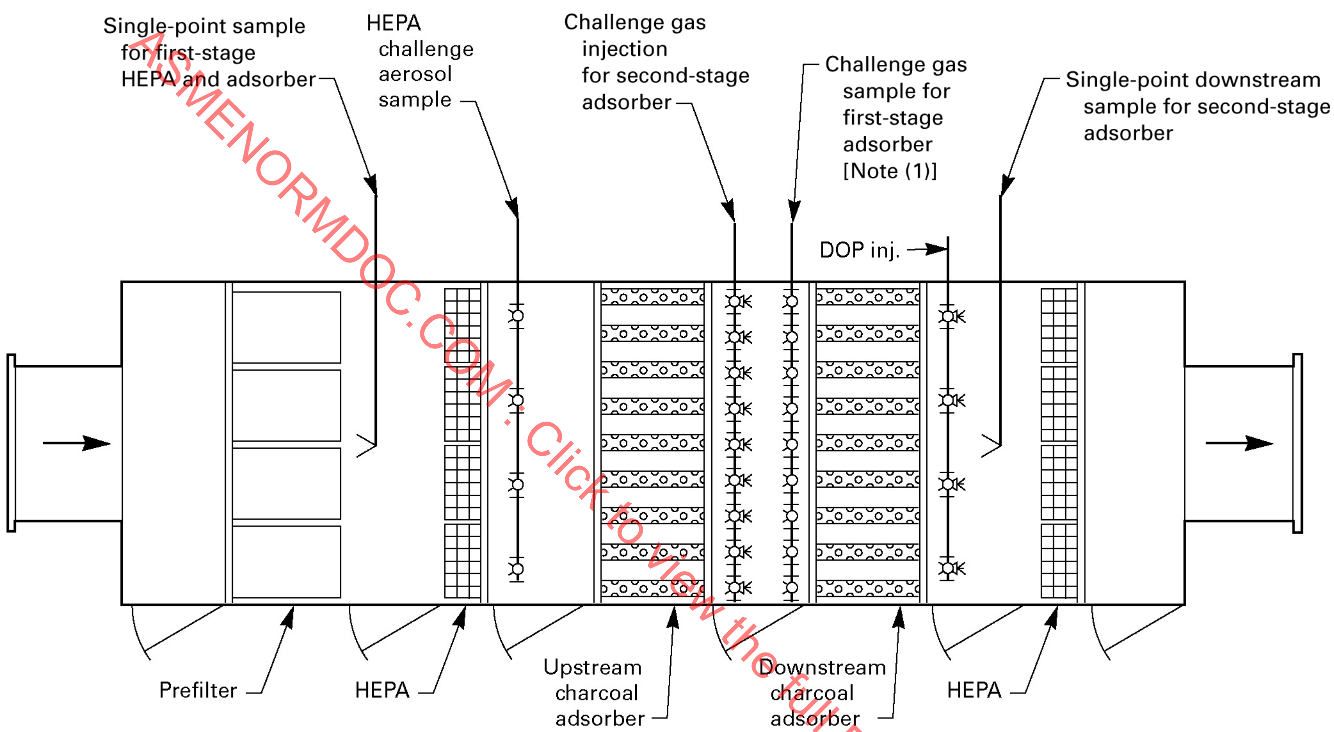


Plan D: Ducted Inlet/Outlet HEPA/Adsorber/Adsorber Configuration

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.

Figure HA-C-1230-5 Common Configurations Requiring Test Manifolds (Plan E)



Plan E: Ducted Inlet/Outlet
HEPA/Adsorber/Adsorber HEPA Configuration

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.

HA-C-1520

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-1530

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-1540

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

(19) ARTICLE HA-D-1000 PERFORMANCE TEST

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.

(19) 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-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.

(19) 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 ACIGH Industrial Ventilation, Chapter 9. If necessary, the number of sampling points, time of 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 ten 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 (19)

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 shipment of the unit.

SECTION RA
REFRIGERATION EQUIPMENT

(19)

ARTICLE RA-1000
INTRODUCTION

RA-1100 SCOPE

This section provides requirements for the performance, design, fabrication, installation, inspection, acceptance design, acceptance testing, and quality assurance for refrigeration equipment used in air treatment systems in nuclear facilities. Heat exchangers for other applications are covered in Sections CA and GA.

RA-1200 PURPOSE

This purpose of this section is to ensure that refrigeration equipment is acceptable in all aspects of design and operation.

RA-1300 APPLICABILITY

This section shall be applied to the performance, design, fabrication, installation, testing, and quality assurance of new HVAC refrigeration equipment.

RA-1310 Clarification of Code Applicability

(a) The requirements contained within this Code are intended to supplement the requirements of ASME BPVC, Sections III and/or VIII, Division 1. The requirements herein do not replace or modify the requirements of those standards. Fittings, piping, valves, and bolted joints with gaskets permitted by ASME BPVC, Sections III or VIII, as applicable, may be used within the limitations of the selected code.

(b) Gaskets and seals are not classified as ASME BPVC items since they are only addressed specifically in Appendices of ASME BPVC, Sections III and VIII dealing with bolted joints. Gaskets and seals are not considered structural items. If they are part of an air or refrigerant pressure boundary, gaskets and seals shall have an environmental qualification analysis and/or test performed to ensure that they are acceptable for the specified conditions for which they are installed.

(c) This section is not intended to provide the criteria for in-service deterioration, which may occur due to unspecified corrosion, erosion, or instability of material. The design specification shall take these effects into account with a view toward the equipment design life, the end purpose for which the equipment shall be used, and the system in which it will be installed.

(d) This section is not intended to cover low pressure or low volume vessels that are excluded from ASME BPVC, Section VIII.

RA-1320 Exclusion of Components

(a) This section does not cover pressure relief devices, refrigerant specialties (i.e., sight glasses, expansion valves, etc.), or piping external to the first connection points of a covered refrigeration machine. This section does not cover water piping, fittings, or pressure regulators external to the first connection points of a covered refrigeration machine. If ASME BPVC, Section III or VIII is referenced and the referenced code grants exclusion to a component, that exclusion is extended to this section as well. This section addresses only general system requirements for instrumentation and controls associated with refrigeration equipment. It does not address requirements for materials or component design for instrumentation and controls. For requirements for instrumentation and controls, see Section IA.

(b) 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 will be installed.

(c) This section does not address system single failure criterion or redundancy.

(d) This section does not provide requirements for drivers or drives for open refrigeration equipment.

(e) This section does not provide requirements for refrigerant transfer system pumps and compressors.

(f) 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 AA-1400. For additional refrigeration terms and definitions, see the ASHRAE online glossary at https://www.ashrae.org/technical-resources/free-resources/ashrae-terminology.

refrigeration equipment: equipment used to move heat from one location to another in controlled conditions by means of a refrigerant cycle using components such as chillers, air conditioning units, and heat pumps.

ARTICLE RA-2000
REFERENCED DOCUMENTS

The codes and standards listed below shall supplement those listed in Article AA-2000. Unless otherwise specified, the latest edition shall apply.

AHRI 450-2007, Performance Rating of Water-Cooled Refrigerant Condensers, Remote Type
AHRI 480-2007, Performance Rating of Remote Type Refrigerant-Cooled Liquid Coolers
ANSI/AHRI 550/590 (I-P)-2018 with Addendum 3, Performance Rating of Water-Chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle
ANSI/AHRI 551/591 (SI)-2018 with Addendum 3, Performance Rating of Water-Chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle
Publisher: Air-Conditioning, Heating, and Refrigeration Institute (AHRI), 2311 Wilson Boulevard, Suite 400, Arlington, VA 22201 (www.ahrinet.org)

ANSI/ASHRAE 15-2016, Safety Standard for Refrigeration Systems
Publisher: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329-2305 (www.ashrae.org)

ASME B31.5, Refrigeration Piping and Heat Transfer Components
Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990 (www.asme.org)

IEEE 43-2013, IEEE Recommended Practice for Testing Insulation Resistance of Electric Machinery
IEEE 382-2006, IEEE Standard for Qualification of Safety-Related Actuators for Nuclear Power Generating Stations
Publisher: Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Lane, Piscataway, NJ 08854-4141 (www.ieee.org)

NEMA MG 1-2016, Motors and Generators
Publisher: National Electrical Manufacturers Association (NEMA), 1300 North 17th Street, Suite 900, Arlington, VA 22209 (www.nema.org)

SSPC-SP 1, Solvent Cleaning
SSPC-SP 6, Commercial Wet Blast Cleaning
SSPC-VIS 1, Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning
Publisher: Society for Protective Coatings (SSPC), 800 Trumball Drive, Pittsburgh, PA 15205 (www.sspc.org)

ARTICLE RA-3000
MATERIALS

RA-3100 GENERAL MATERIAL REQUIREMENTS

(a) 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. The Owner is responsible for the identification of material not suitable for the specific application.

(b) Deterioration of waterside materials caused by unspecified service, such as corrosion or erosion, is outside the scope of this Code. Waterside materials suitable for the conditions must be stated in the design specification, with special attention given to the effects of service conditions on the properties of the materials. Materials for the refrigerant side shall be selected to conform to ASHRAE 15.

(c) The rules of this section do not apply to any instruments or to the permanently sealed, fluid-filled tubing systems furnished with any instruments that function as temperature or pressure-responsive devices.

(d) Allowable stresses and yield strengths of materials for all pressure-retaining items shall conform to the requirements given in ASME BPVC for the appropriate design section and class of service. For codes of record prior to the 1992 Edition, use the applicable ASME BPVC, Section III or VIII Appendix. For codes of record beginning with the 1992 edition, use the applicable ASME BPVC, Section II, Part D Tables.

RA-3110 Pressure-Retaining Materials

(a) All refrigerant-side pressure boundary materials exempted by the codes referenced in RA-3100(d) shall meet the material requirements of ASME B31.5, Chapter III.

(b) All refrigerant-side pressure boundary materials exempted by the codes referenced in RA-3100(d) shall meet the material requirements of ASHRAE 15.

(c) Waterside pressure boundaries shall conform to the applicable ASME BPVC.

(d) Other materials shall conform to material specifications cited in Table AA-3100-1. Components constructed from manufacturer's qualified materials (see AA-3100) 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 BPVC, Section III components within the definitions provided in RA-4510(a) shall meet the material requirements specified in ASME BPVC, Section III, Division 1, Subsection NF, Article NF-2000.

(b) All materials that form the support structure of non-ASME BPVC, Section III components shall be selected from ASME B31.1, Chapter IV; ASME 31.5, Chapter III; or ASME BPVC, Section II.

RA-3130 Materials for Nonmetallic Components

Materials for nonmetallic parts shall be selected to meet the environmental conditions listed in the design specification.

RA-3140 Electrical Materials

Electrical component materials are not within the scope of this section, except as covered by the referenced IEEE documents.

RA-3150 Pump and Compressor Materials

There are materials used in the design and fabrication of lubrication pumps and compressors that are unique to particular manufacturers (see AA-3100). Proof of suitability of these materials, as related to the pressure boundary, shall be demonstrated by test and documented.

RA-3151 Pump and Compressor Motors. Motor materials shall comply with the requirements of BA-3600.

RA-3160 Valve, Piping, and Fitting Materials

RA-3161 Refrigerant. Valves, piping, and fitting materials for refrigeration systems shall meet the material requirements of ASME B31.5, Chapter III and ASHRAE 15, para. 9.1.

RA-3162 Water

(a) Water valves, fittings, and piping that form the pressure boundary of systems subject to ASME BPVC, Section III requirements shall meet the material requirements for Class 3 of that Code (see ASME BPVC, Section III, Division 1, Subsection ND, Article ND-2000).

(b) Valves, piping, and fittings for water systems (refrigerant transfer systems) that are not subject to ASME BPVC, Section III requirements shall meet the material requirements of ASME B31.1, Chapter III.

RA-3163 Lubrication. Valves, piping, and fittings for oil circuits of lubrication subsystems shall meet the material requirements of ASME B31.5, Chapter III of or be as specified in ASHRAE 15.

RA-3164 Control. Valve and piping materials for control systems shall be compatible with the interfacing system materials and shall meet the requirements of ASME B31.1, Chapter III or ASME B31.5, Chapter III.

RA-3170 Welding and Brazing Materials

(a) Materials that form the pressure boundary of systems subject to ASME BPVC, Section III requirements shall meet the material requirements for Class 3 components of that code (see ASME BPVC, Section III, Division 1, Subsection ND) as stipulated by the design specification.

(b) Materials that represent a pressure boundary of systems subject to ASME BPVC, Section VIII requirements shall meet the applicable requirements for materials of that code as stipulated by the design specification.

(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 ASME B31.5, Chapter V.

(d) Materials for welding and brazing of components not covered by Sections III or VIII of ASME BPVC, 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

This Article establishes the design requirements for refrigeration equipment used in nuclear facilities.

RA-4200 DESIGN SPECIFICATION

For ASME BPVC, Section III-designed equipment, a design specification shall be prepared and certified by the Owner or assigned designee in accordance with ASME BPVC, Section III, Division I, Subsection NCA, NCA-3255. For ASME BPVC, Section VIII-designed equipment, a design specification shall be prepared in accordance with ASME BPVC, Section VIII, Division 1, Subsection A, U-2. In either case, sufficient detail shall be provided to form a complete basis for refrigeration equipment design in accordance with this Code. Typical external interface diagrams are shown in Nonmandatory Appendix RA-B.

The design specification shall include, as a minimum, the following data:

(a) ASME BPVC edition, addenda when required, class (Section III only), and applicable Code Cases.

(b) performance requirements for plant operating modes wherein the equipment is expected to perform an intended function.

(c) for the applicable plant operating modes, the following equipment environmental and associated service conditions shall be delineated:

(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 gauge)] 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 and concentration of each chemical for equipment subject to thinning by corrosion.

(6) structural design criteria. Structural loads to which the machine will be subjected. For evaporators and condensers, these loads shall be in accordance with the applicable design section of ASME BPVC. For other parts of the refrigeration machine, loads shall include, but not be 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 should be designed, expressed in tons of refrigeration (kW) (see ASHRAE Terminology).

(9) cooling load profile and time history. The cooling load profile that identifies the range of load the machine must be designed to accommodate, and the expected number of start and stop cycles during the life of the machine.

(10) waterside design pressures for evaporator and condenser. The maximum and normal waterside pressures to which pressure vessels will be subjected shall be given in psig (kPa gauge) including below atmospheric pressures, if applicable. If the water sides will be exposed to subatmospheric pressures, that information shall also be specified.

(11) exposure of refrigeration equipment to harsh environments. Temperature, pressure, relative humidity, and radiation time histories shall be provided for use in qualifying all refrigeration equipment, electrical equipment, cabling, controls, and accessories.

(d) structural load definition. Structural loads to be considered in the design of evaporators and condensers shall be in accordance with the applicable design section of ASME BPVC. Structural loads to be considered in the design of other portions of the 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.

(e) control equipment requirements including all instrumentation and control functions. Provision for such functions shall be specified as well as the NEMA class of all enclosures.

RA-4300 EQUIPMENT PERFORMANCE REQUIREMENTS

The required performance of the refrigeration equipment shall be clearly specified in the design specification. As a minimum, specified performance requirements shall include

(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–K/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 Waterside System

RA-4411 Code Design Section. Waterside pressure vessel components of the refrigeration equipment shall be in accordance with the same ASME BPVC design section as the fluid system in which they will be installed.

RA-4412 Boundaries. The design specification shall define the boundaries of the waterside pressure vessels as required by the applicable paragraphs of ASME BPVC [see ASME BPVC, Section III, Division I, Subsection NCA, NCA-3254 or ASME BPVC, Section VIII, Division 1, U-1(e)].

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 ASME BPVC, Section VIII.

RA-4422 Compressor. This paragraph identifies the design boundaries of refrigeration compressors. Refrigerant compressors include the semi-hermetic, 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. For motor selection, see BA-4220. For drive construction for pumps and open compressors, see BA-4330.

RA-4422.1 Centrifugal Compressor

(a) Semi-Hermetic and Hermetic

(1) The boundary of the semi-hermetic or 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 ASHRAE 15.

(b) Open

(1) The boundary is the same as the semi-hermetic or 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. This Code section does not address drives; therefore, the purchaser of the drive shall assure the compatibility of the drives with the driven equipment.

(2) The design of refrigerant-containing portions of the compressor shall meet the requirements of ASHRAE 15.

RA-4422.2 Reciprocating Compressor

(a) Semi-Hermetic and 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 ASHRAE 15.

(b) Open

(1) The boundary is the same as the semi-hermetic or hermetic compressor except the driver is not considered within the scope of this Code 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 ASHRAE 15.

RA-4422.3 Screw/Scroll Compressor

(a) Semi-Hermetic and 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 ASHRAE 15.

(b) Open

(1) The boundary is the same as the semi-hermetic or hermetic compressor except the driver is not considered within the scope of this Code. 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 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 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 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 ASHRAE 15. Pressure boundary portions of the pump shall be designed, constructed, and assembled to meet the requirements of ASHRAE 15.

RA-4500 STRUCTURAL DESIGN REQUIREMENTS

RA-4510 General

(a) ASME BPVC, Section III equipment and supporting structures shall be designed according to the rules established in the applicable subsections of that code. ASME BPVC, Section VIII, Division 1 equipment shall be designed according to the rules established in the applicable subsections of that code. 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 referenced in RA-4200(d).

(b) Portions of the refrigeration machine not required to comply with ASME BPVC shall be designed, analyzed, and/or tested in accordance with the structural requirements of the design specification.

(c) Equipment classified as non-ASME BPVC, and the equipment as a whole, shall be designed, analyzed, or tested in accordance with the structural requirements of Article AA-4000.

(d) 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.

(e) Applicable structural requirements and load definitions are given in RA-4200(c).

RA-4520 Equipment Attachment Boundary

(a) For refrigeration machines whose pressure-bearing components comply with ASME BPVC, Section III, the attachment of the equipment to the foundation shall be designed according to AA-4360.

(b) For refrigeration machines whose pressure-bearing components comply with ASME BPVC, Section VIII, the attachment of the equipment to the foundation shall be designed according to the applicable requirements of that code section.

RA-4600 ELECTRICAL DESIGN REQUIREMENTS

If specified, all electrical and electromechanical equipment including but not limited to motors, wiring, and control components that are required for the refrigeration equipment to perform its design function during all operating modes specified shall be environmentally qualified in accordance with IEEE 323. Qualification of these components to IEEE 323 can be accomplished by qualification in accordance with the applicable standards referenced within IEEE 323.

RA-4610 Electric Motors

If specified, all Class 1E motors shall be designed and tested in accordance with IEEE 334, IEEE 112, and NEMA MG-1. If specified, all non-Class 1E open motors shall be designed and tested in accordance with IEEE 112 and NEMA MG-1 to ensure operability. Hermetic and semi-hermetic motors shall be tested in accordance with the requirements of RA-5214.

RA-4620 Electric Valve and Vane Actuators

If specified, all Class 1E electric valve and vane actuators shall meet the requirements of IEEE 382.

If specified, all non-Class 1E valve operators shall be suitable for the design condition as specified in the design specification.

RA-4630 Control Systems

If specified, all Class 1E control components and control panels shall meet the requirements of 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 [see RA-4200(d)]. If specified, 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 postulated design basis event and loss of coolant accident.

(b) The design specification shall describe any equipment monitoring required and note whether provisions should 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 a Class 1E interface.

(c) Control system devices that could prevent or limit the machine from performing its design function during all operating modes 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 designee.

ARTICLE RA-5000 INSPECTION, RATING, AND TESTING

The requirements of Article AA-5000 shall apply except where expanded on, modified, or otherwise exempted by RA-5100 and RA-5200.

RA-5100 RATING

Performance ratings shall be based on the actual design conditions supplied by the design specification, rated in accordance with ANSI/AHRI 550/590 or ANSI/AHRI 551/591 as required by the design specification and tested in accordance with Mandatory Appendix RA-I (U.S. Customary) or Mandatory Appendix RA-MI (SI).

RA-5200 TESTING

RA-5210 Pressure Vessel Testing

RA-5211 ASME BPVC, Section III Vessels. ASME BPVC, Section III pressure vessels shall be hydrostatically or pneumatically tested in accordance with the requirements of ASME BPVC, Section III, Division 1, Subsection ND, ND-6100 through ND-6400.

RA-5212 ASME BPVC, Section VIII Vessels. ASME BPVC, Section VIII, Division 1 pressure vessels shall be hydrostatically or pneumatically tested in accordance with the requirements of ASME BPVC, Section VIII, Division 1, Subsection A, UG-99, UG-100, or UG-101 and UG-102.

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 either

(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 gauge) or

(b) be tested in accordance with the requirements of ASME BPVC, Section VIII, provided that the design working pressure is greater than 15 psig (103 kPa gauge)

RA-5213.2 If the requirements of RA-5213.1(a) and RA-5213.1(b) are invoked by not specifying a code or standard, the equipment manufacturer shall document and certify the conditions of test and test results on a suitable test report form for tests performed in accordance with RA-5213.1.

RA-5214 Other Non-ASME Components

RA-5214.1 Semi-hermetic and Hermetic Centrifugal Compressor Testing. The following factory tests shall be performed on the compressors and motor housings:

(a) pressure test. The compressor and motor housings shall be strength tested at the higher of either

(1) 45 psig (310 kPa gauge) or

(2) $1\frac{1}{4}$ 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. Test conditions and test results shall be documented on a suitable test report form for tests performed in accordance with RA-5214.1.

(b) leak test. A leak test shall be performed at the design working pressure of the compressor and 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.

(c) mechanical run test (new motors only). 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.

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) 45 psig (310 kPa gauge) or

(2) $1\frac{1}{4}$ times the design working pressure (pneumatic)

The pressure tests may be performed individually as a discrete assembly or as a subassembly or complete assembly with the other refrigeration machine components. Test conditions and test results shall be documented on a suitable test report form for tests performed in accordance with RA-5214.2.

(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.

(c) mechanical run test (new equipment only). 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.

RA-5214.3 Semi-hermetic and Hermetic Reciprocating Scroll and Screw Compressor Testing. The following factory tests shall be performed on the compressors:

(a) pressure test. The high and low side of the compressor and motor housing assembly shall be pneumatically tested at $1\frac{1}{4}$ times the design pressures as established by 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.

RA-5214.4 Open Reciprocating Scroll and Screw Compressor Testing. The following factory tests shall be performed on the compressors and documented:

(a) Factory Pressure Test. The high and low side of the compressor shall be pneumatically tested at $1\frac{1}{4}$ times the design pressures as established by ASHRAE 15, para. 9.2.

(b) Factory Leak Test. The compressor shall be leak tested and proved tight at the design pressure(s) for which it is rated.

(c) Documentation. Pressure 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 pneumatically pressure tested. The system shall be leak tight at $1\frac{1}{4}$ times (pneumatic) the maximum design pressure. The test shall be documented.

RA-5220 Functional Testing of Motors

NOTE: Rebuilt motors only require routine test unless the design was changed.

RA-5221 Semi-Hermetic and Hermetic Electric Motors

RA-5221.1 Routine Test. For semi-hermetic and hermetic motors, only the following tests are applicable:

(a) high-potential test per NEMA MG-1, 3.1, 12.2, and 12.3

(b) winding resistance test performed in accordance with IEEE 112

(c) insulation resistance test performed in accordance with IEEE 43

RA-5222 Open Electric Motors

RA-5222.1 Routine Test. This test shall include the following:

(a) no-load speed, current, and power test per IEEE 112

(b) locked rotor current test per IEEE 112

(c) routine tests per NEMA MG-1, 12.55 (small and medium motors) and 21.21 (large motors)

(d) temperature rise per Form A-Method A of IEEE 112

(e) high-potential test per NEMA MG-1, 3.1, 12.2, and 12.3

(f) winding resistance test performed in accordance with IEEE 112

(g) vibration test performed in accordance with NEMA MG-1, 7 and 12.6

(h) insulation resistance test performed in accordance with IEEE 43

(i) inspection of each motor for direction of rotation and, as applicable, the airflow of unidirectional cooling fans

(j) inspection of each motor for measurement of air gap with motor stator and rotor at a measured ambient temperature

RA-5222.2 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 [for repaired motors, exclude (a) and (b)]:

(a) complete test as necessary in accordance with IEEE 112 to 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 curves

(b) noise test per NEMA MG-1, 9 and 12.53

(c) shaft current test per IEEE 112 for motors covered by NEMA MG-120 only

RA-5223 Equipment Functional Testing.

The active refrigeration machine (i.e., chiller, etc.) shall be factory tested for proper and safe operation of all components by the manufacturer, using the manufacturer's written procedures. Each complete refrigeration machine shall be given a factory performance test in accordance with the Owner's approved test procedure.

RA-5224 Control Functional Testing.

The manufacturer shall functionally test all control components and assembled control panels as specified in the design specification. All wiring circuits shall have continuity tests conducted by the manufacturer. Test results shall be documented.

RA-5225 Valve and Vane Electric Operator Functional Testing.

The original equipment manufacturer or the refrigeration equipment manufacturer shall conduct the following tests as applicable to the type of machine. In either case, documentation that testing was done shall be furnished to the Owner.

RA-5225.1 All valve and vane operators shall be given a routine test including

(a) no-load speed and current per IEEE 112

(b) locked rotor current list per IEEE 112 and NEMA MG-1, Section 12

(c) high potential test per NEMA MG-1, 12.2 and 12.3

(d) insulation resistance test per IEEE 43

RA-5225.2 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 112.

RA-5225.3 An inspection of direction of rotation and, if applicable, the airflow of unidirectional cooling fans shall be performed on each valve operator.

RA-5300 EXAMINATION

RA-5310 Nondestructive Examination

For condensers and evaporators designed and fabricated in accordance with ASME BPVC, this examination shall comply with the applicable parts of ASME BPVC, Section III or VIII.

RA-5311 Visual Examination of Brazed Joints

(a) For condensers and evaporators designed and fabricated in accordance with Section III of ASME BPVC, brazed joints shall be visually inspected in accordance with AA-5200. Visual examination shall also comply with ASME BPVC, Section III, Division I, Subsections NC/ND-4540, NC/ND-5275, and NC/ND-5360 and ASME BPVC, Section V, Subsection A, Article 9. Acceptance criteria shall be as given in ASME BPVC, Section III, Division I, Subsections NC/ND-5360.

(b) For condensers and evaporators designed and fabricated in accordance with ASME BPVC, Section VIII, brazed joints shall be visually inspected in accordance with AA-5200. Visual examination shall also comply with ASME BPVC, Section V, Subsection A, Article 9 and ASME BPVC, Section VIII, Division 1, Subsection B, Part UB, UB-44. Acceptance criteria shall be as given in ASME BPVC, Section VIII, Division 1, Subsection B, Part UB, UB-44(b) through UB-44(f).

RA-5312 Non-ASME Pressure Vessels. Nondestructive examination (NDE) of non-ASME BPVC pressure-retaining components and component supports shall be in accordance with the design specification and AA-6334. As a minimum, NDE shall consist of visual examination of weldments of pressure-retaining components and component supports in accordance with AWS D1.1, and shall be documented on an NDE Report filed as part of the document package.

ARTICLE RA-6000
FABRICATION AND INSTALLATION

The requirements of Article AA-6000 shall apply except where expanded upon, modified, or otherwise exempted by RA-6100.

RA-6100 WELDING AND BRAZING

RA-6110 Welding

(a) Welding for pressure-retaining components designed and fabricated in accordance with ASME BPVC, Section III shall meet the requirements of ASME BPVC, Sections III and IX, Part QW.

(b) Welds and welded joints in pressure-retaining component supports shall be designed and fabricated in accordance with ASME BPVC, Section III, Division 1, Subsection NF and ASME BPVC, Section IX, Part QW.

(c) Welds and welded joints in pressure-retaining components designed and fabricated in accordance with ASME BPVC, Section VIII shall meet the requirements of ASME BPVC, Section VIII, Division 1, Subsection B, Part UW, plus any relevant rules of the applicable parts of Subsection C covering the materials of construction, and ASME BPVC, Section IX, Part QW, if required by the design specification.

(d) For pressure-retaining components other than those identified in (a), (b), and (c), welding shall be performed using welding procedures and welding personnel qualified in accordance with the requirements of Section IX of ASME BPVC or of AWS D1.1.

RA-6120 Brazing

(a) Brazing for pressure-retaining components designed and fabricated in accordance with ASME BPVC, Section III shall meet the requirements of ASME BPVC, Sections III and IX, Part QB.

(b) Brazing for pressure-retaining components designed and fabricated in accordance with ASME BPVC, Section VIII shall meet the requirements of ASME BPVC, Section VIII, Division 1, Subsection B, Part UB, plus any relevant rules of the applicable parts of subsection C covering the materials of construction, and ASME BPVC, Section IX, Part QB.

RA-6130 Welding and Brazing of Non-ASME BPVC 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/her 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 Section IX of ASME BPVC or AWS D1.1. Once a choice is made between Section IX of ASME BPVC and AWS D1.1, all qualifications shall be consistent with that particular document.

RA-6133.1 Welder or welding operator qualification testing, or both, shall be performed in accordance with Section IX of ASME BPVC or 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 of ASME BPVC and AWS D1.1, all qualification shall be consistent with that particular document.

RA-6200 CLEANING, FINISHING, AND COATING

RA-6210 Cleanliness

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.

RA-6220 Cleaning and Finishing

This subarticle covers the cleaning prior to surface preparation, coating, or painting. Condenser and evaporator internals shall be shop cleaned and prepared for shipment per the requirements of the applicable design section of ASME BPVC.

External 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. Solvents used shall be compatible with materials being cleaned.

RA-6230 Finishing and Surface Preparation

RA-6231 General. Surface preparation of metal surfaces located inside the containment building or other high radiation areas shall conform to the following requirements:

(a) All welds shall be 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.

(b) 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.

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

(d) 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.

RA-6232 General. Surface preparation of metal surfaces located outside the containment building or in low radiation areas shall conform to the following requirements:

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

(b) The minimum surface preparation shall be commercial blast cleaning as specified in SSPC-SP 6 and to a visual degree of cleanness as described in SSPC-Vis 1.

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

(d) 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.

RA-6233 ASME BPVC, Section VIII Equipment. Surface preparation of metal surfaces for ASME BPVC, Section VIII equipment located outside the containment building or in low radiation areas shall conform to the manufacturer's standards unless otherwise required by the design specification.

RA-6240 Coating and Application

RA-6241 For ASME BPVC, Section III-stamped equipment, coating and application shall be in accordance with AA-6543.2 except that AA-6543.2(f) shall be revised to read: "No coating materials shall be applied to heat transfer, galvanized, or stainless steel surfaces unless specifically required by the design specification."

RA-6242 For ASME BPVC, Section VIII equipment, coating and application shall be in accordance with the manufacturer's standards unless otherwise required by the design specification.

RA-6300 INSTALLATION

The equipment manufacturer shall provide detailed start-up, testing, and inspection procedures. These procedures shall be shipped with the equipment. The Owner shall be responsible for post start-up and periodic testing.

ARTICLE RA-7000 PACKAGING, SHIPPING, STORAGE, AND HANDLING

RA-7100 GENERAL REQUIREMENTS

(a) For equipment designed, fabricated, and stamped in accordance with ASME BPVC, Section III, packaging, shipping, and storage requirements shall be in accordance with Article AA-7000; ASME NQA-1, Requirement 13; and the specific requirements of RA-7200 through RA-7500.

(b) For equipment designed, fabricated, and stamped in accordance with ASME BPVC, Section VIII, packaging, shipping, and storage requirements shall be in accordance with the Owner's design specification and part of a quality control program in compliance with ASME BPVC, Section VIII, Division 1, Subsection C, Mandatory Appendix 10.

(c) 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.

(d) Stainless steel shall not be marked with chlorinated marking material.

RA-7200 PACKAGING

RA-7210 ASME BPVC, Section III Equipment

All relevant equipment listed in ASME NQA-1, Subpart 2.2, paras. 302.2 and 302.3 shall meet the packaging requirements of ASME NQA-1, Subpart 2.2, section 300 for Level B or C items, as applicable. The balance of the machine shall meet the packaging requirements of ASME NQA-1, Subpart 2.2, para. 302.4 for Level D items.

RA-7220 ASME BPVC, Section VIII Equipment

(a) Equipment shall meet the following requirements:

(1) Just before packaging, items shall be inspected for cleanness according to the requirements specified in the design specification. Dirt, oil residue, metal chips, or other forms of contamination shall be removed by approved cleaning methods. Any entrapped water shall be removed to the extent possible.

(2) All openings into items shall be capped, plugged, and sealed. Weld end preparations shall be protected from corrosion and physical damage.

(3) Items subject to detrimental contamination or corrosion, either internal or external, shall be suitably protected.

(4) Items packed in containers shall be blocked, braced, or cushioned to prevent damage.

(5) The identity of the item shall be maintained by marking or other appropriate means.

(b) Metallic spares shall meet the following requirements:

(1) Items that are not immediately packaged shall be protected from contamination.

(2) Items that require protection from damage during shipping and handling shall be packaged in containers or crates.

(c) Nonmetallic spares (gaskets, etc.) shall meet the following requirements:

(1) All requirements of (b) shall be met.

(2) Package design requirements shall be for extraordinary environmental protection to avoid the deleterious effects of shock and vibration, to control temperature or humidity within specified limits, or for any other special requirements.

(3) Items requiring protection from water vapor, salt air, dust, dirt, and other forms of contamination penetrating the package shall be packaged with a vaporproof barrier.

(4) Items that can be damaged by condensation trapped within the package shall be packaged with approved desiccant inside the sealed waterproof and vaporproof barrier or by an equivalent method.

RA-7230 Motors Shipped Separately

(a) Short-term: any motor that is to be used within 6 months 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 Level B storage.

(b) Long-term (over 6 months): any motor that is to be stored for a period of 6 months or longer shall be packaged per ASME NQA-1, Level B packaging requirements. If the motor is equipped with space heaters, the space heaters may be energized in storage (according to the manufacturer's recommendations) in lieu of providing moisture barrier wrapping and internal desiccant.

RA-7300 SHIPPING

RA-7310 ASME BPVC Section III Equipment

All relevant equipment listed in ASME NQA-1, Subpart 2.2, paras. 302.2 and 302.3 shall meet the shipping requirements of ASME NQA-1, Subpart 2.2, section 400 for Level B or C items, as applicable. The balance of the machine shall meet the shipping requirements of ASME NQA-1, Subpart 2.2, section 400 for Level D items.

RA-7320 ASME BPVC, Section VIII Equipment

Equipment shall meet the following requirements:

(a) The mode of transportation shall be consistent with the packaging method (see RA-7200) used.

(b) Items that exceed established weight or size limitations for railroads or highways or require special handling shall be given additional consideration in the following areas:

(1) The type of bracing and tie-down methods to be used with the mode of transportation selected for special shipments shall be specified.

(2) NO HUMPING shall be specified on rail shipments of these items, and NO HUMPING signs shall be prominently displayed.

(3) The conveyance used for transport shall be certified to be structurally adequate to take the loads imposed during loading while en route and during unloading. The route shall have been investigated prior to shipping to ensure safe transit.

(c) For loading, the weight, lifting points, or center of gravity indicated by the shipper on the crate, skids, or package shall be used to ensure proper handling during loading, transfer between carriers, and unloading.

(d) Carbon steel rigging equipment shall not come in direct contact with stainless steel — except when attached to lifting lugs, eyes, or pads — in order to avoid surface damage.

(e) All austenitic stainless steel and nickel-base alloy materials shall be handled in such a manner that they are not in contact with lead, zinc, copper, mercury, or other low melting point elements, alloys, or halogenated material.

(f) Package or preservative coatings shall be visually inspected after loading, and damaged areas repaired prior to shipment. Items shipped with desiccants shall be inspected after loading to ensure that sealed areas are intact.

RA-7400 STORAGE

RA-7410 ASME BPVC, Section III Equipment

All relevant equipment listed in ASME NQA-1, Subpart 2.2, paras. 302.2 and 302.3 shall meet the storage requirements of ASME NQA-1, Subpart 2.2, section 600 for Level B or C items, as applicable. The balance of the machine shall meet the storage requirements of ASME NQA-1, Subpart 2.2, section 600 for Level D items.

RA-7420 ASME BPVC, Section VIII Equipment

Equipment shall meet the following requirements:

(a) Pressurized components shall comply with ASME BPVC, Section VIII, Division 1, Subsection C, Mandatory Appendix 10. Other parts of the refrigeration machine shall comply with the design specification requirements.

(b) Nonmetallic spares (e.g., gaskets, etc.) shall be stored within a fire-resistant, tear-resistant, weather-tight, and well-ventilated building or equivalent enclosure with no direct sunlight or artificial UV light. Precautions shall be taken against vandalism and exposure to ozone, solvents, fuels, lubricants, or chemicals that could cause gasket deterioration. The area shall be situated and constructed so that it will not be subject to flooding; the floor shall be paved or equal and well drained. Items shall be placed on pallets or shoring to permit air circulation and protection from loads that would stress the gasket material. The area shall be provided with uniform humidity and temperature control or the equivalent to prevent condensation and corrosion. The minimum temperature shall be 40°F (5°C), and the maximum temperature shall be 140°F (60°C) or less if so stipulated by the manufacturer. The gasket manufacturer's long-term storage duration recommendations shall be followed due to potential aging considerations.

RA-7500 HANDLING AND RIGGING

Handling and rigging requirements shall be in accordance with AA-6610 and RA-7510 and RA-7520.

RA-7510 ASME BPVC, Section III Equipment

All relevant equipment listed in ASME NQA-1, Subpart 2.2, paras. 302.2 and 302.3 shall meet the handling requirements of ASME NQA-1, Subpart 2.2, section 700 for Level B or C items, as applicable. The balance of the machine shall meet the handling requirements of ASME NQA-1, Subpart 2.2, section 700 for Level D items.

RA-7520 ASME BPVC Section VIII Equipment

(a) As a handling prerequisite, evidence of maintenance in accordance with RA-7512(a) shall be verified.

(b) Written detailed procedures are not required.

(c) Items shall be handled by experienced personnel in accordance with good rigging and handling practices (as described in safety handbooks, consensus standards, and corporate or contractor standards designated for the job) and in compliance with regulations.

(d) Manufacturer's load charts and general safe rigging manuals shall be available to personnel.

RA-7600 ASSEMBLY, ERECTION, AND START-UP

RA-7610 Field-Assembled or Field-Erected Equipment

Where the 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 Owner-supplied external connections and services essential to the proper and safe operation of the refrigeration equipment 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 assigned designee of connections or services required for the proper and safe operation of the equipment as stated 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/her equipment. Post-start-up and periodic testing shall be the responsibility of the Owner. 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.

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 the applicable design section of ASME BPVC, except for those materials covered by RA-3120(b), RA-3150, RA-3161, RA-3162(b), RA-3163, RA-3164, RA-3170(c), and RA-3170(d). For RA-3150, RA-3161, RA-3162(b), RA-3163, RA-3164, RA-3170(c), and RA-3170(d), the requirements of this paragraph shall apply. If component material traceability is not obtainable per RA-3110(a) or RA-3110(b), the refrigeration equipment manufacturer shall designate and document which parts of the refrigeration equipment are essential to operation and which parts are not essential to operation.

(a) For parts essential to operation, the manufacturer shall prepare specifications, drawings, or other design documents to describe the part and maintain an inspection and testing program to ensure that the parts comply with the requirements of the specifications, drawings, or other design documents.

(b) For nonessential parts, no further action on the part of the manufacturer is required, and the provisions of Article AA-8000 are not applicable.

ARTICLE RA-9000 NAMEPLATES, STAMPING, AND RECORDS

RA-9100 GENERAL REQUIREMENTS

(a) Portions of refrigeration equipment manufactured under the rules of ASME BPVC, Sections III or VIII shall be stamped in accordance with the applicable rules of the specified design section of ASME BPVC.

(b) Authorization to use the symbol stamp for those portions of the equipment covered by the rules of ASME BPVC, Sections III and VIII must be obtained from ASME. The method for obtaining such authorization is in the applicable ASME BPVC design section.

RA-9200 NAMEPLATES AND STAMPING

The requirements given in AA-9100 shall apply for nameplates, as shall the following requirements:

(a) Components of the refrigeration machine built in accordance with sections of ASME BPVC shall be marked in accordance with the rules of the applicable ASME BPVC section

(b) In place of the requirements of AA-9200, a permanent nameplate of noncorrosive metal, providing the following information, shall be affixed to each refrigeration machine:

(1) the name of the manufacturer and the address of the production plant

(2) the year of manufacture

(3) refrigerant R-number

(4) amount of refrigerant factory charge (if required by design specification), lb (kg)

(5) lubricant identity

(6) amount of lubricant factory charge (if required by design specification), lb (kg)

(7) field test pressure

(8) electrical characteristics (i.e., voltage, phase, full load amps, horsepower)

RA-9300 DATA REPORTS

For ASME BPVC-stamped components, the applicable Code Data Reports (e.g., N-1, U-1, etc.) shall be completed, signed, and dated by the manufacturer's representative and the authorized inspector.

FORM RA-1 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 [Note (1)] ____________________
Date ____________________

NOTE:
(1) Optional. If witness test, prior written agreement must be in effect.

FORM RA-1a CENTRIFUGAL COMPRESSOR OIL PUMP PRESSURE TEST

Manufacturer ____________________

Serial No. ____________________

Model No. ____________________

Test type (check one): hydrostatic ____ pneumatic ____

Test pressure __________ psig (Pa)

Test duration __________ min

Manufacturer's test technician ____________________

Date ____________________

Manufacturer's Q.A. inspector ____________________

Date ____________________

Owner's representative [Note (1)] ____________________

Date ____________________

NOTE:

(1) Optional. If witness test, prior written agreement must be in effect.

FORM RA-1b CENTRIFUGAL COMPRESSOR PRESSURE TEST RECORD

Manufacturer ____

Serial No. ____

Model No. ____

Test type (check one): hydrostatic ____ pneumatic ____

Test pressure __________ psig (Pa)

Test duration __________ min

Leak test

Time ____________________ min

Manufacturer's test technician ____________________

Date ____________________

Manufacturer's Q.A. inspector ____________________

Date ____________________

Owner's representative [Note (1)] ____________________

Date ____________________

NOTE:
(1) Optional. If witness test, prior written agreement must be in effect.

FORM RA-2 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 [Note (1)] ______________________________

Date ____________________

NOTE:

(1) Optional. If witness test, prior written agreement must be in effect.

FORM RA-2a 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 [Note (1)] ____________________

Date ____________

NOTE:

(1) Optional. If witness test, prior written agreement must be in effect.

FORM RA-3 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 [Note (1)] ____________________

Date ____________________

NOTE:

(1) Optional. If witness test, prior written agreement must be in effect.

FORM RA-4 PERFORMANCE TEST RECORD (U.S. 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-4 PERFORMANCE TEST RECORD (U.S. 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 Manufacturer's proposed input)				

Manufacturer's test technician ________

Date ________

Manufacturer's Q.A. inspector ________

Date ________

Owner's representative [Note (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-M4 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-M4 PERFORMANCE TEST RECORD (SI) (CONT'D)
(See Mandatory Appendix RA-MI)

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 [Note (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 (U.S. CUSTOMARY)

ARTICLE RA-I-1000
GENERAL

The performance of the refrigeration equipment shall be certified by conducting a factory performance test as required by RA-5223. The performance test shall be conducted in accordance with ANSI/AHRI 550/590, Appendix A (or Owner-approved performance test procedure for custom-designed equipment), 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 provides guidance only for countries that do not invoke these rules.

RA-I-1100 TEST CONDITIONS

The conditions to be used in this test shall be as shown in Table RA-I-1100-1.

RA-I-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 AHRI 450 and AHRI 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 AHRI 450 and AHRI 480) and tabulated on Form RA-4 as shown in Table RA-I-1200-1.

RA-I-1300 HEAT BALANCE EQUATION

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-4. See also Table RA-I-1300-1.

RA-I-1400 MEASURED HEAT BALANCE

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-I-1500 TABULATION OF CAPACITY

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

$$= \frac{\text{gal/min} \times 62.4 \text{ lb/ft}^3 \times 60 \text{ min/hr}}{7.48 \text{ gal/ft}^3}$$

where the specific heat of water is 1 Btu/lb–°F

and shall be tabulated on Form RA-4 according to Table RA-I-1500-1.

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-1100-1 Test Conditions

	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-1200-1 Effect of Fouling Factor

	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)				
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-1300-1 Heat Balance Equation

	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-1500-1 Tabulation of Capacity

	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 (°F)	Note (3)	Note (3)	Note (3)	Note (3)
t_d — temperature of water leaving unit after correction for fouling (°F)	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 refrigeration equipment shall be certified by conducting a factory performance test as required by RA-5223. The performance test shall be conducted in accordance with ANSI/AHRI 551/591, Appendix A (or Owner-approved performance test procedure for custom designed equipment), with modifications to its paragraphs as outlined in RA-MI-1100 through RA-MI-1700.

RA-MI-1100 TEST CONDITIONS

The conditions to be used in this test shall be as shown in Table RA-MI-1100-1.

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 AHRI 450 and AHRI 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 AHRI 450 and AHRI 480) and tabulated on Form RA-M4 as shown in Table RA-MI-1200-1.

RA-MI-1300 HEAT BALANCE EQUATION

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-M4. See also Table RA-MI-1300-1.

RA-MI-1400 MEASURED HEAT BALANCE

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 TABULATION OF CAPACITY

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/h

$$= \frac{\text{L/min} \times \text{g/cm}^3 \times 60\ \text{min/h}}{\text{L}/1\,000\ \text{cm}^3}$$

where the specific heat of water is 1 cal/g–°C

and shall be tabulated on Form RA-M4 according to Table RA-MI-1500-1.

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-1100-1 Test Conditions

	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-1200-1 Effect of Fouling Factor

	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)				
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-1300-1 Heat Balance Equation

	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-1500-1 Tabulation of Capacity

	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-1000-1 Mandatory List of Instrumentation Functions and Control Functions

Control Functions	Manufacturer's 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	Gauge or digital display	. . .
15. Condenser refrigerant pressure	Gauge or digital display	. . .
16. Compress or oil pressure high (if applicable)	Gauge or digital display	. . .
17. Compressor oil pressure low (if applicable)	Gauge 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 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-1000-1 begins on the following page.

Table RA-A-1000-1 Division of Responsibility

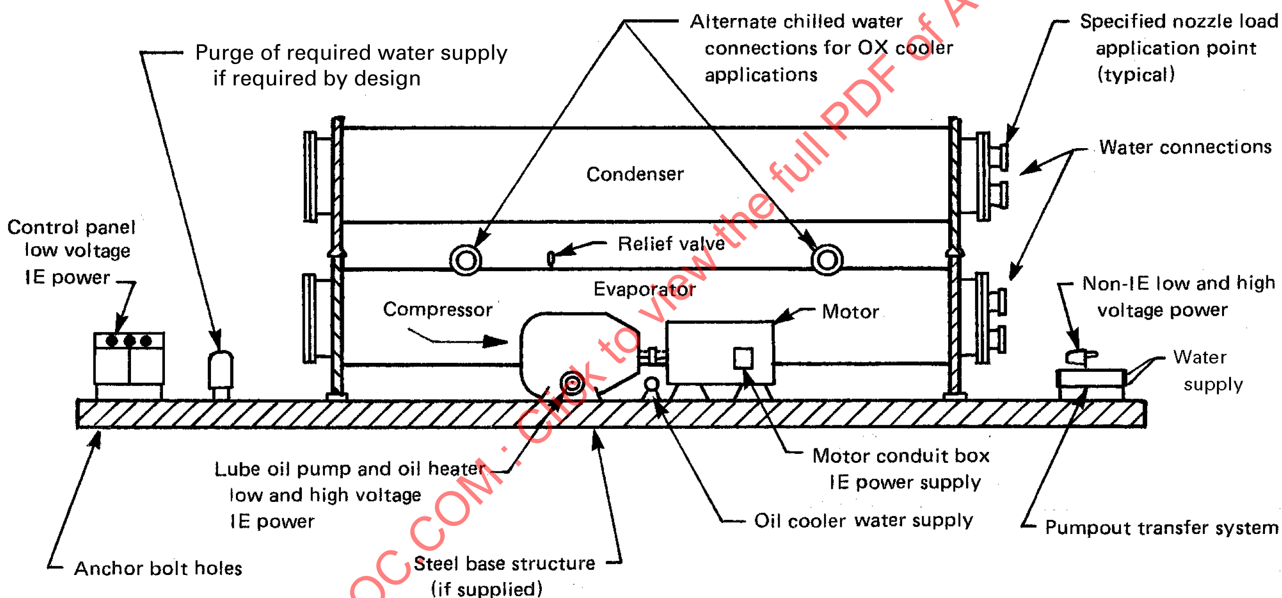
RA-	Item	Responsibility
3100(a)	Properties and composition of materials	Engineer
	Prohibited or limited materials	Engineer
	Specific materials	Engineer
3100(b)	Effects of service conditions on properties of material	Engineer
4200	Purpose (design function)	Engineer
4200	Safety classification	Engineer
4200	External interface safety classification	Engineer
4200(a)	Performance under all operating modes	Engineer
4200(b)(1)	Temperature	Engineer
4200(b)(2)	Pressure	Engineer
4200(b)(3)	Humidity	Engineer
4200(b)(4)	Radiation levels	Engineer
4200(b)(5)	Chemicals	Engineer
4200(b)(6)	Structural design criteria	Engineer
4200(b)(7)	Electrical transients	Engineer
4200(b)(8)	Cooling load requirements	Engineer
4200(b)(9)	Cooling load profile and time history	Engineer
4200(b)(10)	Water-side design pressures for evaporator and condenser	Engineer
4200(b)(11)	Refrigeration equipment exposed to harsh environments	Engineer
4200(c)	Magnitude of the loads	Engineer
4300(a)	Design load, tons of refrigeration	Engineer
4300(b)	Entering and leaving evaporator fluid temperature	Engineer
4300(c)	Entering condenser fluid	Engineer
4300(d)	Evaporator and condenser flow rates	Engineer
4300(e)	Evaporator and condenser fouling factors	Engineer
4300(f)	Tube material and nominal wall thickness for evaporator and condenser	Engineer
4300(g)	Fluid to be cooled and condensing fluid	Engineer
4300(h)	Electrical characteristics	Engineer
4300(i)	Pressure drop for liquid	Engineer
4300(j)	Maximum tube velocities	Engineer
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)	Ensuring equipment is accessible for repair	Manufacturer
4700(b)	Providing maintenance and access criteria	Manufacturer
5213.1	Non–ASME BPVC pressure vessel testing	Engineer
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

Table RA-A-1000-1 Division of Responsibility (Cont'd)

RA-	Item	Responsibility
5313	Nondestructive pressure-retaining components and component supports	Engineer
6100	Welding and brazing on non–ASME BPVC pressure-retaining components	Manufacturer
6133.2	Qualifications consistent with ASME BPVC, Section IX, or ANSI/AWS D1.1	Manufacturer
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 Certification Mark	Society
Form RA-1	Centrifugal compressor test record	Inspector/Manufacturer
Form RA-1a	Centrifugal compressor oil pump pressure test record	Manufacturer
Form RA-1b	Centrifugal compressor pressure test record	Manufacturer
Form RA-2	Reciprocating scroll/screw compressor test record	Manufacturer
Form RA-2a	Reciprocating scroll/screw compressor pressure test record	Manufacturer
Form RA-3	Electrical test record	Manufacturer
Form RA-4/M4	Performance test record (U.S. customary/SI)	Engineer/Manufacturer
Mandatory Appendix RA-I/RA-MI	Optional capacity test points	Engineer

NONMANDATORY APPENDIX RA-B
TYPICAL EXTERNAL INTERFACE DIAGRAMS

Figure RA-B-1000-1 Interface Points — Typical Two-Vessel Design



GENERAL NOTES:
(a) Shaded portions are NF boundaries.
(b) A power panel with oil pump starter may be used 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 overcurrent 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

ARTICLE CA-1000
INTRODUCTION

CA-1100 SCOPE

This section provides requirements for the performance, design, fabrication, installation, inspection, acceptance testing, and quality assurance for forced circulation air cooling and heating coils and electric heating coils used in air treatment systems in nuclear facilities.

CA-1200 PURPOSE

The purpose of this section is to ensure that forced circulation air cooling and heating coils and electric heating coils are acceptable in all aspects of design and operation.

CA-1300 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 and electric heating coils used in air treatment systems used in nuclear facilities.

CA-1310 Clarification of Code Applicability

Pressure-retaining parts whose design, materials, manufacture, test, and documentation are covered by ASME BPVC shall be in accordance with the applicable requirements of the specified Section of that Code. When conflict exists between this section and ASME BPVC, the latter shall take precedence.

CA-1320 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, finned tubular condensing coils, shell-and-tube-type refrigerant evaporators and condensers, and compressors.

CA-1330 Interfacing Boundaries

The requirements of this section are limited to the flange face of the coil, the piping connections on the fluid side, and the electrical control cabinet for electrical connections.

CA-1400 DEFINITIONS AND TERMS

CA-1410 General

Only specialized terminology not defined elsewhere is listed in CA-1420 and CA-1440. Also see AA-1400 and ASHRAE's Terminology website, www.ashrae.org/ashraeterms.

CA-1420 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).

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 or AHRI 410.

component support: a structural element that carries the component weight and transmits loads from the ASME BPVC, Section III 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 BPVC, Section III 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: an inlet or outlet connection located between the header and system piping.

return bend: a U-shaped section of the tube located on the tube ends.

CA-1440 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: a 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 listed below shall supplement those listed in Article AA-2000. Unless otherwise specified, the latest edition shall apply.

AHRI 410-2001 with Addenda 1, 2, and 3, Forced-Circulation Air-Cooling and Air-Heating Coils
Publisher: Air Conditioning, Heating, and Refrigeration Institute (AHRI), 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201 (www.ahrinet.org)

ASHRAE 15-13, Safety Code for Mechanical Refrigeration
ASHRAE 33-16, Methods of Testing Forced Circulation Air Cooling and Air Heating Coils
ASHRAE Terminology: A Comprehensive Glossary of Terms for the Built Environment (www.ashrae.org/ashraeterms)
Publisher: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329 (www.ashrae.org)

ASME B16.5, Pipe Flanges and Flanged Fittings: NPS $\frac{1}{2}$ Through NPS 24, Metric/Inch Standard
ASME B31.5, Refrigeration Piping and Heat Transfer Components
Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990 (www.asme.org)

AWS A5.31M/A5.31:2012, Specification for Fluxes for Brazing and Braze Welding
Publisher: American Welding Society (AWS), 8669 NW 36 Street, No. 130, Miami, FL 33166-6672 (www.aws.org)

SAE AMS3410K-2016, Flux, Silver Brazing
SAE AMS3411E-2016, Flux, Silver Brazing High Temperature
Publisher: SAE International, 400 Commonwealth Drive, Warrendale, PA 15096 (www.sae.org)

SSPC-PA 1-00(Revised 2004), Shop, Field, and Maintenance Painting of Steel
SSPC-SP 6/NACE No. 3-07, Commercial Blast Cleaning
SSPC-VIS 1-02, Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning
Publisher: SSPC: The Society for Protective Coatings, 800 Trumbull Drive, Pittsburgh, PA 15205 (www.sspc.org)

UL 1996, Rev 4-2009, UL Standard for Safety Electric Duct Heaters
Publisher: Underwriters Laboratories, Inc. (UL), 333 Pfingsten Road, Northbrook, IL 60062-2096
Order Address: Comm 2000, 151 Eastern Avenue, Bensenville, IL 60106 (www.ul.com)

ARTICLE CA-3000 MATERIALS

CA-3100 MATERIAL SPECIFICATIONS

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 CA-4110. When the equipment application requires the use of specific materials, these materials shall be explicitly defined in the design specification.

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 ASME BPVC for the appropriate design Section and class of service. For codes of record prior to the 1992 Edition, use the applicable ASME BPVC, Section III or Section VIII Appendices. For codes of record beginning with the 1992 Edition, use the applicable ASME BPVC, Section II, Part D Tables.

CA-3220 Pressure-Retaining Materials for Volatile Refrigerant Coils

Material for all pressure-retaining items shall conform to the allowable stresses of ASME B31.5, Table 502.3.1. In addition to conforming to the stresses of this Table, the materials shall meet the requirements of this Code and the impact ductility requirements for material subject to ASME B31.5, Section 523.2. All materials selected shall be suitable for the intended service.

CA-3230 Non-Pressure-Retaining Materials

Materials shall be selected to meet the environmental conditions listed in the design specification.

CA-3240 Load-Bearing Members

(a) Structural loads to be considered in the design of coils covered by this section are defined in ASME BPVC, Section III, Subsection NCA and applicable parts of Subsections NC, ND, and NF for Section III components, or in ASME BPVC, Section VIII, Division 1, Subsection A, Part UG and the applicable Parts of Subsections B and C for Section VIII components. 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 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.

(b) All materials that form the support structure of components other than ASME BPVC, Section III or Section VIII components shall be selected from ASME B31.1, Chapter IV; ASME 31.5, Chapter III; or ASME BPVC, Section II.

(c) Applicable ASME Code Cases in effect on the date of the ASME BPVC edition and addenda listed in the design specification may be used by mutual consent of the Owner or designee and the Certificate Holder.

CA-3250 Non-Load-Carrying Members

Materials that are part of the coil casing or tube support and for which no structural credit is taken shall be selected from Table AA-3100-1 and shall comply with the applicable requirements of the specified ASME BPVC section.

CA-3400 ELECTRIC HEATING COIL MATERIALS

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 AA-3100-1, as a minimum. Materials that exceed the requirements in Table AA-3100-1 may be used subject to the approval of the Owner or designee.

CA-3500 CERTIFICATION OF MATERIALS

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) For ASME BPVC, Section III coils, or if required by the design specification, the manufacturer shall supply to the purchaser Certified Material Test Reports (CMTRs) 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 conformance 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 BPVC, Section III, Subsection NF materials shall be supplied with CMTRs, except as designated in NF-2600.

(d) For ASME BPVC, Section VIII coils, the manufacturer shall ensure the material meets the requirements of Section VIII, Division 1, Subsection A, Part UG and the applicable parts of Subsections B and C.

(e) For non-pressure-boundary coil material and electric heaters, a Material Manufacturer's certificate of conformance with the material specification, grade, class, and heat-treated condition, as applicable, is acceptable in lieu of a CMTR.

ARTICLE CA-4000 DESIGN

CA-4100 DESIGN CONDITIONS FOR WATER AND STEAM COILS

CA-4110 Design Specification

For equipment designed to ASME BPVC, Section III, a design specification shall be prepared and certified by the Owner or designee in accordance with Section III, Subsection NCA, NCA-3255. For equipment designed to ASME BPVC, Section VIII, a design specification shall be prepared in accordance with Section VIII, Division 1, Mandatory Appendix 10. In either case, sufficient detail shall be provided to form a complete basis for equipment design in accordance with this Code. The design specification shall include, as a minimum, the following data:

(a) the ASME BPVC edition, addenda (if applicable), Section, design class (if applicable), and applicable Code Cases

(b) coil type

(c) corrosion allowance

(d) fouling factor, fluid side

(e) safety classification per ASME BPVC, Section III, Subsection NCA, NCA-2110 (for Section III designed equipment only)

(f) boundaries of jurisdiction per ASME BPVC, Section III, Subsection NCA, NCA-3254 for Section III designed equipment, or per CA-1330 and as defined by the design specification for ASME BPVC, Section VIII designed equipment

(g) tube and fin minimum material thickness

(h) maximum and minimum 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 BPVC, Section III, Subsection NCA, NCA-2140, and applicable parts of Subsections NC, ND, and NF for Section III components; or per ASME BPVC, Section VIII, Division 1, Subsection A, Part UG and the applicable Parts of Subsections B and C for Section VIII components

(l) magnitude and direction of all external nozzle loads

(m) clear definitions of any superimposed loads of a cyclical nature, including the occurrence of water flow variation or reversal, or both, where applicable

(n) radiation, total integrated dosage, rad (gray)

(o) coating system requirements

(p) seismic response spectra

(q) procedures and documents to be submitted for approval

In addition to the requirements of (a) through (q), 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 ASME BPVC, Section III or Section VIII, as requested by the design specification.

(b) All fluid-side coil components stamped with the Certification Mark with "N" Designator shall be, as a minimum, of the same ASME Code class as the fluid system in which they are to be installed. The design specification shall identify the 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-4122-1.

(c) Any other water coil tube material permitted for ASME BPVC, Section III or Section VIII service by Section II, Part D, 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.

(d) Steam coils shall be capable of withstanding twice the maximum fluid-side pressure.

CA-4123 Return Bends

(a) Separate non-cleanable return bends are allowed.

(b) Hairpin tubes (U-tubes) with integral return bends are allowed.

Table CA-4122-1 Maximum Water Velocities in Water Coils

Alloy	Maximum Velocity			
	Fresh Water		Brackish Water	
	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

(c) The wall thickness of the tube in the apex of a return bend or hairpin tube (U-tube) shall not be less than the value determined from the equation given in ASME BPVC, Section II, Part B, SB-395, 12.2.3.

(d) When a minimum tube wall thickness is specified, the return bends or hairpin tubes (U-tubes) shall be formed from tube with increased wall thickness sufficient to maintain the specified minimum tube wall thickness in the apex of the bends. As a minimum, such increased wall thickness shall be the equivalent of one gauge [Birmingham wire gauge (BWG)] heavier than the specified minimum tube wall thickness but need not be greater than the equivalent of two gauges (BWG) heavier than the specified minimum tube wall thickness.

(e) Cleanable return bends shall be cast or machined fittings with plugs and O-rings.

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 and hydraulic tube expansion 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 AA-3100-1.

CA-4127 Design Recommendations. Design recommendations for 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 function under all design conditions.

CA-4133 Load Definition. Structural loads to be considered in the design of coils covered by this section are defined in ASME BPVC, Section III, Subsection NCA and applicable parts of Subsections NC, ND, and NF for Section III components, or in ASME BPVC, Section VIII, Division 1, Subsection A, Part UG and the applicable Parts of Subsections B and C for Section VIII components. 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 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.

CA-4134 Structural Verification

CA-4134.1 General. ASME BPVC, Section III equipment and supporting structures shall be designed according to the rules established in the applicable subsections of that Code. ASME BPVC, Section VIII, Division 1 equipment shall be designed according to the rules established in the applicable subsections of that Code. 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 referenced in CA-4133.

CA-4134.2 Deflection Acceptance Criteria. Deflection is not a failure mode applicable to installed coils. Therefore, no acceptance criteria are required.

CA-4200 DESIGN CONDITIONS FOR VOLATILE REFRIGERANT COILS

CA-4210 Design Specification

A design specification shall be prepared by the Owner or 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) procedures and documents to be submitted
(c) materials of construction
(d) refrigerant type
(e) safety classifications per ASHRAE 15
(f) maximum allowable fin spacing
(g) conditions of operation (normal, accident, etc.)
(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, rad (gray)
(11) coating system requirements
(12) refrigerant-side design pressure in accordance with ASHRAE 15

CA-4220 Technical Requirements

CA-4221 General

(a) Volatile refrigerant coils shall be designed in accordance with the structural requirements given in the applicable sections of the code of record established in the design specification. Structural requirements and load definitions specific to volatile refrigerant coils are given in CA-4132 through CA-4134.2.

(b) The fluid side of the volatile refrigerant coil shall be designed, constructed, rated, and tested in accordance with the design specification and ASME B31.5, AHRI 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 1.3 times the maximum fluid-side pressure defined in the design specification, per ASME B31.5.

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 ASME BPVC, Section II, Part B, SB-395, 12.2.3.

CA-4224 Distributors

(a) Distributors shall be used when required to disperse the refrigerant evenly through the coil.

(b) Distributor feed tubes shall be oriented in a nonuniform configuration and shall be 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.

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 AA-3100-1.

CA-4228 Design Recommendations. Design recommendations for coils are contained in Nonmandatory Appendix CA-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-4400 DESIGN CONDITIONS FOR ELECTRIC HEATING COILS

CA-4410 Design Specification

A design specification shall be prepared by the Owner or 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, rad (gray)
(q) procedures and documents to be submitted

CA-4420 Technical Requirements

CA-4421 General

(a) Electric heating coils shall be designed following the guidelines of NFPA 70 and UL 1996, 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 B344.

(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 AA-3100-1.

CA-4424 Thermal Cutouts

(a) Primary and secondary temperature thermal cutouts shall be provided in accordance with UL 1996 and 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 1996 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 type 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 gauge.

CA-4427 Electrical Requirements

(a) Electric heating coils shall be constructed in accordance with applicable requirements of 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.

(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 de-energized.

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 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. Support boundaries specific to electric heating coils are given in CA-4132.

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 function under all design conditions.

ARTICLE CA-5000 INSPECTION AND TESTING

CA-5100 GENERAL REQUIREMENTS

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 Performance Verification and Validation

Coil performance (for nuclear power plant installations) shall be verified or validated by one of the methods described in CA-5211 or CA-5212, as determined from the design specification.

CA-5211 Performance Verification for Normal Operating Conditions. The performance of air coils shall be verified by one of the methods described in CA-5211.1 through CA-5211.3, as determined from the design specification.

CA-5211.1 Verification, Method 1 — Normal. For coil types that have been certified in accordance with AHRI 410, acceptable verification shall be a copy of the results of automated rating/selection computer procedures for each specified design condition. The copy of the results shall be certified by the manufacturer and, as a minimum, shall state the following:

(a) the applied rating thermal capacity based upon the specified design parameters

(b) the fouling factors used in the computation

(c) the reference number associated with the AHRI-certified coil line designation

(d) identification and revision number of the automated rating/selection computer procedures associated with the AHRI-certified coil line designation

CA-5211.2 Verification, Method 2 — Normal. For coil line designations that have not been certified in accordance with AHRI 410, or in lieu of Verification, Method 1 — Normal (see CA-5211.1), acceptable verification shall be by means of a topical report that demonstrates by calculation that the minimum design thermal capacity is achieved. Values used for air-side thermal resistance shall be based on prototype testing that utilizes the methodology of ASHRAE 33. For coils operating under similar design conditions at a single installation and whose performance results are generated by computerized selection programs, a representative calculation of the design condition for one coil is sufficient verification demonstration. As a minimum, the verification report shall address the following:

(a) the dimensions used to establish coil face area

(b) fin dimensions (e.g., height, length, spacing)

(c) length of fin collars, when applicable

(d) tube diameter and wall thickness

(e) tube spacing and geometry

(f) number of tubes per coil row

(g) number of rows of tubes per coil

(h) thermal resistances

(i) fouling factors used in the computations

(j) heat transfer surface amount

(k) relevant thermal characteristics of the heat transfer media

(l) relevant velocities of the heat transfer media

(m) thermal capacities (total and sensible, as applicable)

CA-5211.3 Validation, Method 3 — Normal. A performance test that utilizes the methodology of ASHRAE 33 shall be conducted on a prototype coil to determine the coil thermal performance rating. The test shall be conducted to match the specified design condition as close as reasonably achievable. The results of the test shall be documented in a report that includes the following, as a minimum:

(a) design thermal conditions

(b) test thermal parameters

(c) description of the test method

(d) test results

(e) a statement of coil capacity

CA-5212 Performance Verification for Accident Conditions. For accident conditions that cannot be satisfactorily evaluated using the methods for normal operating conditions, such as for accident conditions inside the containment building of a nuclear power plant, performance tests that include the effects of condensate flooding shall be conducted on a prototype coil to determine the coil thermal performance rating under similar air-side pressure and temperature conditions. Acceptable verification shall be by means of a topical report that demonstrates that the performance results generated by computerized thermal models are similar to and validated by the results of the prototype performance tests. As a minimum, the topical report shall address the following:

(a) the characteristics of the prototype test coil

(b) comparison of the prototype test conditions to the specified design conditions

(c) description of the test method

(d) applicability of the test results to the coil being verified

(e) supporting calculations, as applicable

(f) a statement of minimum coil capacity

(19) CA-5220 Pressure Testing for Water and Steam Coils

(a) The Owner or designee shall approve leak testing procedures when required by the design specification. Shop water quality analysis shall be reviewed and an appropriate filter shall be included during testing when required to meet specified water quality.

(b) Components that comply with ASME BPVC, Section III shall be hydrostatically or pneumatically tested in accordance with the requirements of Section III, Subsection NC, Article NC-6000, or Subsection ND, Article ND-6000. Components that comply with ASME BPVC, Section VIII shall be hydrostatically or pneumatically tested in accordance with the requirements of Section VIII, Division 1, Subsection A, UG-99 or UG-100, as required.

CA-5230 Pressure Testing for Volatile Refrigerant Coils

All refrigerant coils shall be pneumatically tested in accordance with ASME BPVC, Section V, Article 10 except that the test pressure shall be 1.25 times the design pressure in accordance with ASHRAE 15.

CA-5240 Nondestructive Examination

CA-5241 Material Examination. For coils designed and fabricated in accordance with ASME BPVC, Section III, material examination, when required by the design specification, shall comply with the applicable parts of Section III, and with Section V, Article 8 and Article 26.

Coils designed to ASME BPVC, Section VIII shall comply, when required by the design specification, with the applicable parts of Section VIII, Division 1, Subsection A, UG-93 and UG-95, and with Section V, Article 8. For volatile refrigerant coils, ASTM E243 shall be used.

Coil tubing material shall be eddy current tested when required by the design specification.

CA-5242 Visual Examination of Brazed Joints

(a) For coils designed and fabricated in accordance with ASME BPVC, Section III, brazed joints shall be visually inspected in accordance with AA-5200. Visual examination shall also comply with Section III, Subsection NC or Subsection ND, 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 coils designed and fabricated in accordance with ASME BPVC, Section VIII, brazed joints shall be visually inspected in accordance with AA-5200. Visual examination shall also comply with Section V, Article 9, and Section VIII, Division 1, Subsection B, UB-44. Acceptance criteria shall be as given in UB-44(b) through UB-44(f).

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 gauges 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 gauges 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 ASME BPVC, Section III shall meet the requirements of Section III and of Section IX, Part QW.

(b) Welds and welded joints in coil casings designed and fabricated in accordance with ASME BPVC, Section III, Subsection NF shall meet the requirements of NF-3324.5, NF-4240, and NF-4300, and of Section IX, Part QW.

(c) Welds and welded joints in coils designed and fabricated in accordance with ASME BPVC, Section VIII shall meet the requirements of Section VIII, Division 1, Subsection B, Part UW plus any relevant rules of the applicable Parts of Subsection C covering the materials of construction, and of Section IX, Part QW.

(d) Welding for electric heating coils shall be in accordance with AA-6300.

CA-6130 Brazing

(a) Brazing for pressure-retaining components designed and fabricated in accordance with the ASME BPVC, Section III shall meet the requirements of Section III and of Section IX, Part QB.

(b) Brazing for pressure-retaining components designed and fabricated in accordance with the ASME BPVC, Section VIII shall meet the requirements of Section VIII, Division 1, Subsection B, Part UB plus any relevant rules of the applicable Parts of Subsection C covering the materials of construction, and of Section IX, Part QB.

Filler metals shall be chosen from AWS/SFA 5.8. Fluxes shall be AWS A5.31, Type FB 3A or Type FB 3C; SAE AMS3410; or SAE AMS3411. A combination of fluxes is acceptable.

CA-6140 Mechanical Joining

(a) Bolts and bolted joints in coil frames designed and fabricated to the requirements of ASME BPVC, 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-SP 1. Halogen based materials or chlorinated degreasers shall not be used for surface preparation.

CA-6220 Finishing and Surface Preparation

CA-6221 ASME BPVC, Section III Equipment

(a) Surface preparation of metal surfaces for ASME BPVC, Section III equipment located inside the containment building or other high-radiation areas shall conform to the following requirements:

(1) All welds shall be free from sharp projections and spatters, and blended smoothly into the base metal. The surface shall be cleaned in accordance with SSPC-SP 10, 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 or in low-radiation areas shall conform to the following requirements:

(1) All welds shall be 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-SP 6 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-6222 ASME BPVC, Section VIII Equipment. Surface preparation of metal surfaces for ASME BPVC, Section VIII equipment located outside the containment building or in low-radiation areas shall conform to the manufacturer's standards unless otherwise required by the design specification.

CA-6230 Coating and Application

CA-6231 ASME BPVC, Section III Equipment. For ASME BPVC, Section III equipment, coating and application shall be in accordance with AA-6543.2 except that AA-6543.2(f) shall be revised to read: "No coating materials shall be applied to heat transfer, galvanized, or stainless steel surfaces unless specifically required by the design specification."

CA-6232 ASME BPVC, Section VIII Equipment. For ASME BPVC, Section VIII equipment, coating and application shall be in accordance with the manufacturer's standards unless otherwise required by the design specification.

ARTICLE CA-7000 PACKAGING, SHIPPING, STORAGE, AND HANDLING

CA-7100 GENERAL REQUIREMENTS

(a) For equipment designed, fabricated, and stamped in accordance with ASME BPVC, Section III, packaging, shipping, and storage requirements shall be in accordance with Article AA-7000; ASME NQA-1, Requirement 13; and the specific requirements of CA-7200 through CA-7500 or below.

(b) For equipment designed, fabricated, and stamped in accordance with ASME BPVC, Section VIII, packaging, shipping, and storage requirements shall be in accordance with the Owner's design specification and part of a quality control program in compliance with Section VIII, Division 1, Mandatory Appendix 10.

(c) 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.

(d) *Marking.* Stainless steel shall not be marked with chlorinated marking material.

CA-7200 PACKAGING

(a) Water, steam, and volatile refrigerant coils shall meet the requirements of Packaging Level C of ASME NQA-1, Part II, Subpart 2.2, para. 300.

(b) Electric heating coils, control panels, terminal boxes, and nonmetallic spares (gaskets, etc.) shall meet the requirements of Packaging Level B of ASME NQA-1, Part II, Subpart 2.2, para. 300.

CA-7300 SHIPPING

(a) Water, steam, and volatile refrigerant coils shall meet the requirements of Shipping Level C of ASME NQA-1, Part II, 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, Part II, Subpart 2.2, para. 400.

CA-7400 STORAGE

(a) Water, steam, and volatile refrigerant coils shall meet the requirements of Storage Level C of ASME NQA-1, Part II, Subpart 2.2, para. 600.

(b) Electric heating coils, control panels, terminal boxes, and nonmetallic spares (gaskets, etc.) shall meet the requirements of Storage Level B of ASME NQA-1, Part II, Subpart 2.2, para. 600.

CA-7500 HANDLING

Handling and rigging requirements shall be in accordance with AA-6610 and the following:

(a) Water, steam, and volatile refrigerant coils shall meet the requirements of Handling Level C of ASME NQA-1, Part II, Subpart 2.2, para. 700.

(b) Electric heating coils, control panels, terminal boxes, and nonmetallic spares (gaskets, etc.) shall meet the requirements of Handling Level B of ASME NQA-1, Part II, Subpart 2.2, para. 700.

ARTICLE CA-8000 QUALITY ASSURANCE

CA-8100 GENERAL REQUIREMENTS

CA-8110 Introduction

Quality requirements identified in Article AA-8000 shall apply except as noted below.

(a) For ASME BPVC, Section III equipment, 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 because it ensures that the physical characteristics of components or materials meet specified requirements. Quality assurance programs shall be in accordance with ASME BPVC, Section III, Subsection NCA, Article NCA-4000, including the requirements of ASME NQA-1 as modified by NCA-4134.

(b) ASME BPVC, Section VIII equipment is designed, fabricated, tested and/or stamped in accordance with a quality control program that compiles with Section VIII, Division 1, Mandatory Appendix 10.

(c) The organizations responsible for a project shall establish documented quality assurance or quality control programs in accordance with the requirements of (a) or (b). A project includes design, fabrication, assembly, shipping, packaging, 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

CA-8121 ASME BPVC, Sections III and VIII Equipment. The lifetime and nonpermanent quality assurance records (see Tables CA-8121-1 and CA-8121-2) shall be in accordance with the following:

(a) *Coils, ASME BPVC, Section III.* For equipment designed and fabricated in accordance with ASME BPVC, Section III, permanent and nonpermanent records shall be in conformance with ASME NQA-1 as amended by Section III, Subsection NCA, 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) *Coils, ASME BPVC, Section VIII.* For equipment designed and fabricated in accordance with ASME BPVC, Section VIII, permanent and nonpermanent records shall be in conformance with the applicable requirements of the Owner's document control procedures. Documentation package requirements shall be as listed in the design specification.

(c) In addition to the minimum requirements stated in (a) and (b), the Owner may identify other requirements.

CA-8122 Other Equipment. 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-8121-1 shall be maintained as a minimum.

ARTICLE CA-9000 NAMEPLATES AND RECORDS

CA-9100 GENERAL REQUIREMENTS

Nameplates and stamping requirements shall meet the requirements of Article AA-9000, except as provided in this Article.

CA-9200 COILS

Coils manufactured under the rules of ASME BPVC, Section III or Section VIII shall be stamped in accordance with the applicable rules of those Sections.

Table CA-8121-1 Lifetime Quality Assurance Records

Record	Water, Steam, and Volatile Refrigerant Coils	Electric Heating Coils
1. Index to lifetime records	X	X
2. Design specification	X	X
3. Design calculations and drawings	X	X
4. As-built drawings	X	X
5. CMTR and documentation providing traceability to location used, if required	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
11. Factory test reports, as required	...	X
12. Environmental report	...	X

Table CA-8121-2 Nonpermanent Quality Assurance Records

Record	Retention Period
1. QA program manual	3 yr after superseded or invalidated
2. Design, procurement, and QA procedures	3 yr after superseded or invalidated
3. Installation and nondestructive examination procedures	10 yr after superseded or invalidated
4. Personnel qualification records	3 yr after superseded or invalidated
5. Purchase orders	10 yr after superseded or invalidated
6. Audit and survey reports	3 yr after completion of report
7. Calibration records	Until recalibrated
8. Process sheets, travelers, or checklists	10 yr after completion

CA-9300 INFORMATION ON NAMEPLATES

CA-9310 Water, Steam, and Volatile Refrigerant Coils

A separate, permanent, noncorrosive nameplate shall be affixed to HVAC and refrigerant service coils and shall include the following information:

(a) manufacturer, model number, year manufactured

(b) design pressure, psia (kPa), and design temperature, °F (°C)

(c) type of fluid

(d) fluid flow rate for water, gpm (L/s), and steam coils, lb/hr (kg/h)

(e) item tag number, if furnished by the purchaser

(f) serial number

(g) type of refrigerant for volatile refrigerant coils

(h) customer reference number (e.g., purchase or shop order or procurement specification number, if requested, as agreed between manufacturer and Owner)

CA-9320 Electric Heating Coils

(a) In place of the requirements of AA-9200, a permanent nameplate of noncorrosive metal, providing the following information, shall be affixed to electric heating coils:

(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) Panels that are mounted in a location remote from the heating coils shall be provided with the same nameplate data as the heating coils.

CA-9400 NAMEPLATE 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-9220 does not apply.

CA-9500 DATA REPORTS

CA-9510 Coils

(a) Coils designed, fabricated, and stamped in accordance with ASME BPVC, Section III shall have a Form N-1 Certificate Holder's Data Report completed for each coil.

(b) Coils designed, fabricated, and stamped in accordance with ASME BPVC, Section VIII shall have a Form U-1 Manufacturer's Data Report completed for each coil.

CA-9520 Volatile Refrigerant Coils

For volatile refrigerant coils, a manufacturer's data report shall be provided containing the following as a minimum:

(a) date of test
(b) manufacturer
(c) manufacturer's serial number
(d) testing location
(e) testing medium
(f) test pressure
(g) design pressure
(h) test temperature
(i) design temperature
(j) test procedure criteria (pressure)
(k) signature of examiner or inspector

ARTICLE CA-10000 REPAIRS AND REPLACEMENTS

CA-10100 GENERAL

The repair and replacement shall be in accordance with the code of record for the facility.

NONMANDATORY APPENDIX CA-A
DIVISION OF RESPONSIBILITY

This 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.

(19) **Table CA-A-1000-1 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	Manufacturer
	Code class	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
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
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
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	Nameplates and records	Manufacturer

NONMANDATORY APPENDIX CA-B
DESIGN RECOMMENDATIONS

ARTICLE CA-B-1000
RECOMMENDED DESIGN CRITERIA FOR WATER, STEAM, AND VOLATILE REFRIGERANT COILS

CA-B-1100 SCOPE

The system design parameters, features, or specifications given in this Article are recommended for water, steam, and volatile refrigerant coils.

CA-B-1200 GENERAL 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

ARTICLE FA-1000
INTRODUCTION

FA-1100 SCOPE

This section provides requirements for the performance, design, fabrication, inspection, acceptance testing, and quality assurance for moisture separators used in air and gas treatment systems in nuclear facilities.

FA-1200 PURPOSE

The purpose of this section is to ensure that moisture separators are acceptable in all aspects of design and operation.

FA-1300 APPLICABILITY

FA-1310 Moisture Separators

This section applies to modular, impingement-type liquid droplet separators in liquid water entrained airstreams, which typically employ layers of fibers, layers of mesh, or alternating layers of each.

This section does not cover high efficiency mist eliminators, which operate on the principle of Brownian diffusion, or wave-plate (louver) liquid droplet separators, which operate on the principle of inertial separation.

FA-1320 Limitations

This section does not cover the integration of moisture separators into a complete air cleaning system.

FA-1400 DEFINITIONS AND TERMS

The following terms have special meaning in the context of this section:

case: a 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 airstream.

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: the concentration of entrained liquid droplets exiting from a moisture separator expressed as a percentage of inlet concentration.

Also, see AA-1400.

ARTICLE FA-2000
REFERENCED DOCUMENTS

Codes and standards may be listed below to supplement those listed in Article AA-2000.

ARTICLE FA-3000
MATERIALS

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 A240, Type 304 stainless steel.

FA-3130 Rivets

Rivets shall be 300 series austenitic steel meeting the minimum requirements of ASTM A581, Type 303.

FA-3140 Gaskets

Gaskets shall be closed cell silicone rubber sponge, Grade 2C3 or 2C4, in accordance with ASTM D1056.

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, and comply with the standard for air filter units, UL 900.

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.

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 rad, 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-4100-1. Refer to Figure 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-4100-1.

FA-4220 Moisture Separator Assembly

The case shall be formed and assembled in a manner to meet the requirements of Table FA-4100-1. 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 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-4212-1.

FA-4340 Acceptance Criteria

The acceptance criteria are listed in Table AA-4321-1. The design stress allowable values, S, shall be $0.6S_y$.

ARTICLE FA-5000 INSPECTION AND TESTING

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 Airflow 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-4100-1 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-4100-1 without any visible physical damage or change in pressure drop (clean, wet) at rated flow.

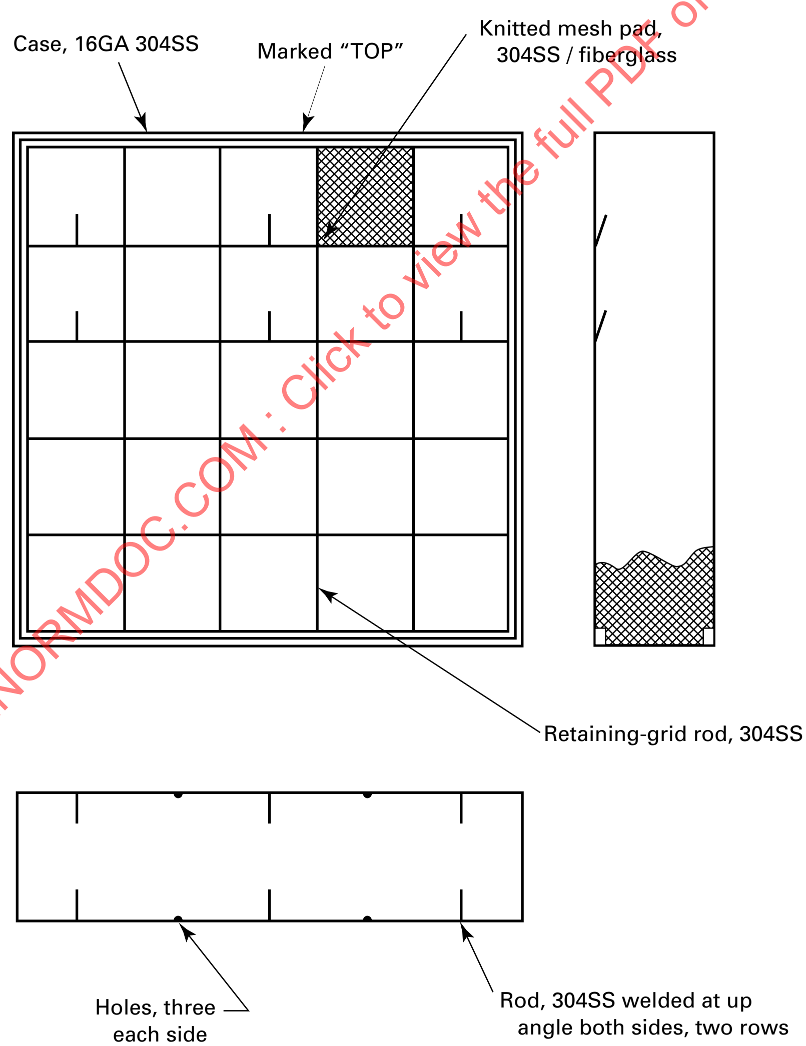
(19)

Table FA-4100-1 Moisture Separator Performance Specifications

Requirement	Value
Airflow 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. wg (250 Pa)
Maximum pressure drop at rated moisture removal capacity (clean, wet)	2.0 in. wg (500 Pa)
Minimum burst pressure (clean, wet)	20.0 in. wg (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 min per 1 700 m^3/h)
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.)

(19)

Figure FA-4100-1 Typical Moisture Separation Configuration



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-4100-1.

FA-5200 PRODUCTION INSPECTION AND TESTING

Each moisture separator to be delivered to the purchaser shall be inspected and tested in accordance with 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 Airflow 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-4100-1 for the clean, dry condition.

ARTICLE FA-6000 FABRICATION

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 A380 before any welding.

FA-6300 TOLERANCES

FA-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.

FA-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.

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

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 Section FA.

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 alphanumeric 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
DIVISION OF RESPONSIBILITY

This 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-1000-1 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

ARTICLE FB-1000
INTRODUCTION

FB-1100 SCOPE

This section provides requirements for the performance, design, fabrication, inspection, acceptance testing, and quality assurance for medium efficiency filters used in air and gas treatment systems in nuclear facilities.

FB-1200 PURPOSE

The purpose of this section is to ensure that medium efficiency filters are acceptable in all aspects of design and operation.

FB-1300 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 a minimum efficiency reporting value (MERV) rating of 9 to 15 per ASHRAE 52.2.

FB-1310 Limitations

This section does not cover the following:
(a) system design requirements for the use of filters
(b) mounting frames for medium efficiency filters

FB-1320 Responsibility

Nonmandatory Appendix FB-A contains division of responsibility guidelines.

(19) FB-1400 DEFINITIONS AND TERMS

Definitions with common application are contained in AA-1400 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: the 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: a device used to support and position folds in the filter media to provide air passage.

ARTICLE FB-2000
REFERENCED DOCUMENTS

The codes and standards listed below shall supplement those listed in Article AA-2000. Unless otherwise specified, the latest edition shall apply.

ASQ Z1.4-2003, Sampling Procedures and Tables for Inspection by Attributes
Publisher: American Society for Quality (ASQ), P.O. Box 3005, Milwaukee, WI 53201-3005 (www.asq.org)

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 Frames

The filter frames shall consist of corrosion-resistant material suitable for the environment as specified in accordance with Article FB-4000. Acceptable materials are listed in Table AA-3100-1.

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 D1056, 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 take appropriate precautions.

ARTICLE FB-4000 DESIGN

FB-4100 GENERAL DESIGN

Medium efficiency (MERV 9–15) filters shall be replaceable, extended media, dry-type, and shall comply with the standard for air filter units, UL 900.

FB-4200 DESIGN CRITERIA

A design criteria shall be prepared by the Owner or 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/h), per ASHRAE 52.2
(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/h)
(g) MERV per ASHRAE 52.2
(h) initial resistance, in. wg (Pa), at rated flow per ASHRAE 52.2
(i) rated final resistance, in. wg (Pa), at rated flow per ASHRAE 52.2
(j) dust holding capacity, lb (kg), per ASHRAE 52.2
(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 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 ASHRAE 52.2. 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, composite average efficiencies, MERV, average synthetic dust weight arrestance, and dust holding capacity. The various parameters at which the filters are rated are defined in ASHRAE 52.2.

FB-5220 Certification

Medium efficiency filters shall comply with the standard for air filter units, UL 900.

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 $\frac{1}{16}$ in. (1.6 mm). The case shall be square to within a total allowance of $\frac{1}{8}$ in. (3 mm) when measured diagonally across the corners of both faces.

FB-6220 Overall Dimensions

Filters the size of 24 in. × 24 in. × $5\frac{1}{8}$ in. (610 mm × 610 mm × 149 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. (+1.6 mm, −0 mm). All filters smaller than the above shall be +0 in., $-\frac{1}{16}$ in. (+0 mm, −1.6 mm) outside dimensions except depth, which shall be $+\frac{1}{16}$ in., −0 in. (+1.6 mm, −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 Article 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/h)
(e) rated initial pressure drop, in. wg (Pa)
(f) recommended maximum pressure drop, in. wg (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" indicating orientation for shipping and storage, and "FRAGILE" in letters no less than $^3\!/_4$ in. (19 mm) high

(d) purchase order number or other identifying markings requested by the purchaser

NONMANDATORY APPENDIX FB-A DIVISION OF RESPONSIBILITY

This 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-1000-1 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

ARTICLE FC-1000
INTRODUCTION

FC-1100 SCOPE

This section provides requirements for the performance, design, fabrication, inspection, acceptance testing, and quality assurance for high efficiency particulate air (HEPA) filters used in air and gas treatment systems in nuclear facilities.

FC-1200 PURPOSE

This purpose of this section is to ensure that HEPA filters are acceptable in all aspects of design and operation.

FC-1300 APPLICABILITY

FC-1310 HEPA Filters

This section applies to extended-medium 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-4110-1.

FC-1320 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-4110-1

(19) FC-1400 DEFINITIONS AND TERMS

available-to-flow medium area (ATFMA): the effective surface area of the filter medium within the assembled filter element, oriented in the direction through which the air or gas stream passes. This does not include area blocked by adhesives sealing the filter pack to the case, or area blocked by corrugated aluminum separators, glass ribbon separators, thread separators, or the contact area of embossed or corrugated medium separator. The ATFMA, as described herein, can be expressed using the following equation: ATFMA = (total medium area installed in filter) − (area block by adhesive sealing the filter pack) − (area block by separators)

filter: a device having a porous or fibrous medium for removing suspended particles from air or gas.

HEPA filter: a high efficiency particulate air filter. A throwaway, extended-medium 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.

medium: a porous material that separates the solid particles or liquid droplets from the air or the gas passing through it. The plural form is *media*.

medium face velocity: the linear velocity of a stream of air or gas at the face of the filtering medium, which can be calculated as the volumetric flow divided by the available-to-flow medium area.

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 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 particle 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 (19)

The codes and standards listed below shall supplement those listed in Article AA-2000. Unless otherwise specified, the latest edition shall apply.

APA PS1, Structural Plywood
Publisher: APA – The Engineered Wood Association, 7011 S. 19 th Street, Tacoma, WA 98466-5333 (www.apawood.org)

ASME B18.6.1, Wood Screws (Inch Series)
ASME B18.21.1, Lock Washers: Helical Spring-Lock, Tooth Lock, and Plain Washers (Inch Series)
ASME B18.21.2M, Lock Washers (Metric Series)
ASME B18.22M, Metric Plain Washers
Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990 (www.asme.org)

ASTM A492, Standard Specification for Stainless Steel Rope Wire
ASTM D3359-09, Standard Test Methods for Measuring Adhesion by Tape Test
ASTM E84-17, Standard Test Method for Surface Burning Characteristics of Building Materials
ASTM E2016-99 (Reapproved 2004), Standard Specification for Industrial Woven Wire Cloth
ASTM F1667Standard Specification for Driven Fasteners: Nails, Spikes, and Staples
Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 (www.astm.org)

FED-STD-141D-2001, Paint, Varnish, Lacquer and Related Materials: Methods of Inspection, Sampling and Testing
MIL-STD-282 (1956), Notice 4 (1995), Filter Units, Protective Clothing, Gas-Mask Components and Related Products: Performance Test Methods
Publisher: U.S. Government Publishing Office (GPO), 732 North Capitol Street, NW, Washington, DC 20401 (www.gpo.gov)

IEST-RP-CC007.3-2007, Testing ULPA Filters
Publisher: Institute of Environmental Sciences and Technology (IEST), 1827 Walden Office Square, Suite 400, Schaumburg, IL 60173 (www.iest.org)

SAE AS8660, Silicone Compound NATO Code Number S-736
Publisher: SAE International (SAE), 400 Commonwealth Drive, Warrendale, PA 15096 (www.sae.org)

UL 586, Standard for Safety for High-efficiency, Particulate, Air Filter Units
UL 723, Standard for Safety for Surface Burning Characteristics of Building Materials
Publisher:Underwriters Laboratories, Inc. (UL), 333 Pfingsten Road, Northbrook, IL 60062 (www.ul.com)

ARTICLE FC-3000 MATERIALS

FC-3100 ALLOWABLE MATERIALS

FC-3110 Case Materials (19)

The case shall be made from the following materials:

(a) stainless steel per ASTM A240 in sheet form, having a minimum 14 gauge USS thickness equal to 0.078 in. ± 0.006 in. (1.98 mm ± 0.15 mm).

(b) exterior plywood, minimum grade A–C (A, interior side; C, exterior side) according to APA PS 1. The thickness shall be within the range of 0.734 in. to 0.766 in. (18.65 mm to 19.45 mm) in accordance with 3/4 PERF CAT for sanded grades per APA PS 1, Table 10. The plywood shall be flame retardant treated and have a flame spread classification of 25 or less when tested as specified in ASTM E84 or UL 723.

FC-3111 Fasteners. Approved fasteners used for the assembly of HEPA filter cases are listed herein. (19)

(a) stainless steel bolts: 300 series per ASTM A320 or ASTM A193

(b) stainless steel nuts: 300 series per ASTM A194

(c) stainless steel lock washers: 300 series per ASME B18.21.1/B18.21.2M

(d) stainless steel plain washers: 300 series per ASME B18.22.1/B18.22M

(e) nails or staples: galvanized or zinc-coated carbon steel or stainless steel in accordance with ASTM F1667

(f) wood screws: galvanized or zinc-coated carbon steel or stainless steel in accordance with ASME B18.6.1

(g) stainless steel rivets: 300 series per ASTM A580 or ASTM A581. Consideration should be given when selecting the proper filter fasteners serving seismic and other unusual requirements.

FC-3120 Gasket Materials

FC-3121 Elastomers. The elastomer shall be of an oil-resistant, closed-cell expanded cellular type in accordance with Grade 2C3 or 2C4 of ASTM D1056, with the physical and tolerance requirements specified for ASTM D1056 cellular rubbers classified as Type 2, Class C, Grade 3 (2C3) or Grade 4 (2C4). (19)

FC-3122 Gelatinous Seals. The gelatinous seals shall be self-adhesive and self-healing cured gel seals made of polydimethylsiloxane. The material shall be self-extinguishing as demonstrated by the qualification test requirement in FC-5160. The gelatinous seal substance shall be corrosion resistant; shall not relax, crack, separate, or excessively stick or adhere to the knife edge; and shall be insoluble in water. Evaporation shall be less than 2% when tested in accordance with SAE AS8660 for 24 hr at 390°F (198°C). (19)

(19) ## FC-3130 Filter Media

The filter medium shall conform to the requirements of Section FN.

(19) ## FC-3140 Faceguards

Metallic faceguards shall be fabricated from 4 × 4 mesh, [nominal center-to-center distance between wires of ¼ in. (6.4 mm)], wire fabric (hardware cloth) made from wire having a minimum diameter of 0.025 in. (0.64 mm) and conforming to either galvanized steel ASTM A740, or stainless steel ASTM E2016-99.

FC-3150 Adhesives

Adhesives used to fasten gaskets or face guards to the filter case or to bond and seal the filter pack to the case shall be self-extinguishing.

(19) ## FC-3160 Separators

(a) Aluminum. Aluminum separators shall be made from corrugated aluminum, 0.0015 in. (0.038 mm) minimum thickness, conforming to ASTM B209 alloy 5052-H38, 3003-H18, or 1100-H18 aluminum. To protect the filter medium, the separators shall be provided with a hemmed edge.

(b) Acid Resistant Aluminum. Acid resistant aluminum separators shall be made from corrugated aluminum or aluminum alloy 1100-H18, 5052-H38, or 3003-H18 conforming to ASTM B209, 0.0015 in. (0.038 mm) minimum thickness, 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 medium, the separators shall be provided with a hemmed edge.

(c) Glass Ribbon. Glass ribbon separators shall be ribbons of glass fiber medium bonded to the filter medium.

(d) String. String separators shall be threads of self-extinguishing material bonded to the filter medium.

(19) ## FC-3170 Ancillary Accessories

Components attached to the filter case, such as extraction clips or handling/lifting bails, shall be fabricated from stainless steel per ASTM 240 or ASTM A492 for lifting bails made from wire rope.

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 (19)

Materials other than those referenced in this Code section that are 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.

ARTICLE FC-4000
DESIGN

FC-4100 GENERAL DESIGN

Four types of HEPA filters are addressed.

(a) Type A — folded filter medium with corrugated separator/supports

(b) Type B — mini pleat filter medium with glass ribbon or self-extinguishing thread separators

(c) Type C — continuous corrugated filter medium folded without separators

(d) Type D — filter constructed with glass or self-extinguishing thread separators

FC-4110 HEPA Filters (19)

(a) Filters shall be constructed as depicted in Figures FC-4110-1 through FC-4110-5. The size and ratings shall be as specified in Table FC-4110-1. 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 available-to-flow medium area provided within the filter pack shall be such that maximum medium face 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-4110-1 are acceptable provided that the minimum ratings of Table FC-4110-1 and requirements of FC-4200 are met.

FC-4111 Splices and Patches. No splices or patches are allowed.

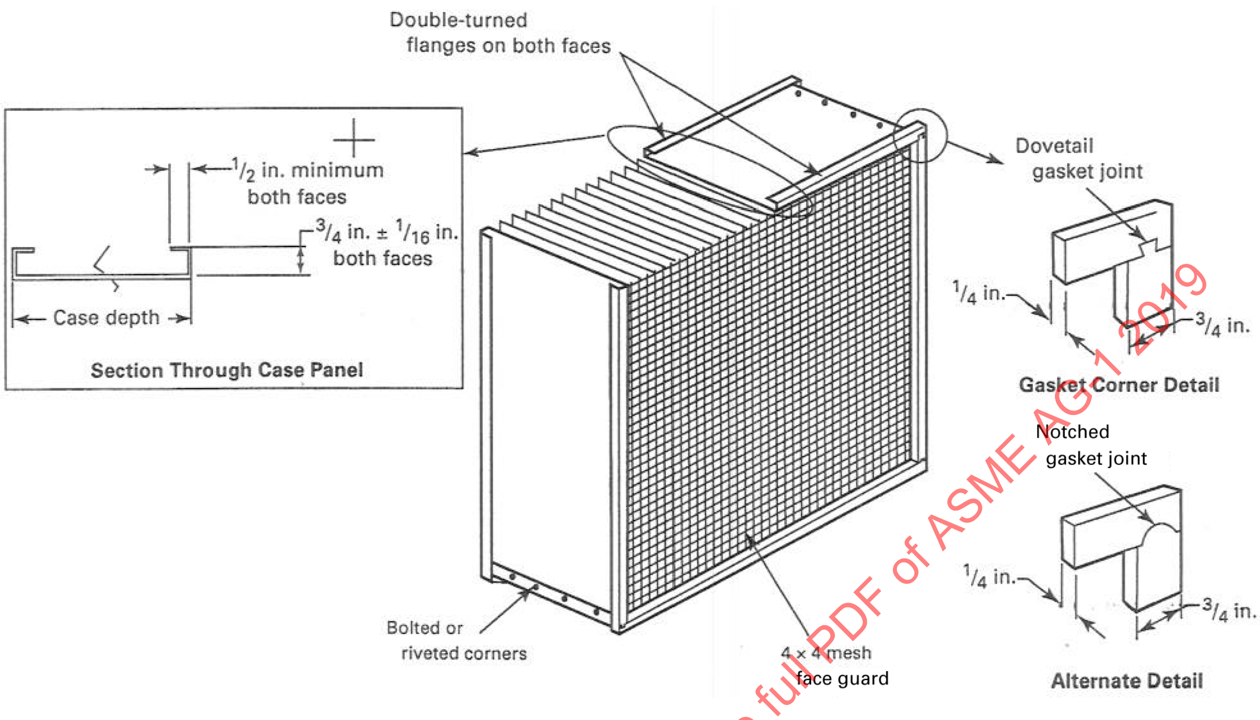
FC-4120 Filter Case

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.

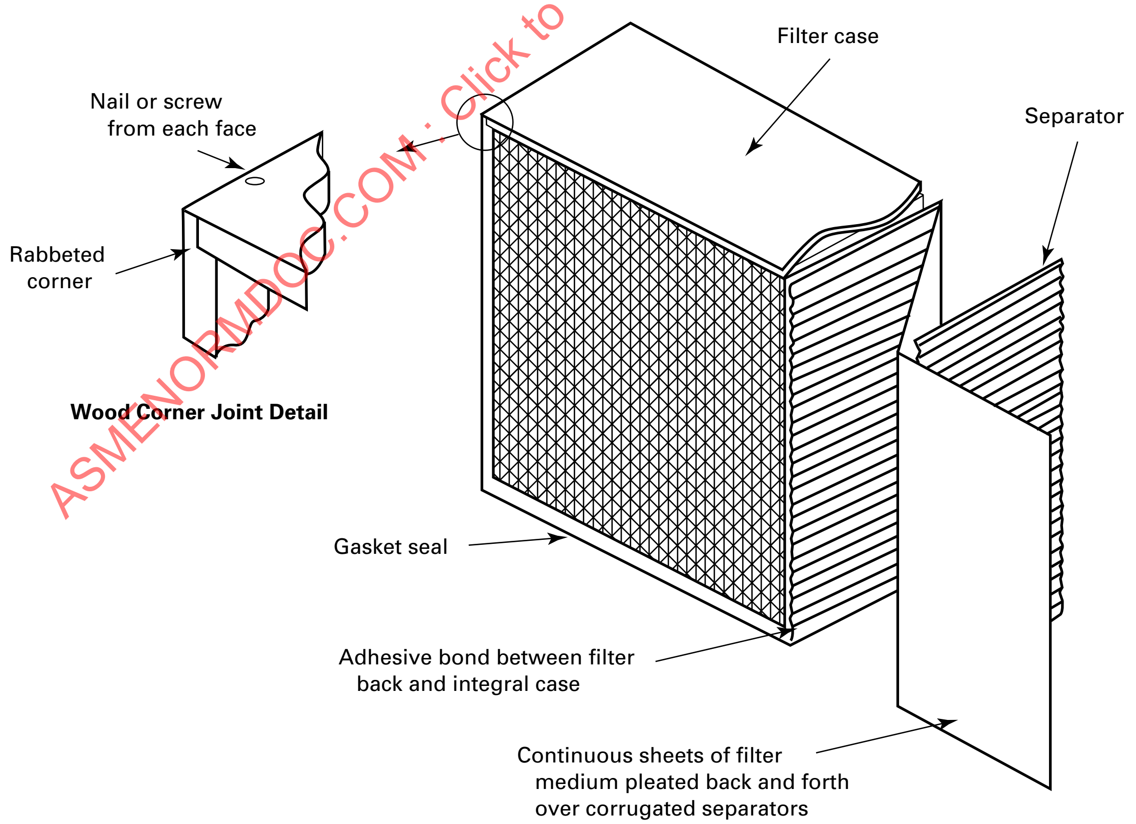
FC-4130 Filter Pack (19)

(a) Type A filter packs shall be made by folding the medium to the required depth. The folded filter medium shall be supported with corrugated separators.

(19) **Figure FC-4110-1 Type A, C, or D Metal-Cased, Gasket-Sealed Filter**



(19) **Figure FC-4110-2 Type A Wood Case Separator Filter**



(19) **Figure FC-4110-3 Type B Mini Pleat Filter**

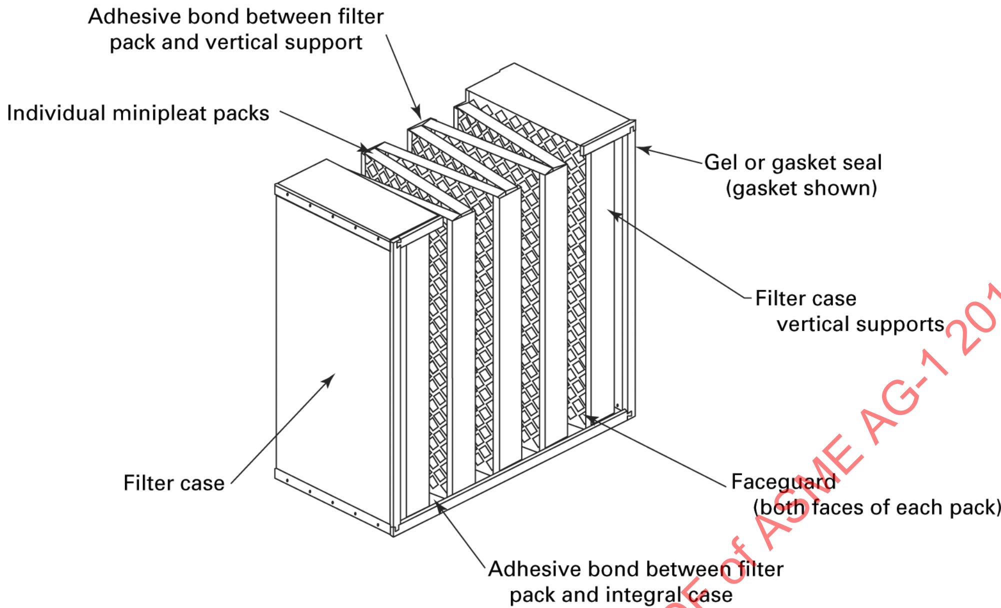
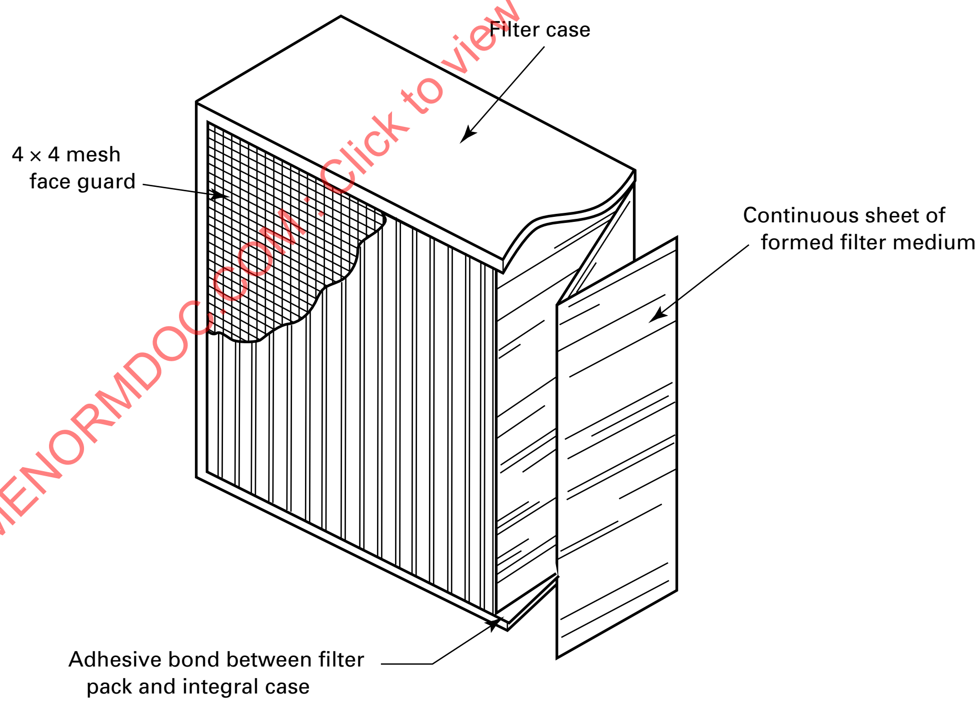


Figure FC-4110-4 Type C Separatorless Filter



The ends of the filter medium pleats shall be recessed by a minimum of $^1\!/_8$ in. (3 mm) within 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 medium pack is bonded to the case. The filter pack shall be rigid within the case, and the separators shall be perpendicular to two opposite

Figure FC-4110-5 Type D Thread Separator Filter

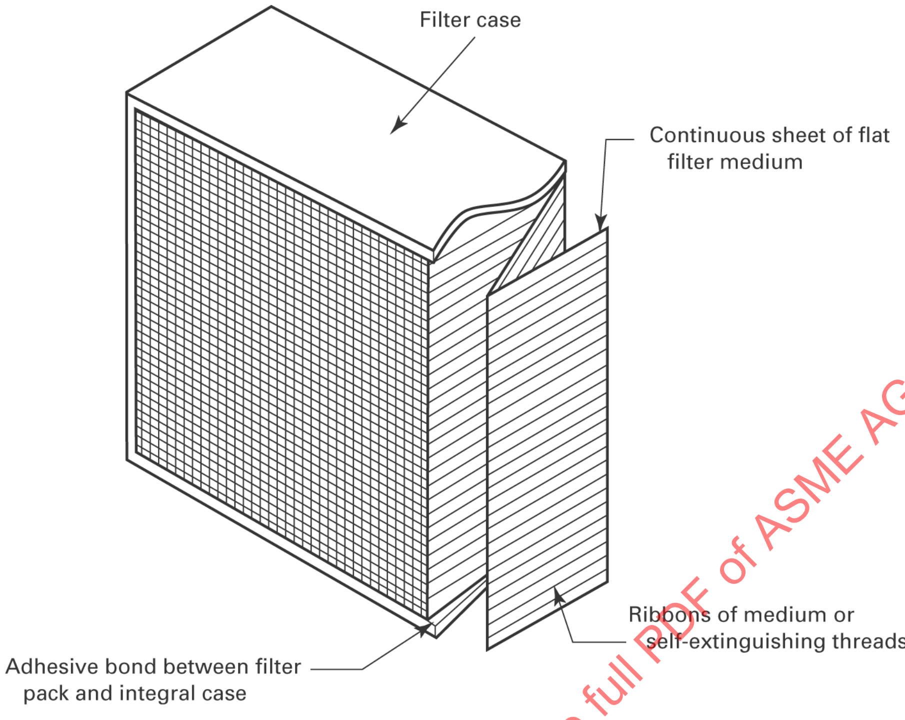


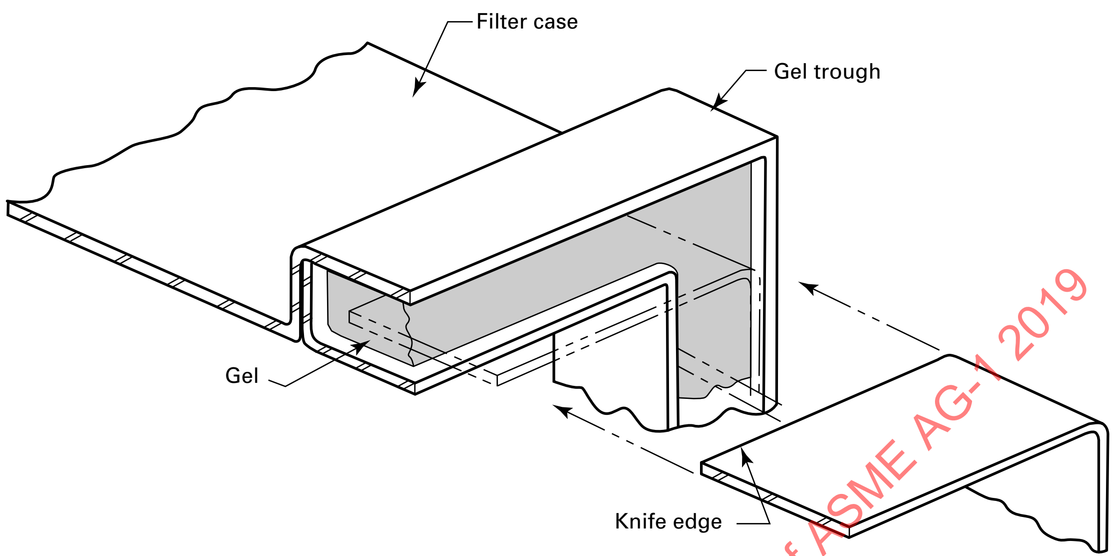
Table FC-4110-1 Nominal Sizes and Ratings

Number Designation	Size		Minimum Rated Airflow		Maximum Resistance	
	in.	mm	scfm	m^3/h	in. wg	Pa
1	8 × 8 × 3^1⁄$_{16}$	203 × 203 × 78	25	40	1.3	320
2	8 × 8 × 5⅞	203 × 203 × 150	50	80	1.3	320
3	12 × 12 × 5⅞	305 × 305 × 150	125	210	1.3	320
4	24 × 24 × 5⅞	610 × 610 × 150	500	850	1.0	250
5	24 × 24 × 11½	610 × 610 × 292	1,000	1 700	1.0	250
6	24 × 24 × 11½	610 × 610 × 292	1,250	2 100	1.3	320
7	24 × 24 × 11½	610 × 610 × 292	1,500	2 500	1.3	320
8	24 × 24 × 11½	610 × 610 × 292	2,000	3 400	1.3	320
9	12 × 12 × 11½	305 × 305 × 292	250	420	1.3	320

parallel sides of the case. Separators and filter medium shall not vary more than ¼ in. (6 mm) from a straight line connecting the fixed ends. Abrupt deviations, as defined by a maximum deviation of one-half the pleat to pleat distance along any 2-in. (50-mm) length of pleat fold, are not acceptable.

(b) Type B filter packs shall be made from a series of flat panels of pleated filter medium, which are assembled in a V form. Pleats shall be separated and supported by ribbons of glass fiber medium or self-extinguishing threads bonded to the filter medium. 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 ¼ in. (6 mm). No ribbons or medium supports shall vary from a straight line by more than ¼ in. (6 mm). Side panels shall be securely bonded to the side of the filter case with adhesive.

(19) **Figure FC-4142-1 Gel Seal Filter Corner — Isometric**



(c) Type C filter packs shall be made by corrugating or embossing a continuous sheet of filter medium and folding the medium 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 medium 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 the filter medium, as defined by a maximum deviation of one-half the pleat to pleat distance along any 2-in. (50-mm) length of pleat fold, are not acceptable. Filter medium or filter medium 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 filter medium.

(d) Type D filter packs shall be made by folding the medium to the required depth. The folded filter medium shall be separated and supported by ribbons of glass fiber medium or self-extinguishing threads glued to the filter medium. The filter pack shall be rigid within the case, and the pleats of filter medium shall be perpendicular to two opposite parallel sides of the case. Abrupt deviations in filter medium, as defined by a maximum deviation of one-half the pleat to pleat distance along any 2-in. (50-mm) length of pleat fold, are not acceptable. When the panels are installed in the filter case, the top and bottom of the 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 extend more than $^1/_{16}$ in. (1.5 mm) beyond the inside or outside edge of the case at any point. 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 Figure FC-4110-1. (19)

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, so as to create a leak-tight interface. At locations of maximum thickness, the gelatinous material shall not extend beyond the outer edge of the channel, and at locations of minimum thickness, shall not lie more than $^3/_{16}$ in. (5 mm) away from the outer edge of the channel. See Figure FC-4142-1. Extraction clips may be included, on the opposite side of the gelatinous seal, to interface with the housing system for separation of the filter gelatinous seal from the knife-edge. (19)

FC-4150 Separators

Separator material shall be capable of withstanding continuous service under all specified operating conditions without swelling, sagging, or melting.

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: (19)

(a) The coating shall meet or exceed a rating of 3A when tested using Method A of ASTM D3359.

(b) Off-gas volatiles, as determined by thermo-gravimetric analysis, shall not exceed 5% by weight when a 2 in. × 2 in. (50 mm × 50 mm) sample of the coated separator is subjected to temperatures from 68°F to 1,800°F (20°C to 980°C).

(c) The coated separator shall pass a flexibility test in accordance with FED-STD-141D, Method 6221.

FC-4160 Face Guards

A face guard shall be installed on each face of the filter in such a manner that it shall not directly contact the gasket or create a leak path. The face guard edges shall also be installed such that there are no wires or edges that create a medium puncture hazard or that project from the perimeter of the filter. Edges formed when slitting or shearing the face guards shall be smoothed on both surfaces of the material before installation, or otherwise covered.

(19) 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) Airflow. 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 the end user deems it necessary.

Designs shall be qualified in accordance with Article FC-5000.

FC-4210 Test Aerosol Particle Penetration

The total test aerosol particle penetration through the filter medium, frame, adhesive bond, and gasket shall not be greater than 0.03% of upstream concentration when tested at rated airflow and at 20% of rated airflow when tested in accordance with FC-5120. Filters with a rated airflow of less than 125 cfm shall be tested at the rated airflow only.

FC-4220 Resistance to Airflow

The resistance to airflow at the rated airflow of the clean filter shall meet the requirements of Table FC-4110-1, when tested in accordance with FC-5110.

FC-4300 SEISMIC QUALIFICATION (19)

The HEPA filters shall be seismically qualified by test in accordance with AA-4350, if specified by the end user.

ARTICLE FC-5000
INSPECTION AND TESTING

The inspection and testing of HEPA filters shall conform to the requirements in the following paragraphs.

FC-5100 QUALIFICATION TESTING (19)

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 shall consist 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. The following allowances are acceptable for filters of the same design, meaning that (i) the case design and depth are the same and (ii) the pack type, as identified in FC-4130, and depth are the same:

(a) Qualification of a filter design in Table FC-4110-1 qualifies all filters of the same design with a lower flow rate listed in Table FC-4110-1 except size designation 4. Size designation 4 filters shall be qualified separately.

(b) 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.

(c) Qualification of a filter design with one allowable stainless steel case material per FC-3110 qualifies the same design with all other allowed stainless steel case materials as long as the case material thickness remains the same.

(d) Qualification of a filter design with one allowable face guard material per FC-3140 qualifies the same designs with all other allowable face guard materials.

(e) Qualification of a filter design with or without ancillary accessories such as extraction clips or handling/lifting bails installed allows the qualification of the same design with or without the accessory. The test sequence is detailed in Table FC-5100-1.

Each filter in the qualification sample shall be visually examined for defects and all attributes as defined in FC-5200.

Table FC-5100-1 Test Groups and Sequence

Group	Quantity	Requirement	Test Paragraph
I	4	Resistance to rated airflow	FC-5110
		Test aerosol particle penetration at rated airflow and at 20% of rated airflow	FC-5120
		Resistance to pressure	FC-5140
		Test aerosol particle penetration at 20% of rated airflow only	FC-5120
II	4	Resistance to rated airflow	FC-5110
		Test aerosol particle penetration at rated airflow and at 20% of rated airflow	FC-5120
		Resistance to rough handling	FC-5130
		Test aerosol particle penetration	FC-5120
III	1	Resistance to spot flame	FC-5160
IV	3	Resistance to heated air	FC-5110
		Test aerosol particle penetration at rated airflow only	FC-5120

The qualification samples shall be tested for all the requirements of this section. Objective evidence of conformance to UL 586 will be accepted as testing for compliance to FC-5150 and 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-4110-1 when tested in accordance with FC-5120.

FC-5120 Test Aerosol Particle Penetration

The test aerosol particle penetration shall be determined in accordance with Table FC-5120-1. The test conditions shall be corrected to standard temperature and pressure. The total aerosol particle penetration through the filter medium, case, adhesive bond, 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 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 liquid materials for the Q-76 or the Q-107 penetrometer are dioctylphthalate (DOP), dioctylsebacate (DOS/DEHS), and 4 centistoke polyalphaolefin (PAO). If using a penetrometer with a particle counter, the aerosol material shall be as defined in IEST-RP-CC-007 section 4.2.9.

Table FC-5120-1 Acceptable Test

Filter Size	Test Mechanism
1–3	Q-76 Penetrometer, Laser
4–9	Q-107 Penetrometer, Laser

FC-5130 Resistance to Rough Handling (19)

Filters shall be tested on a rough-handling machine for 15 min at ¾ in. (19 mm) total amplitude at 200 cycles per min in accordance with Test Method 105.10 of MIL-STD-282. Type A, C, and D filters 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 bond, or loose or deformed filter medium separators or face guards.

After the rough-handling test, the same filter shall meet the requirements of FC-5120.

FC-5140 Resistance to Pressure (19)

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%.

(19) **Table FC-5140-1 Test Conditions and Requirements**

Test Conditions	Test Requirements
Temperature	95°F ± 5°F (35°C ± 3°C)
Relative humidity (RH) of air	95% RH ± 5% RH
Rate of airborne water droplets flowing toward the filter [Note (1)]	1 lb/min ± 0.25 lb/min (0.45 kg/min ± 0.11 kg/min) per 1,000 cfm (1 700 m^3/h) of nominal filter airflow capacity
Pressure differential across filter	10.0 in. of water ± 0.2 in. of water (2.4 kPa ± 0.05 kPa)
Time to reach pressure	0.5 min, maximum
Time duration at sustained differential pressure	1 hr, minimum
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 1 in. (25.4 mm) before the face of the filter.

After being conditioned, the filters shall withstand the airflow and water spray environment listed in Table FC-5140-1 without rupture of the filter medium.

Within 15 min after completion of the pressure test and while still wet, the filter shall meet the requirement of FC-5120 at 20% of rated 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 particle penetrations through the filter medium, case, adhesive bond, and gasket 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.

(19) 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, sealing materials, and gasket or gelatinous seal. 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 upstream or 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 after exposure to rough handling, resistance to pressure, or seismic qualification. Each filter shall satisfy the following:

(a) No structural damage, such as deformation, ruptures, or tears in the medium; deformation of separators; bent or cracked frames; and loose or deformed face guards, shall be evident by visual examination.

(b) Airflow resistance and aerosol particle penetration requirements of FC-5110 and FC-5120 shall be met.

FC-5200 INSPECTION (19)

Each HEPA filter shall be visually inspected to show conformance with the specifications of Article FC-6000. The inspection shall verify that test results are documented on the filter label in accordance with FC-9100 and meet the values of maximum flow and flow resistance of Table FC-4110-1 and the penetration values of FC-5120. Gasket and gelatinous seal adherence shall be inspected. The faces of the media pack shall be inspected for any signs of holes, splices, or patches.

FC-5300 PRODUCTION TESTING

Each filter manufactured for delivery shall be tested for resistance to airflow and test aerosol particle penetration in accordance with FC-5110 and FC-5120. Test results shall be marked on the label of each filter in accordance with FC-9100.

ARTICLE FC-6000 FABRICATION

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

(19) **FC-6211 Flatness and Squareness.** The faces of the case shall be flat and parallel within $\frac{1}{16}$ in. (1.5 mm). The case shall be square within $\frac{1}{8}$ in. (3 mm) when measured diagonally across the corners of both faces.

(19) **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 and extraction clips.

FC-6220 Medium Installation

The filter medium shall be fastened to the top, bottom, and sides of the filter case with adhesive to bond and completely seal the edges of the medium to the filter case. Repairs of holes or tears in the medium 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, or deformation or sagging of the medium, separators, and face guards. The filter shall also be free of any cracks in the adhesive bond and cracks or holes in the exposed portions of the filter medium. All required fasteners shall be securely installed.

ARTICLE FC-7000
(19) # PACKAGING, SHIPPING, AND STORAGE

Packaging, shipping, and storage shall be in accordance with Article AA-7000 and ASME NQA-1 Level B and Part II, Subpart 2.2. 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. HEPA filters with gelatinous seals shall be packaged in a manner to minimize the gelatinous compound from sticking to the packaging material or being gouged or pulled out of the continuous channel when the filter is removed from the shipping carton/plastic bag. 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 FC-8100 and FC-8200.

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

The certificate of conformance shall state that the filters conform to Section FC.

ARTICLE FC-9000
LABELS AND MARKINGS (19)

FC-9100 FILTER MARKING (19)

Marking or labeling of each filter shall be on the top of the filter when the pleats are vertical (except for Type B filter packs, where the pleats are horizontal), 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 resistance to airflow tests no less than $\frac{1}{8}$ in. (3.2 mm) high
(f) resistance to airflow in inches of water, at 100% rated flow
(g) overall penetration at rated flow
(h) overall penetration at 20% of rated flow
(i) date of production test
(j) available-to-flow medium area, ft^2 (m^2)
(k) 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 $\frac{3}{8}$ in. (10 mm) high
(c) filter model number
(d) purchase order number or other identifying marking requested by purchaser

MANDATORY APPENDIX FC-I

(19)

DELETED

NONMANDATORY APPENDIX FC-A DIVISION OF RESPONSIBILITY

This 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.

(19) **Table FC-A-1000-1 Division of Responsibility**

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	Labels and markings	Manufacturer

SECTION FD
TYPE II ADSORBER CELLS

ARTICLE FD-1000
INTRODUCTION

FD-1100 SCOPE

This section provides requirements for the performance, design, fabrication, inspection, acceptance testing, and quality assurance for modular gas phase adsorber cells used in air and gas treatment systems in nuclear facilities.

FD-1200 PURPOSE

The purpose of this section is to ensure that modular gas phase adsorber cells are acceptable in all aspects of design and operation.

FD-1300 APPLICABILITY

The Type II adsorber unit is a single cell composed of 2 in. (50 mm) 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-1400 DEFINITIONS AND TERMS

The following terms have special meaning in the context 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: an unperforated 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 unperforated members that comprises the volume into which the adsorbent is packed.

blank/blank area: an unperforated 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 ASHRAE 34.

refrigerant-12: dichlorodifluoromethane in accordance with ASHRAE 34.

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: a partial gas stream bypass of the adsorbent that occurs along an unbaffled metal to adsorbent interface.

ARTICLE FD-2000
REFERENCED DOCUMENTS

The codes and standards listed below shall supplement those listed in Article AA-2000. Unless otherwise specified, the latest edition shall apply.

ASHRAE 34-2007, Designation and Safety Classification of Refrigerants
Publisher: American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329 (www.ashrae.org)

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 A240. Perforation shall be round and arranged in standard IPA (International Perforators Association) Pattern No. 105; hole size diameter shall be 0.045 in. (1.14 mm) 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 A240. The material thickness shall be as stated in Article FD-4000. Handles, spacers, and baffles shall meet the requirements of ASTM A240 or ASTM A479 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 D1056.

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 A320, Grade B8; or ASTM A193, Grade B8. Nuts for use with this bolting material shall be in accordance with ASTM A194, 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 D1056 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 adsorbent beds a minimum of 2 in. (50 mm) thick in a modular unit as shown in Figure FD-4100-1. Alternatively, the cell may be of a "wraparound" type, wherein all beds are perpendicular to direction of airflow.

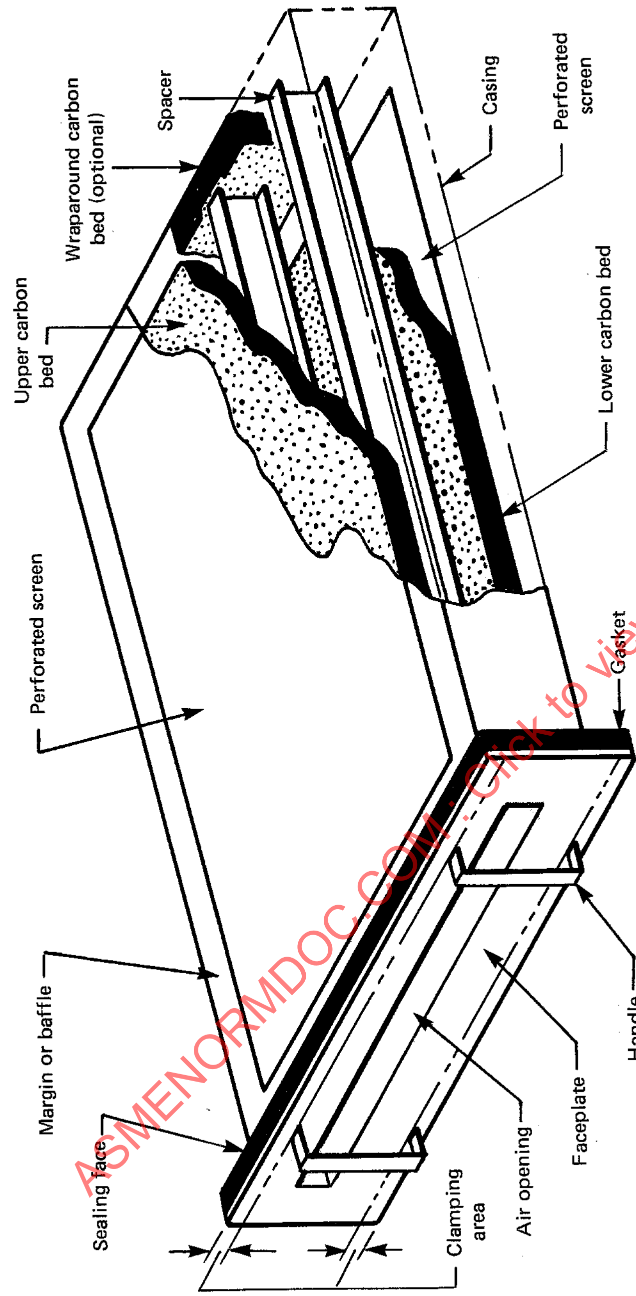
The beds shall be enclosed by a nonperforated case on three sides (except for alternate design) and a faceplate on the fourth side. The cell shall be installed horizontally in a cabinet-like mounting frame to which the faceplate is clamped and sealed. Handles are provided on the front of the cell to 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 FD-I. The filled cell shall have a maximum airflow resistance of 1.25 in. wg (0.31 kPa) when tested at rated flow.

Figure FD-4100-1 Type II Adsorber Cell



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 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 unperforated 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 Figure FD-4100-1 to interface with standard mounting frame design.

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 (19)

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 normal operating pressure differential (NOPD) 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 [operating basis earthquake (OBE) and safe shutdown earthquake (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-4212-1 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-4321-1. 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 ± 0.8 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 and 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 (565.8 m^3/h ± 28.9 m^3/h). 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-5332-1 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-5332-1 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-5332-1 Detector Sensitivity for Leak Test

Refrigerant	Minimum Sensitivity, vppm
R-11	0.0005
R-12	0.05

Table FD-6100-1 Cell Dimensions and Tolerances

	Width		Height		Depth	
Cell Part	in.	mm	in.	mm	in.	mm
Faceplate	$25\frac{3}{4} \pm \frac{1}{16}$	654 ± 1.6	$7\frac{3}{4} \pm \frac{1}{16}$	197 ± 1.6	. . .	. . .
Body (less gasket)	$24 + 0, - \frac{1}{8}$	610 + 0, − 3.2	$6\frac{1}{4} + 0, - \frac{1}{8}$	160 + 0, −3.2	30 max.	762 max.

GENERAL NOTES:
(a) Bed thickness: 2 in. (50 mm) minimum between inside surfaces of screens of each bed.
(b) Bed screen displacement: $\pm\frac{1}{8}$ in. (±3.2 mm) from manufacturing tolerance after cell is filled with adsorbent.

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-6100-1.

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 used 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 (19)

Metal surfaces shall be cleaned and degreased in accordance with ASTM A680 before any welding, installation of gaskets or seal pads, or 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 (19)

(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) Filters should be stored in

(1) correct orientation (check marking arrows on cartons)

(2) factory-packed cartons and not removed until just prior to installation

(3) in a manner 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 that 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

FD-9100 PERMANENT NAMEPLATE

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:

(a) Type II cell

(b) manufacturer's name or symbol

(c) serial number

(d) month/year (of manufacture)

(e) empty weight

FD-9200 FILLING LABEL

Each cell shall bear a replaceable label with the following information:

(a) adsorbent manufacturer's name or symbol

(b) adsorbent type and grade designation, lot, and batch

(c) filled weight

(d) adsorbent weight

(e) airflow resistance at specified airflow rating

(f) refrigerant leak test results

(g) 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:

(U.S. Customary Units)

$$T = \frac{t(A - B)}{28.8Q}$$

(SI Units)

$$T = 3.6 \times 10^{-3} \frac{t(A - B)}{Q}$$

where

3.6 = product of 3,600 s/h and 10^{-3} m/mm
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 or outlet side, whichever is smaller, in.^{2} (cm^2)
B = total area of baffles, blanks, margins of all screens, in.^{2} (cm^2)
Q = total cell volumetric airflow, cfm (m^3/h)
T = resident time, sec
t = thickness of bed, in. (cm)

MANDATORY APPENDIX FD-II SAMPLE CANISTERS

ARTICLE FD-II-1000 INTRODUCTION

(19)

FD-II-1100 SCOPE

This Appendix establishes requirements for design, manufacture, performance, testing, and filling of adsorbent sample canisters.

FD-II-1200 APPLICABILITY

Sample canisters are auxiliary devices containing a representative sample of the same adsorbent as contained in the installed adsorber bank. The function of sample canisters is to allow for exposure of a representative sample of the in-service adsorbent to the same operating conditions and duration as the adsorbent in the installed Type II cells. The sample canisters can be removed and emptied. The use of test tray assemblies is permitted as an alternative to sample canisters.

(19) FD-II-1300 DEFINITIONS AND TERMS

sample canister: a device for containing a representative sample of the same adsorbent as is installed in the Type II adsorber cells.

test tray assembly: an adsorber cell modified to allow for removal of a representative portion of the adsorbent without disturbing the remainder of the adsorbent.

ARTICLE FD-II-2000 GENERAL DESIGN

(19)

Sample canisters shall be designed to contain an adsorbent bed between two pieces of perforated metal sheet (IPA-105). They are typically cylindrical, with axial airflow being parallel to the cylinder wall. When sample canisters are intended to be used, they must withstand refilling, reinstallation, removal, and emptying cycles without reduction of their ability to meet the requirements of this Appendix. (See Figure FD-II-2000-1 for examples of sample canister configurations.)

The sample canisters shall be installed on connections that are in parallel with the adsorber bed. Unused connections shall be sealed with the appropriate plug, cap, or blank plate.

Canisters should be mounted to preclude bypass due to adsorbent settling. Vertical mounting and down-flow through the bed is the preferred orientation for Type II cells.

After a test canister is removed for analysis, the connection shall be sealed with the appropriate plug, cap, or blank plate if it is not used again. An in-service leak test of the filter bank is not required.

FD-II-2100 TECHNICAL REQUIREMENTS

FD-II-2110 Design Requirements

The sampling canister, when filled with adsorbent, shall have an average air velocity within ±10% of the adsorber bank. The bed diameter shall be a minimum of 2.25 in. (57.2 mm). Sampling canister bed depth shall be the same as the bed depth of the adsorber bank (see Figure FD-II-2110-1). When the sampling canister is filled with adsorbent, the pressure drop at the same velocity as the filled adsorber bank trays shall be within ±10% of bank value.

FD-II-2120 Sample Canister Casing

The casing shall be solid metal and be configured parallel to airflow. There shall be baffles at the screen-case interface to prevent bypass of the filled sample bed.

FD-II-2130 Assembly

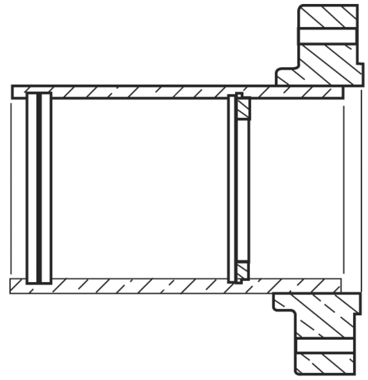
The sampling canister shall have provisions for emptying and refilling that do not degrade the structural integrity of the filled canister or interfere with removal from the air cleaning system.

A cap, plug, or blank shall be provided to seal the test canister connection when the test canister is removed from the air filter unit.

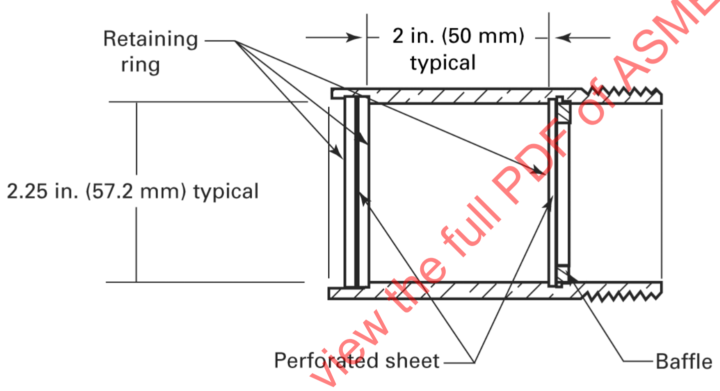
ARTICLE FD-II-3000 FILLING METHOD QUALIFICATION

Objective evidence shall be provided that the sampling canister contains a weight per volume of adsorbent within ±5% of the ASTM D2854 laboratory test value for the adsorbent loaded in the main bed. Filling method shall not crush, break, grind, or otherwise damage the adsorbent.

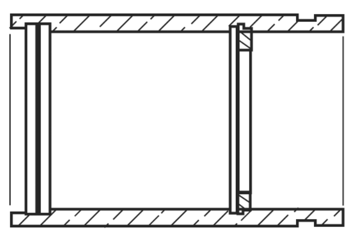
Figure FD-II-2000-1 Examples of Sample Canister Configurations



(a) Example 1: Flanged Connection

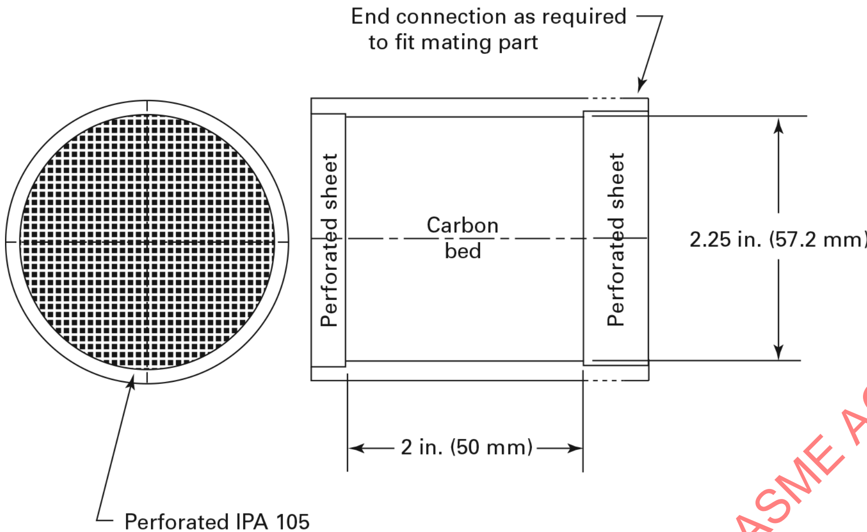


(b) Example 2: Pipe Thread Connection



(c) Example 3: O-Ring Fit Connection

Figure FD-II-2110-1 Detail of a Typical 2-in. Sample Canister



GENERAL NOTE: Material of construction is 300 series stainless steel.

The test canister qualification shall include an airflow versus pressure drop test.

ARTICLE FD-II-4000 NAMEPLATES

Each canister shall be legibly and permanently marked with a nameplate or by stamping. Such marking shall be done in a manner that will not damage the structural integrity of the canister.

The nameplate shall include the following information:

ADSORBENT SAMPLING CANISTER
(Manufacturer's name or symbol)
CANISTER SERIAL NUMBER: ____________
DESIGN BED DEPTH: _____ in. (_____ mm)
ADSORBENT BED VOLUME: _____ in.^{3} (_____ mm^3)

ARTICLE FD-II-5000 FILLING LABEL

At time of filling, each canister shall be provided with a label recording the following information:

(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) resistance at specified airflow rating after filling
(e) refrigerant penetration test results
(f) date of filling
(g) name of the person who filled the canister
(h) differential pressure at specified airflow

NONMANDATORY APPENDIX FD-A
DIVISION OF RESPONSIBILITY

This 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.

(19) **Table FD-A-1000-1 Division of Responsibility**

FD-	Item	Responsible Party
3000	Materials	Manufacturer/Owner
4000	Design	Manufacturer/Owner
5100	Dimensional inspection	Manufacturer
5200	Welding inspection	Manufacturer
5210	Spot welds	Manufacturer
5220	Other welds	Manufacturer
6000	Fabrication	Manufacturer
7100	Packaging	Manufacturer/Owner
7200	Loading for shipment	Manufacturer/Owner
7300	Storage	Manufacturer/Owner
7400	Containers	Manufacturer/Owner
8000	Quality assurance	Manufacturer
8100	Documentation	Manufacturer
9000	Nameplates and certification	Manufacturer

SECTION FE
TYPE III ADSORBERS

ARTICLE FE-1000
INTRODUCTION

FE-1100 SCOPE

This section provides requirements for the performance, design, fabrication, installation, inspection, acceptance testing, and quality assurance for gas phase adsorber units used in air and gas treatment systems in nuclear facilities.

FE-1200 PURPOSE

The purpose of this section is to ensure that modular gas phase adsorber units are acceptable in all aspects of design and operation.

FE-1300 APPLICABILITY

FE-1310 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-1320 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 carbon for all specification requirements are allowable.

FE-1330 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-1340 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-1400 DEFINITIONS AND TERMS (19)

Definitions that have common application are contained in AA-1400. 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: an unperforated 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 unperforated members that comprises the volume into which the adsorbent is packed.

blank/blank area: an unperforated 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 ASHRAE 34.

refrigerant-12: dichlorodifluoromethane in accordance with ASHRAE 34.

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 Mandatory Appendix FE-I).

wall effect: the partial gas stream bypass of the adsorbent that occurs along an unbaffled metal to adsorbent interface.

ARTICLE FE-2000 REFERENCED DOCUMENTS

The codes and standards listed below shall supplement those listed in Article AA-2000. Unless otherwise specified, the latest edition shall apply.

ASHRAE 34-2007, Designation and Safety Classification of Refrigerants
Publisher: American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329 (www.ashrae.org)

ASTM D2000-08, Standard Classification System for Rubber Products in Automotive Applications
ASTM D2854-09, Standard Test Method for Apparent Density of Activated Carbon
ASTM D2862-97 (R2009), Standard 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 (www.astm.org)

Designers, Specifiers, and Buyers Handbook for Perforated Metals
Publisher: Industrial Perforators Association (IPA), 6737 W. Washington Street, Suite 4210, Milwaukee, WI 53214 (www.iperf.org)

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 ASTM A240 or ASTM A276.

FE-3130 Gaskets and Seal Pads

The material for gaskets and seal pads shall be closed-cell, ozone-resistant, neoprene or silicone rubber sponge Grade SCE-43E1 (or SCE-44E1) in accordance with ASTM D1056.

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 A240

(b) stainless steel bar and structurals: ASTM A276 or ASTM A479

(c) stainless steel tubing: ASTM A511, ASTM A554, ASTM A213, or ASTM A269

(d) stainless steel pipe: ASTM A312 or ASTM A376

(e) stainless steel fitting: ASTM A182, ASTM A351, or ASTM A403

(f) stainless steel bolting: ASTM A193, ASTM A194, or ASTM A320

(g) adhesives: ASTM D903

ARTICLE FE-4000 DESIGN

FE-4100 GENERAL

FE-4110 Type III Adsorbers (19)

Type III adsorbers consist 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 welded into an assembly. Air enters the upstream face of the bed, passes through the packed adsorbent, and exits from the downstream face. Figure FE-4110-1 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

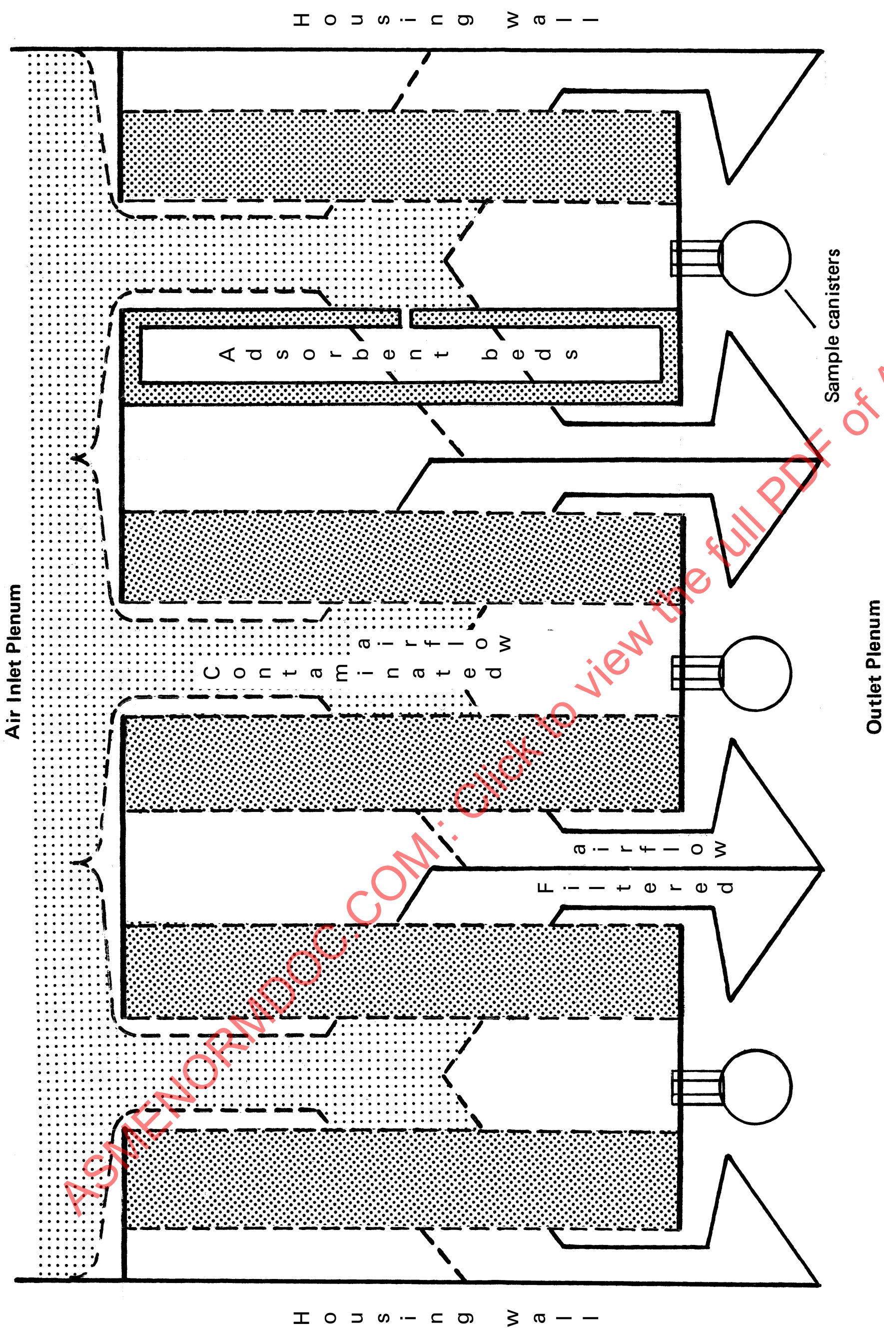
(e) temperature (operating range)

(f) relative humidity (operating range)

(g) contaminants to be removed

(h) adsorbent type

Figure FE-4110-1 Horizontal Section of Type III Adsorber Bed



(i) required adsorber performance efficiency
(j) face velocity and bed thickness of the adsorbent or
(k) face velocity and residence time (see Mandatory 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 FE-4210(j) or FE-4210(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, unperforated frame by welding. The frame, or an unperforated margin on the sheet, shall be of such width as to prevent bypass. Each bed shall have 1 in. (25.4 mm) minimum margins 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.

(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 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-4212-1) 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-4321-1. 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 Mandatory 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 change out. 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 Sampling of Installed Adsorbents

FE-4611 General. Provision shall be made to periodically remove a representative sample of adsorbent from an installed system for testing.

A representative sample is a sample of the same lot and batch as installed in the Type III adsorber bed that has been exposed in parallel to the same process stream as the Type III adsorber bed, with a bed depth equal to the design bed depth of the main adsorber bed, and at a face velocity within ±10% of the design face velocity of the system main adsorber bed. The detailed means to achieve this is left to the designer of each system, but detailed supporting data (either theoretical or empirical) shall be presented to substantiate that the flow is representative and the sample is, therefore, representative of the entire adsorber bank.

FE-4612 Design Considerations for Samplers. The design criterion can be met only when the sampler bed depth is equal to the system design bed depth and the calculated residence time is within ±10% of the system design residence time at the system design bed depth. All flow restrictions shall be taken into account when designing a sampler to ensure that the pressure drop across the sampler is consistent with a volumetric flow rate through the sampler that produces a face velocity and residence time within ±10% of the main bed design. Pipe stubs, valves, unions, fittings, elbows, nozzle effects, and similar items or effects add pressure drop to the flow path and tend to make a sampler nonrepresentative. This paragraph does not restrict any specific approach or hardware but requires that the flow criterion for equal bed thickness must be met.

FE-4613 General Types of Samplers.

FE-4613.1 Test Canisters. An adsorbent test canister shall be designed to hold adsorbent for testing. The canister shall be the same depth as the main bed, a minimum of 2.25 in. (57.2 mm) in diameter. If there is a guard bed, it shall be duplicated for the sampler.

The sampler shall be filled with adsorbent from the same lot and batch as the main bed.

The details of test canister designs are provided in Mandatory Appendix FE-V and shall include provisions to ensure that no bypass will occur, that the sampler (s) will be halide leak tested concurrently with main bank leak testing, and that the flow path will be sealed leak tight after the sampler is removed.

FE-4613.2 Solids Tube Samplers. For Type III adsorbers, a sample may be taken with a solids-tube-type sampler if sufficient test canisters are not available. ASTM E300 contains details on the design and use of solids tube samplers.

(a) For systems where the adsorbent bed thickness is 2 in. (50 mm) deep, insert the sampler into the bed far enough to ensure that the sample will be taken from an area where flow is experienced by the adsorbent.

(b) For systems where the adsorbent bed thickness is greater than 2 in. (50 mm), the following shall be considered when determining the position at which to insert the sampler:

(1) When a single sample representative of the entire bed is desired, the sampler should be inserted at an angle to pick up carbon from both the inlet and outlet faces of the bed. No carbon shall be taken from areas of less than full flow.

(2) Where separate samples from inlet and outlet faces are desired, sample positions shall be noted and the separate samples shall not be mixed. When separate

samples are taken, it may be required to calculate a composite efficiency for the bed.

FE-4613.3 Quantity of Test Canisters. 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.

(19) **FE-4621 Fire Detection.** The requirements for fire detection are located in SA-4455 and HA-4444.

FE-4622 Fire Control Systems

FE-4622.1 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-4622.2 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-4622.3 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-4622.4 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 Type 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 gpm/ft^2 (2.2 L/s/m^2) of horizontal adsorber bed area. 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 Nonmandatory 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 Mandatory 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 Mandatory 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 Mandatory 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 Mandatory 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. (12.7 mm) 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 (QA) 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) certificate of conformance 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 (19)

Each Type III adsorber shall be legibly and permanently marked either with 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 (_____ m^3/s)
DESIGN BED DEPTH: _____ in. (_____ mm)
ADSORBENT BED VOLUME: _____ ft^3 (_____ m^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) name of person who filled the adsorber

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:

$$T = \frac{t(A - B)}{KQ} \tag{1}$$

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 from ft^3-sec to in.^{3}-min = 28.8

Q = total cell volumetric airflow, cfm

T = resident time, sec

t = thickness of bed, in.

NOTE: Equation (1) may be evaluated using any other system of consistent units.

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 (19)

If the bed depth varies by more than the bed depth deviation allowed by design, 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 FILLING METHOD

The filling method shall be qualified by the procedures in Article FE-III-4000. 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 Mandatory 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 D2854 and ASTM D2862. 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 D2862. 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:

$$\mathrm{CP} = \frac{W - L}{V_B} \tag{1}$$

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

NOTE: Equation (1) may be evaluated using any other system of consistent units.

FE-III-4300 ADSORBENT LOSSES (19)

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, any fines visible after filling shall be collected by vacuum cleaning the beds and other areas where the fines have collected 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 D2854.

(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 Appendix 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 with a stimulant until breakthrough occurs.

(19)

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 and has 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, as illustrated by the following discussion.

Curve 1 of Figure FE-IV-3000-1 illustrates the adsorbate 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 would be as illustrated in Curve 2.

This analysis of a carbon bed is based on the following principles:

(a) 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) the adsorbate/airflow through the bed can be interrupted and the bed media sampled without disturbing the distribution

(c) this sample taken from the bed can be sliced into thin layers, starting at the inlet face and ending at the outlet face

(d) 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) 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.

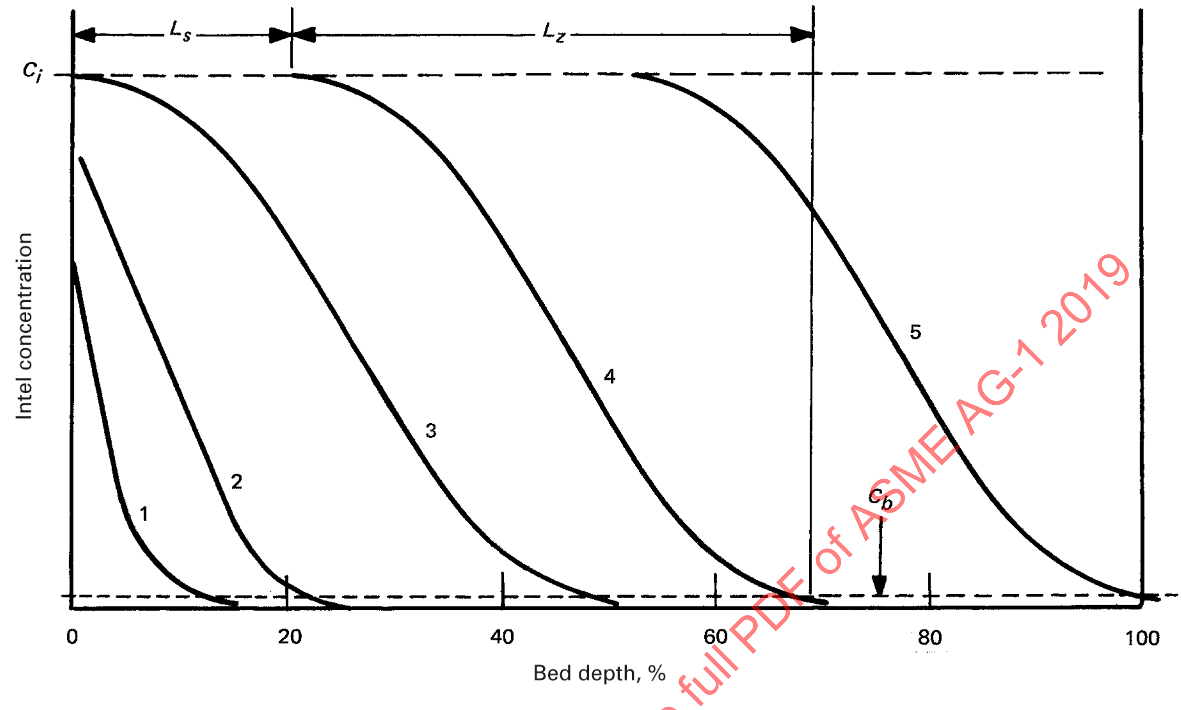
The mass transfer zone can be calculated using eq. (1) and some experimental data for each bed design of interest.

$$tb = \frac{W_s dA}{FC_i} \times [Lt(1 - f)L_Z] \tag{1}$$

where

A = effective bed face area, ft^2
C_i = inlet contaminant concentration, lb/lb of air
d = adsorbent bulk density, lb/ft^3
F = mass flow rate, lb air/unit time

(19) **Figure FE-IV-3000-1 Adsorbate Distribution Curves**



f = constant — depending on the allowable (desired) breakthrough concentration C_b for the selected simulant, 0.5 in the example using H_2O
L_t = total bed depth, in.
L_Z = length of MTZ, L_Z in Figure FE-IV-3000-1
tb = breakthrough time, time unit (sec, min, or hr)
W_s = adsorption capacity of adsorbent for contaminant, lb/lb of adsorbent

NOTE: Equation (1) may be evaluated using any other system of consistent units.

This qualification method of challenging a bed with a selected contaminant until bed breakthrough first occurs (as illustrated by Curve 5 on Figure FE-IV-3000-1) 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 are 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 (Mandatory 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% relative humidity (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 L_Z 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-4100-1 shows the general test arrangement.

FE-IV-4200 TEST PROCEDURE

(a) Predetermine the moisture content of the adsorbent using ASTM D2867.

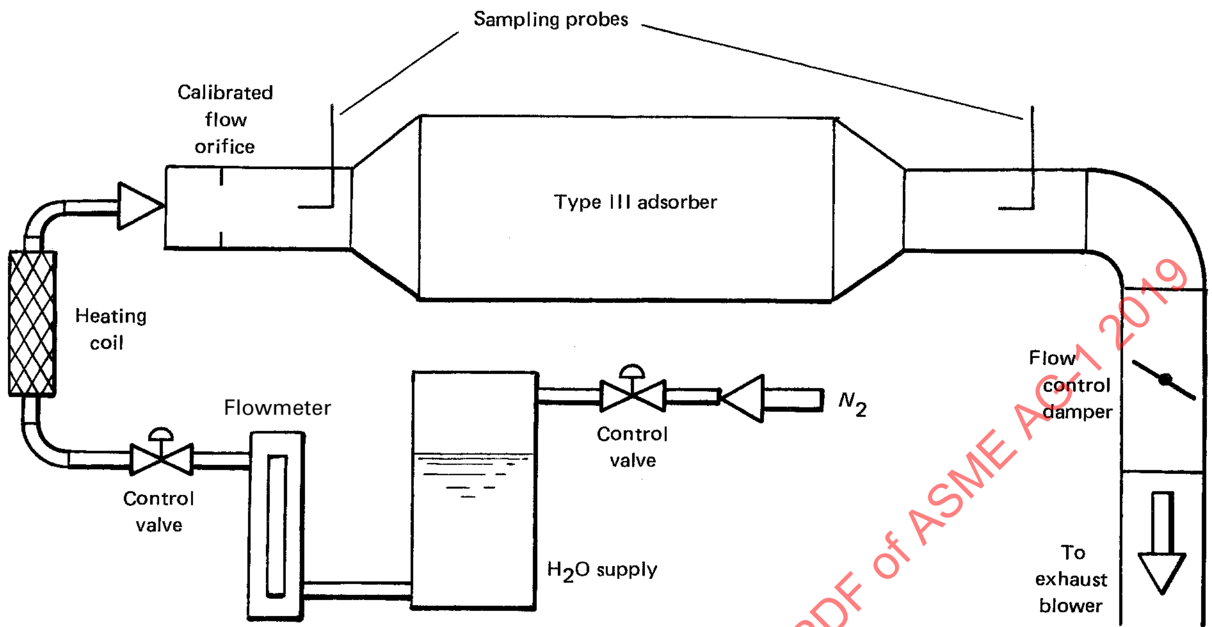
(b) Fill the adsorber bed in accordance with the filling procedure.

(c) Assemble the test hardware in accordance with Figure FE-IV-4100-1.

(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 airstream at a rate to result in 70% ± 5% RH in the flowing air.

(19) **Figure FE-IV-4100-1 Test Adsorber Setup**



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.

(19) ## 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 not to disturb the adsorbent during sampling and to insure 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 D2867.

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.

MANDATORY APPENDIX FE-V SAMPLE CANISTERS

(19)

ARTICLE FE-V-1000 INTRODUCTION

FE-V-1100 SCOPE

This Appendix establishes requirements for design, manufacture, performance, testing, and filling of adsorbent sample canisters.

FE-V-1200 APPLICABILITY

Sample canisters are auxiliary devices containing a representative sample of the same adsorbent as contained in the installed Type III adsorber bank. The function of sample canisters is to allow for exposure of a representative sample of the in-service adsorbent to the same operating conditions and duration as the adsorbent in the installed Type III adsorber bank. The sample canisters can be removed and emptied.

FE-V-1300 DEFINITIONS AND TERMS

sample canister: a device for containing a representative sample of the same adsorbent as is installed in the Type III adsorber bank.

(19)

ARTICLE FE-V-2000 GENERAL DESIGN

Sample canisters shall be designed to contain an adsorbent bed between two pieces of perforated metal sheet (IPA-105). They are typically cylindrical, with axial airflow being parallel to the cylinder wall. When sample canisters are intended to be used, they must withstand refilling, reinstallation, removal, and emptying cycles without reduction of their ability to meet the requirements of this Mandatory Appendix. (See Figure FD-II-2000-1 for examples of sample canister configurations.)

The sample canisters shall be installed on connections that are in parallel with the adsorber bed. They may be installed on either the upstream side or the downstream side. Unused connections shall be sealed with the appropriate plug, cap, or blank plate.

Canisters shall be mounted to preclude bypass due to adsorbent settling. Vertical or angled mounting and downflow through the bed is the preferred orientation for Type III adsorber banks.

After a test canister is removed for analysis, the connection shall be sealed with the appropriate plug, cap, or blank plate if it is not used again. An in-service leak test of the filter bank is not required.

FE-V-2100 TECHNICAL REQUIREMENTS

FE-V-2110 Design Requirements

The sampling canister, when filled with adsorbent, shall have an average air velocity within ±10% of the adsorber bank. The bed diameter shall be a minimum of 2.25 in. (57.2 mm). Sampling canister bed depth shall be the same as the bed depth of the adsorber bank (see Figure FD-II-2110-1). When the sample canister is filled with adsorbent, the pressure drop at the same velocity as the filled adsorber bank shall be within ±10% of bank value.

FE-V-2120 Sample Canister Casing

The casing shall be solid metal and be configured parallel to airflow. There shall be baffles at the screen-case interface to prevent bypass of the filled sample bed.

FE-V-2130 Assembly

The sampling canister shall have provisions for emptying and refilling that do not degrade the structural integrity of the filled canister or interfere with removal from the air cleaning system.

A cap, plug, or blank shall be provided to seal the test canister connection when the test canister is removed from the air filter unit.

ARTICLE FE-V-3000 FILLING METHOD QUALIFICATION

Objective evidence shall be provided that the sampling canister contains a weight per volume of adsorbent within ±5% of the ASTM D2854 laboratory test value for the adsorbent loaded in the main bed. Filling method shall not crush, break, grind, or otherwise damage the adsorbent.

The test canister qualification shall include an airflow versus pressure drop test.

ARTICLE FE-V-4000 NAMEPLATES

Each canister shall be legibly and permanently marked with a nameplate or by stamping. Such marking shall be done in a manner that will not damage the structural integrity of the canister.

The nameplate shall include the following information:

ADSORBENT SAMPLING CANISTER
(Manufacturer's name or symbol)
CANISTER SERIAL NUMBER:_____________
DESIGN BED DEPTH: ____ in. (____ mm)
ADSORBENT BED VOLUME: ____ in.^{3} (____ mm^3)

ARTICLE FE-V-5000 FILLING LABEL

At time of filling, each canister shall be provided with a label recording the following information:

(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) resistance at specified airflow rating after filling

(e) refrigerant penetration test results

(f) date of filling

(g) name of person who filled the canister

(h) differential pressure at specified airflow

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 recommendations in FE-A-1100 through FE-A-1500 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 continuous.
(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 (19)

(a) Adsorber service systems do not allow bypass of the adsorber sections.
(b) Adsorber service systems have adequate isolation/shutoff valves to meet the leakage requirements.

FE-A-1400 INSPECTION OPENINGS (19)

(a) Covers are adequately gasketed to meet leakage specifications.
(b) Closure/clamping systems provide required clamping forces.
(c) Inspection openings provide visual access to all adsorber sections.

FE-A-1500 LABELING

(a) Labeling meets the requirements of Article FE-9000 and other system requirements.
(b) Labeling is visible after the adsorber section is installed in its intended housing.

NONMANDATORY APPENDIX FE-B
DIVISION OF RESPONSIBILITY

This 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-1000-1 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
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 requirements for the performance, design, manufacturing, inspection, acceptance testing, and quality assurance for adsorbent media used in air and gas treatment systems in nuclear facilities.

FF-1200 PURPOSE

The purpose of this section is to ensure that adsorbent media are acceptable in all aspects of design and operation.

FF-1300 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-1400 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 listed in Article AA-2000. Unless otherwise specified, the latest edition shall apply.

ASTM D2652-05, Standard Terminology Relating to Activated Carbon

ASTM D2854-09, Standard Test Method for Apparent Density of Activated Carbon

ASTM D2862-97(2009), Standard Test Method for Particle Size Distribution of Granular Activated Carbon
ASTM D3466-06, Standard Test Method for Ignition Temperature of Granular Activated Carbon
ASTM D3467-04(2009), Standard Test Method for Carbon Tetrachloride Activity of Activated Carbon
ASTM D3802-79(2005), Standard Test Method for Ball-Pan Hardness of Activated Carbon
ASTM D3803-91(2009), Standard Test Method for Nuclear-Grade Activated Carbon
ASTM D4069-95(2008), Standard Specification for Impregnated Activated Carbon Used to Remove Gaseous Radio-Iodines 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 (www.astm.org)

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. Furthermore, system design criteria and parameters in other sections of this Code 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 that are outside the limits under which the adsorbent was qualified can cause desorption or result in adsorption efficiency that 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 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 in FF-5100 through FF-5300.

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 D3467 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 D2854 to a minimum level of 0.38 g/mL.

(b) a test of particle size distribution in accordance with ASTM D2862 to satisfy the following ASTM E11 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 D3466 and shall be a minimum level of 626°F (330°C).

(d) ball-pan hardness shall be measured in accordance with ASTM D3802 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 D4069. Batch tests are to be performed on each batch of material supplied, and as indicated in ASTM D4069.

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 176°F (80°C) and 95% relative humidity when tested in accordance with ASTM D3803.

FF-5212 Elemental Iodine Removal. Verify elemental iodine removal efficiency to be not less than 99.9% at 86°F (30°C) and 95% relative humidity when tested in accordance with ASTM D3803.

(19) **FF-5213 Methyl Iodide Removal (High Temperature).** Verify methyl iodide removal efficiency to be not less than 98% at 266°F (130°C) and 95% relative humidity when tested in accordance with ASTM D3803 for carbon installation 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 86°F (30°C) and 95% relative humidity in accordance with ASTM D3803. 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 356°F (180°C) in accordance with ASTM D3803. 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 D4069 for impregnated activated carbon, but the requirements are included in this Article for completeness. Any impregnated activated carbon that satisfies the requirements of ASTM D4069 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 (4.4°C)

(c) maximum temperature of 120°F (48.9°C)

(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 D3803)

(e) laboratory performing the tests

(f) test results

(g) identity and signature of person performing laboratory work

ARTICLE FF-9000 NAMEPLATES AND CERTIFICATION (19)

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 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.

(19) **Table FF-A-1000-1 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 shipping	Manufacturer/Owner
7200	Storage	Owner
7300	Containers	Manufacturer/Owner
8000	Quality assurance	Manufacturer
8100	Documentation	Manufacturer
9000	Nameplates and certification	Manufacturer

SECTION FG
MOUNTING FRAMES FOR AIR-CLEANING EQUIPMENT

ARTICLE FG-1000
INTRODUCTION

FG-1100 SCOPE

This section provides requirements for the performance, design, fabrication, installation, inspection, acceptance testing, and quality assurance of mounting frames for filters and adsorber cells used in air and gas treatment systems in nuclear facilities.

(19) ### FG-1200 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. This section is not applicable to side access or bag-in/bag-out housings.

FG-1300 PURPOSE

The purpose of this section is to ensure that mounting frames for filters and adsorber cells are acceptable in all aspects of design and operation.

FG-1400 RESPONSIBILITY

Nonmandatory Appendix FG-A contains a suggested division of responsibility.

ARTICLE FG-2000
REFERENCED DOCUMENTS

The codes and standards listed below shall supplement those listed in Article AA-2000. Unless otherwise shown, the latest edition and addenda are applicable.

ASME B46.1, Surface Texture (Surface Roughness, Waviness, and Lay)
Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990 (www.asme.org)

ARTICLE FG-3000
MATERIALS

FG-3100 ALLOWABLE MATERIALS

Table AA-3100-1 provides a list of the allowable materials used in the construction of mounting frames. Those materials shall conform to the specification requirements of materials given in Table AA-3100-1. 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.

ARTICLE FG-4000
DESIGN

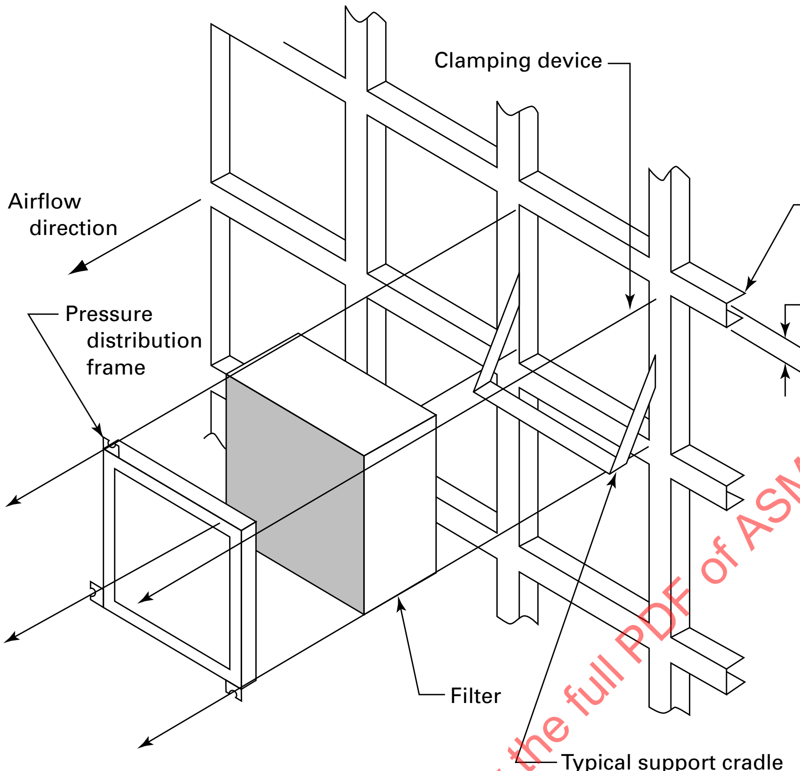
FG-4100 GENERAL DESIGN

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 Figure FG-4110-1.

Figure FG-4110-1 Typical Filter Mounting Frame



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 $^{1}/_{16}$ in. (1.5 mm) and shall be 2 in. (50 mm) smaller than the filter size. Reference Table FC-4110-1 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 $^{5}/_{8}$ in. (16 mm) deep and a minimum of 14 gauge (1.9 mm) thick. The tolerance on each knife-edge shall be plane within $^{1}/_{8}$ in. (3 mm).

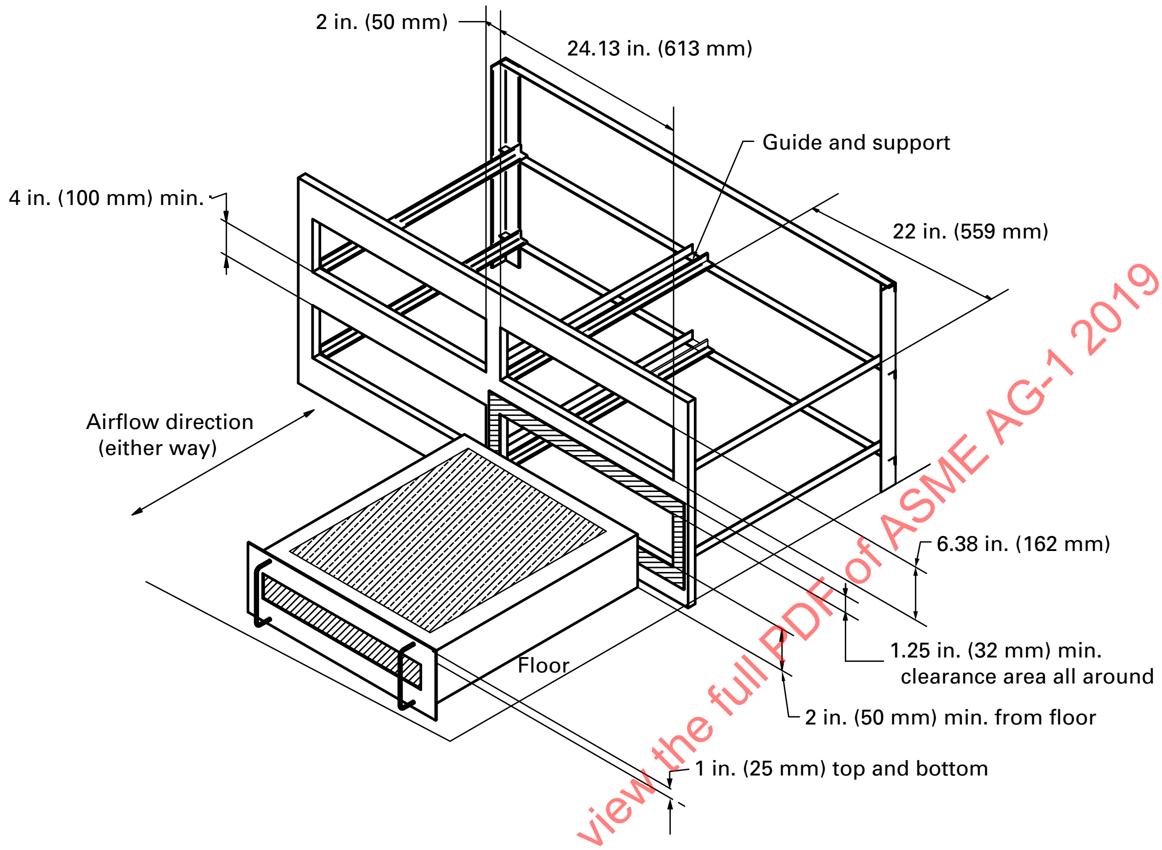
FG-4113 HEPA Filter Support. Supports or cradles are required for HEPA filters to facilitate installation. The supports shall permit inspection of the filter-to-frame interface when the filter is installed. Refer to Figure FG-4110-1.

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 Figure FG-4120-1.

Figure FG-4120-1 Typical Type II Adsorber Mounting Frame



FG-4121 Type II Adsorber Cell Mounting Frame Dimensions. Mounting frame openings for installing Type II adsorber cells shall be $6\frac{3}{8}$ in. × $24\frac{1}{8}$ in. ($+\frac{1}{8}$ in., −0 in.) [162 mm × 613 mm (+3 mm, −0 mm)].

For adjoining adsorber cells, there shall be a minimum frame width (space between openings) of 4 in. (100 mm) for horizontal members and 2 in. (50 mm) for vertical members for Type II adsorber cell mounting frames.

For adsorber cells directly adjoining a wall, floor, or ceiling, there shall be a minimum frame width (space between the opening and the wall, floor, or ceiling) of 2 in. (50 mm) for vertical members and 2 in. (50 mm) for horizontal members for Type II adsorber cell mounting frames.

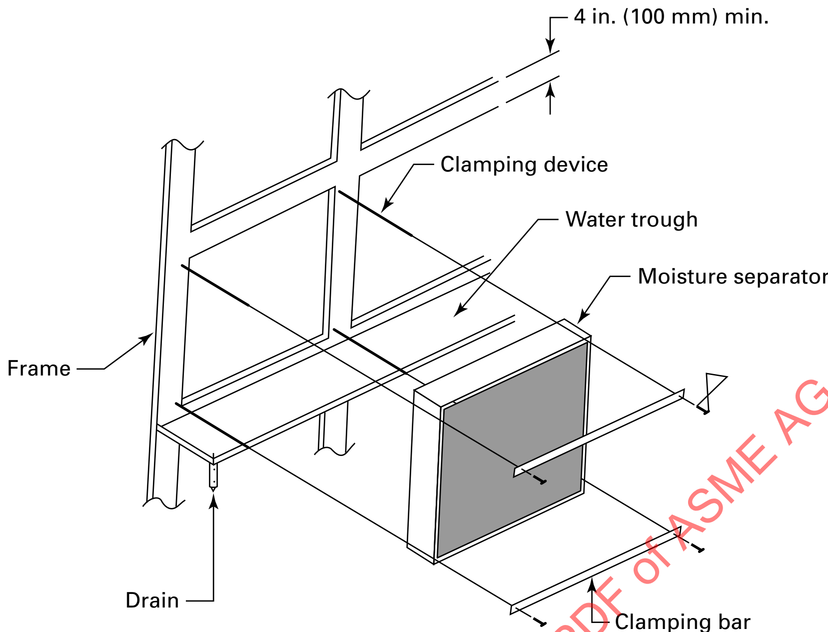
FG-4122 Type II Adsorber Cell Clamping. Major requirements of adsorber cell clamping systems toward effecting positive sealing are magnitude and uniformity of clamping. Essential to continuous sealing is minimal relative movement between clamping system components and the frame, due to component deformation 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 $3\frac{1}{2}$ in. (90 mm) of the right and left sides of the adsorber faceplate and within 1 in. (25 mm) of the top and bottom edge of the faceplate (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 Figure 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 of test canisters. Any penetration in the mounting frame shall be seal welded and isolatable.

Figure FG-4140-1 Typical Moisture Separator Mounting Frame



FG-4130 Medium Efficiency Filter Mounting Frames

A typical mounting frame is shown in Figure 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 Figure FG-4140-1.

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-4100-1.

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.

(19) ## FG-4220 Load Definition

Loads listed in AA-4211 having the following definitions shall be considered in the structural design of mounting frames:

(a) Deadweight (DW) is the weight of the mounting frame members.

(b) External load (EL) shall be 100 lbf (445 N) for each filter and moisture separator and 200 lbf (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.

(c) Normal operating pressure differential (NOPD) shall be 1.25 in. wg (310 Pa) for Type II adsorber cells as defined in FD-1300 and shown in Figure FD-4100-1; 1.5 times the dirty filter pressure drop for filters; and 2.0 in. wg (500 Pa) for moisture separators as defined in Table FA-4100-1, unless specified otherwise by the Owner in the design specification. The dirty filter pressure drop value shall be stated in the design specification.

(d) System operation pressure transient (SOPT) shall be provided in the design specification.

(e) The seismic acceleration and response spectra [operating basis earthquake (OBE) and safe shutdown earthquake (SSE)] shall be provided in the design specification.

(f) 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-4212-1 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-4321-1. 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 (19)

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

$$W = 0.036(1.5)\Delta pC \qquad (1)$$

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, lbf/in.
Δp = dirty filter pressure drop across bank, in. wg

The value of W shall be multiplied by 0.175 to convert lbf/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 be either determined by analysis or be selected directly from the tables of structural shape properties given in Part 1 of AISC 325.

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 lbf/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 be shall either determined by analysis or selected directly from the tables of structural shape properties given in Part 1 of AISC 325.

(19) ### 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 AISC 325 and be compared with the minimum values obtained from the equation

$$M = \frac{1.25(W_i L^2/8)}{S} \tag{2}$$

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, lbf/in.^{2}

W_i = pressure impulse loading on frame, lbf/in.

= $\Delta p_i C$, where Δp_i is the gauge pressure drop of pressure impulse, lbf/in.^{2}; and C is 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.

= $3C$

The values obtained in eq. (2) shall be less than the value in AISC 325 for the structural shape selected for the mounting frame.

The value of M obtained from eq. (2) shall be multiplied by 16.4×10^3 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 filters, 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 ASME 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 ASME 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 $^1/_2$–13 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 Section SA or Section HA 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 nonsealing 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 stamping necessary shall be specified in the design specifications.

NONMANDATORY APPENDIX FG-A
DIVISION OF RESPONSIBILITY

This 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-1000-1 begins on the following page.

Table FG-A-1000-1 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
4131	Medium efficiency filter mounting frame dimensions	Engineer/Manufacturer
4132	Medium efficiency filter clamping	Engineer/Manufacturer
4134	Medium efficiency filter mounting frame penetrations	Manufacturer
4141	Moisture separator mounting frame dimensions	Engineer/Manufacturer
4142	Moisture separator clamping	Engineer/Owner
4144	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
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
5400	Weld inspection	Manufacturer

Table FG-A-1000-1 Division of Responsibility (Cont'd)

FG-	Item	Responsible Party
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

ARTICLE FH-1000
INTRODUCTION

FH-1100 SCOPE

This section provides requirements for the performance, design, fabrication, installation, inspection, acceptance testing, and quality assurance for Type IV modular gas phase adsorber cells used in air and gas treatment systems in nuclear facilities.

FH-1200 PURPOSE

The purpose of this section is to ensure that Type IV modular gas phase adsorber cells are acceptable in all aspects of design and operation.

FH-1300 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-1400 DEFINITIONS AND TERMS

Terms used in this section are defined in Article AA-1000 and FD-1400.

ARTICLE FH-2000
REFERENCED DOCUMENTS

Codes and standards may be listed below to supplement those listed in Article AA-2000.

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 A240 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 A240 stainless steel.

The material thickness shall be as stated in FH-4230. Spacers and baffles shall meet the requirements of ASTM A240 or ASTM A276 as appropriate.

FH-3140 Adhesives and Sealants

FH-3141 Adhesives. Adhesives used to splice gaskets, bond gasket to cell, or 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.

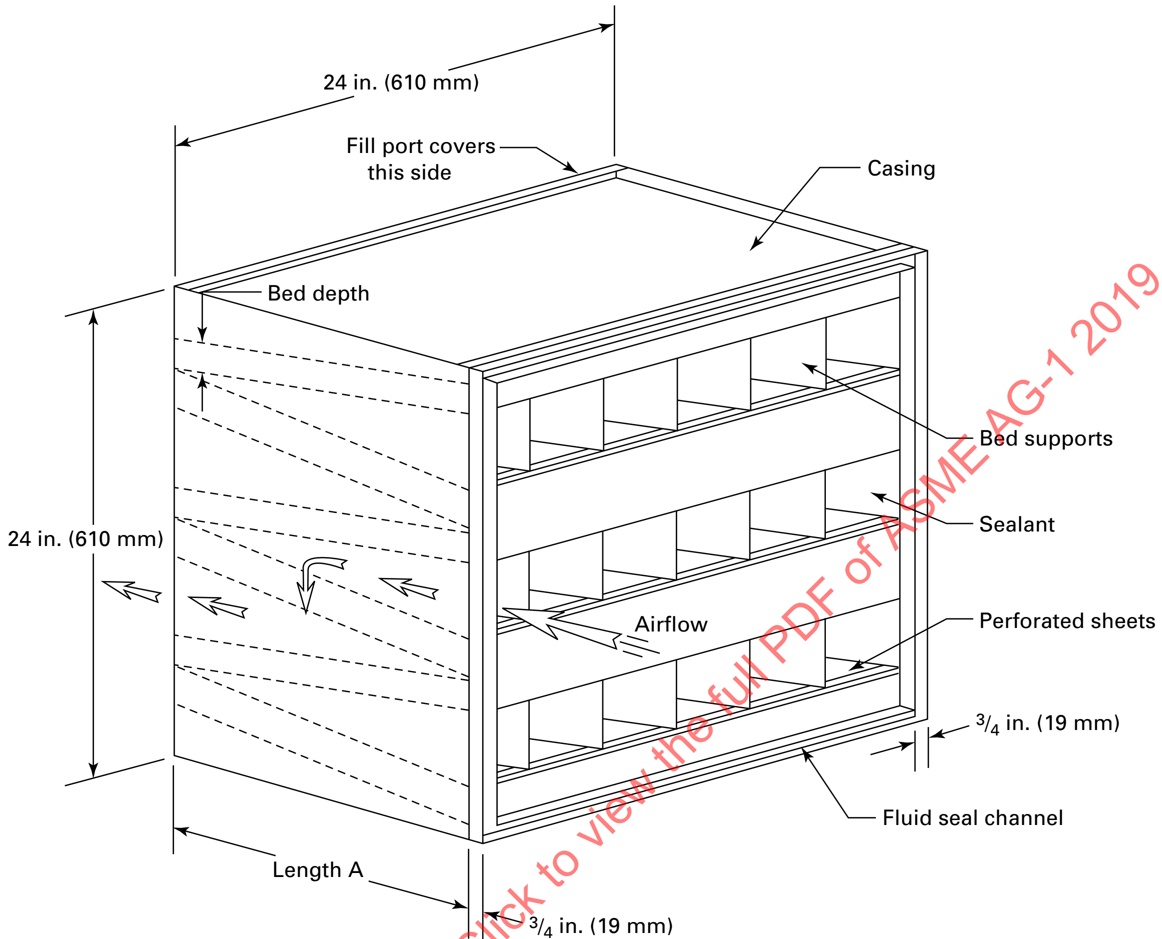
FH-3200 LIMITS

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.

Figure FH-4100-1 Type IV "V" Adsorbers Model (Fluid Seal Version)



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 a 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 D1056 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)

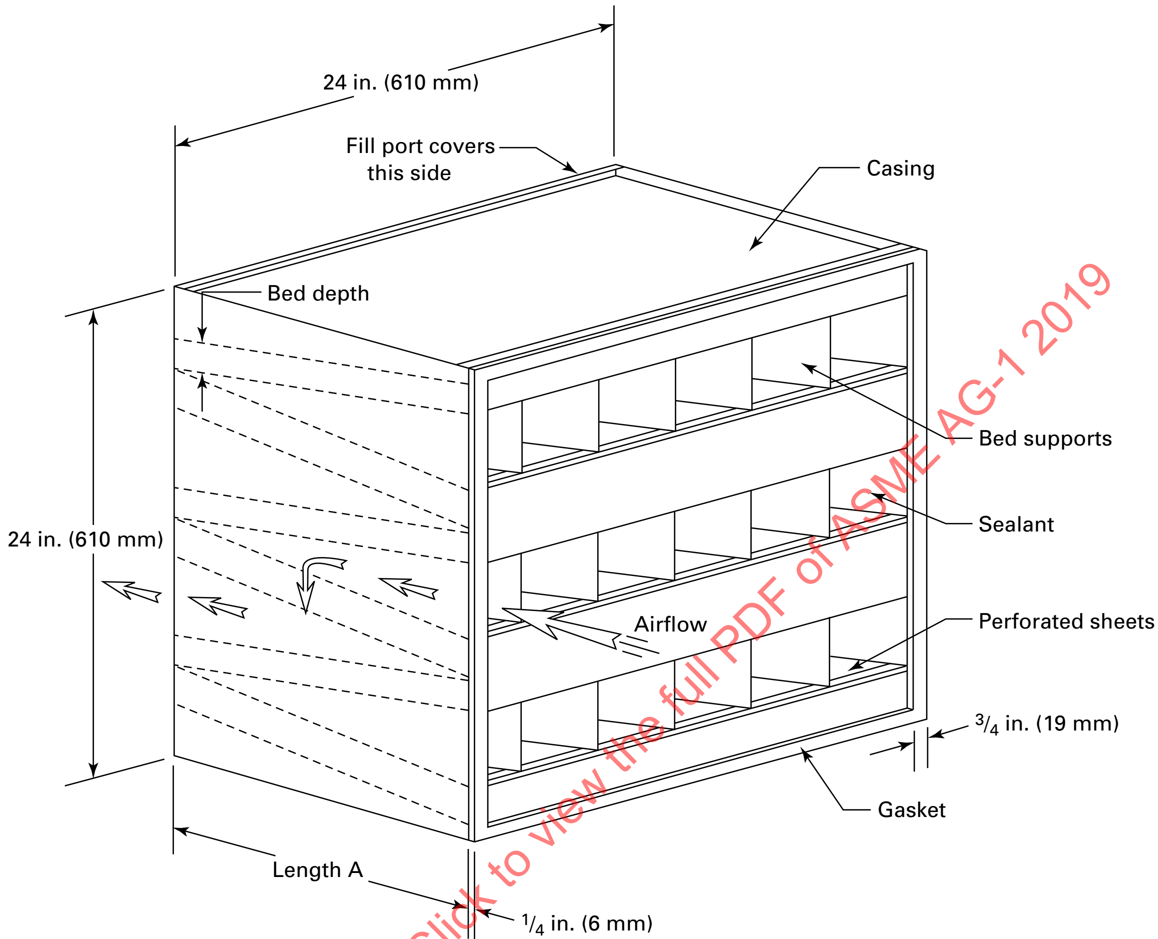
Manufacturer's Certificate of Conformance is required.

ARTICLE FH-4000 DESIGN

FH-4100 GENERAL DESIGN

The "V" configuration is illustrated in Figures FH-4100-1 through FH-4100-3, with additional dimensions and representative operating parameters shown in Table FH-6100-1. The "U" configuration is illustrated in Figure FH-4100-4. 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

Figure FH-4100-2 Type IV "V" Bed Adsorbers Model (Gasketed Version)



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. (0.05 s/cm) 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)

$$T = t(A/2 - B)/28.8Q$$

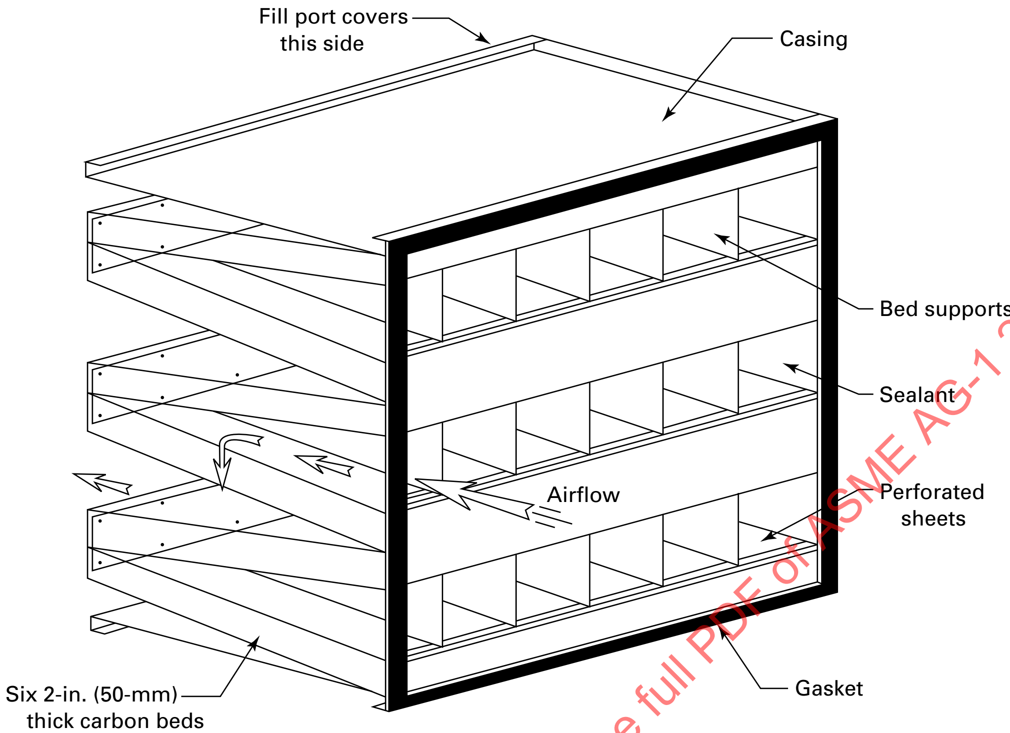
(SI Units)

$$T = 3.6t(A/2 - B)/Q$$

where

3.6 = product of 3,600 s/h and 10^{-3} m/mm

Figure FH-4100-3 Type IV "V" Adsorbers Model, Exploded View



28.8 = product of 1,728 in.^{3}/ft^3 and $\frac{1}{60}$ min/sec
A = gross screen area of all screens on inlet side and on the outlet side, in.^{2} (m^2)
B = total area of baffles, blanks, margins, of all screens, in.^{2} (m^2)
Q = total cell volumetric airflow, cfm (m^3/h)
T = residence time, sec
t = minimum thickness of bed, in. (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 means of maintaining bed thickness and minimizing distortion when the cell beds are filled.

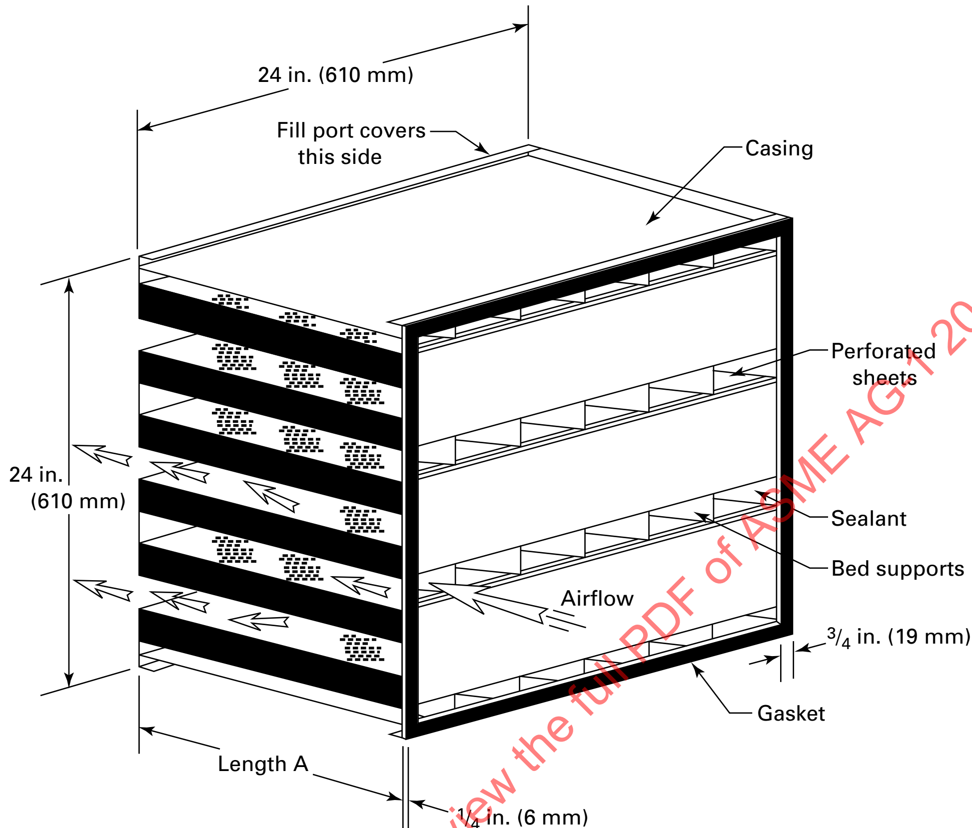
(19) FH-4230 Case and Assembly

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 interface of the perforated sheet and the solid side. 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 gauge USS nonperforated stainless steel sheet, 0.0751 in. (1.83 mm) minimum thickness, Type 304, conforming to ASTM A240. 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 11 gauge USS stainless steel, 0.120 in. (3.05 mm) minimum thickness, Type 304, conforming to ASTM A240.

Figure FH-4100-4 Type IV "U" Bed Adsorbers Model (Gasketed Version)



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 D1056. If gasket material joints are 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 $^3/_4$ 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.

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) shall 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-4212-1 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-4321-1. The design stress value S shall be $0.6S_u$, as defined in AA-4332.3.

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-6100-1. 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.

Table FH-6100-1 Dimensional Requirements

Dimensions	in.	mm
Height	24 + 0, − $\frac{1}{16}$	610 + 0, − 1.6
Width	24 + 0, − $\frac{1}{16}$	610 + 0, − 1.6
Minimum length	11.5 + $\frac{1}{16}$, − 0	290 + 1.6, − 0
Maximum length	18.75 + $\frac{1}{16}$, − 0	475 + 1.6, − 0

GENERAL NOTE: Face diagonal tolerances are ±$\frac{1}{8}$ in. (3.2 mm).

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 airstream 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/h and 425 m^3/h). 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-6100-1. 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 used in fabrication and installation shall be performed in accordance with Article AA-6000.

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 (19)

Metal surfaces shall be cleaned and degreased in accordance with ASTM A380 before any welding, installation of gaskets or sealants, or filling with adsorbent.

ARTICLE FH-7000 PACKAGING AND SHIPPING

FH-7100 PACKAGING

Per Article AA-7000, packing and shipping shall be in accordance with ASME NQA-1, Basic Requirement 13.

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 PERMANENT NAMEPLATE

Each cell shall be legibly and permanently marked on a noncorroding nameplate 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

FH-9200 FILLING LABEL

Each cell shall bear a replaceable label with the following information:

(a) adsorbent manufacturer's name or symbol

(b) adsorbent type and grade designation, lot, and batch

(c) filled weight

(d) adsorbent weight

(e) airflow resistant at specified airflow rating

(f) challenge vapor leak test results

(g) date of filling

NONMANDATORY APPENDIX FH-A DIVISION OF RESPONSIBILITY

This 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.

(19) **Table FH-A-1000-1 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	Nameplates and certification	Manufacturer

SECTION FI
METAL MEDIA FILTERS

(In the Course of Preparation)

SECTION FJ
LOW EFFICIENCY FILTERS

ARTICLE FJ-1000
INTRODUCTION

FJ-1100 SCOPE

This section provides requirements for the performance, design, fabrication, inspection, acceptance testing, and quality assurance for low efficiency filters used in air and gas treatment systems in nuclear facilities.

FJ-1200 PURPOSE

The purpose of this section is to ensure that low efficiency filters are acceptable in all aspects of design and operation.

FJ-1300 APPLICABILITY

This section shall be applied to the use of low efficiency filters installed in nuclear facilities. The typical function of these filters is to reduce the particulate loading to HEPA filters and to protect air conditioning/air handling equipment. This section applies to dry type filters with an ASHRAE 52.2 minimum efficiency reporting value (MERV) rating of 1 to 8.

FJ-1310 Limitations

This section does not cover
(a) system design requirements for the use of filters
(b) mounting frames for low efficiency filters

FJ-1320 Responsibility

Nonmandatory Appendix FJ-A contains a suggested division of responsibility.

(19) ### FJ-1400 DEFINITIONS AND TERMS

Definitions that have common applications are contained in Article AA-1000. The following terms have special meaning in the context of this section.

extended media filter: a filter having pleated media or media in the form of bags, socks, or other shape to increase the surface area relative to the face area of the filter.

filter frame: a structure that encloses the edges of the filter media (or filter pack) and provides a filter-mounting surface.

filter media: the part of the filter designed to remove particulate matter from the air or gas stream.

flat-panel filter: a filter that contains all of the media on the face of the filter in the same plane (e.g., no pleats). This design maintains the filter face velocity equal to the media velocity.

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.

minimum efficiency reporting value (MERV): a measurement scale developed by ASHRAE to rate the efficiency of air filters

sealants: materials used for the following purposes:
(a) hold the filter media in position in the frame
(b) attach gaskets
(c) splice media

separator: a device used to support and position folds in the filter media to provide air passage.

ARTICLE FJ-2000
REFERENCED DOCUMENTS

The codes and standards listed below shall supplement those listed in Article AA-2000. Unless otherwise specified, the latest edition shall apply.

ASQ Z1.4, Sampling Procedures and Tables for Inspection by Attributes
Publisher: American Society of Quality (ASQ), P.O. Box 3005, Milwaukee, WI 53201-3005 (www.asq.org)

ARTICLE FJ-3000
MATERIALS

FJ-3100 ALLOWABLE MATERIALS

FJ-3110 Filter Media

The filter media shall consist of material suitable for the environment defined by design criteria in Article FJ-4000.

FJ-3120 Filter Frame

The filter frame shall consist of material suitable for the environment defined by design criteria in Article FJ-4000.

FJ-3130 Separators

The separators, if used, shall consist of corrosion-resistant material suitable for the environment defined by design criteria in Article FJ-4000.

FJ-3140 Sealants and Adhesives

Sealants and adhesives shall be suitable for the environment defined by design criteria in Article FJ-4000.

FJ-3150 Gaskets

Gasket material, if used, shall be oil resistant, expanded, cellular elastomer that conforms to the requirements of ASTM D1056, Grade 2C3 or 2C4.

FJ-3200 SPECIAL LIMITATIONS OF MATERIALS

A consideration of material deterioration caused by service is outside the scope of this Code section. It is the responsibility of the Owner or the Owner's designee to identify the environment in which the filter must operate.

ARTICLE FJ-4000 DESIGN

FJ-4100 GENERAL DESIGN

FJ-4110 MERV 1–5 Filters

Low efficiency (MERV 1–5) filters shall be replaceable, dry-type, panel filters and shall comply with the standard for air-filter units, UL 900.

FJ-4120 MERV 6–8 Filters

Low efficiency (MERV 6–8) filters shall be replaceable, extended media, dry-type filters and shall comply with the standard for air-filter units, UL 900.

FJ-4200 DESIGN CRITERIA

Design criteria shall be prepared by the Owner or the Owner's designee in sufficient detail to provide a complete basis for low efficiency filter design in accordance with this Code section. As a minimum, design criteria shall be specified for the following parameters:

(a) type of gas to be treated
(b) rated airflow, nominal, acfm (m^3/h) per ASHRAE 52.2
(c) design differential pressure, in. wg (Pa)
(d) temperature operating range, °F (°C)
(e) relative humidity operating range, % RH
(f) contaminants to be removed, g/acfm, ($g/m^3/h$)
(g) MERV per ASHRAE 52.2
(h) initial resistance, in. wg (Pa) at rated flow per ASHRAE 52.2
(i) rated final resistance, in. wg (Pa), at rated flow per ASHRAE 52.2
(j) dust holding capacity, grams, per ASHRAE 52.2
(k) nominal low efficiency filter frame dimensions, in. (mm) (height × width × depth)
(l) frame material

FJ-4300 STRUCTURAL REQUIREMENTS

See seismic requirements in FJ-5240 and FJ-5241.

ARTICLE FJ-5000 INSPECTION AND TESTING

The inspection and testing of low efficiency filters shall conform to the requirements of Article AA-5000 and the specific requirements of this Article.

FJ-5100 INSPECTION PLAN

The manufacturer shall establish a sampling and inspection plan in accordance with ASQ Z1.4 or by another method acceptable to the Owner or designee.

FJ-5110 Inspection Requirements (19)

The manufacturer's quality assurance program shall contain measures to assure that filters packaged for shipment have been inspected for

(a) splits, tears, or holes of the filter media
(b) splits, tears, or holes of the connection between the filter media and the filter frame
(c) missing or incorrect parts or components
(d) incorrect fit of parts or components
(e) workmanship
(f) cleanliness and appearance
(g) correct identification on the filter label and carton

FJ-5120 Rejection and Reinspection

A 100% inspection shall be performed on a 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.

FJ-5200 QUALIFICATION TESTING

New or revised filter designs shall require qualification testing prior to acceptance and production.

FJ-5210 Testing Requirements

To obtain standard ratings, three low efficiency filters of the design to be qualified shall be tested and test results shall be provided in accordance with ASHRAE 52.2. 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, composite average efficiencies, MERV, average synthetic dust weight arrestance, and dust-holding capacity. The various parameters at which the filters are rated are defined in ASHRAE 52.2.

FJ-5220 Certification

Low efficiency filters shall comply with the standard for air-filter units, UL 900.

FJ-5230 Requalification

The filter design shall be requalified whenever there is a change in design, material, or manufacturing methods.

FJ-5240 Seismic Qualification

Each design of low efficiency filter shall be qualified by testing in accordance with AA-4350. At least one unit of each design shall be tested.

FJ-5241 Acceptance Criteria. The low efficiency filter shall be visually inspected per FJ-5110(a) and FJ-5110(b) after testing and shall show no structural damage.

ARTICLE FJ-6000 FABRICATION

FJ-6100 GENERAL

Low efficiency filters shall be assembled from materials that conform to Article FJ-3000 and meet the design requirements of Article FJ-4000.

Following assembly, the filter shall be inspected and tested in accordance with the requirements of Article FJ-5000.

FJ-6200 MANUFACTURE AND ASSEMBLY

The general requirements for fabrication and installation are contained in AA-6200 and AA-6300.

FJ-6210 Tolerances

Low efficiency filters shall be +⅛ in., −⅛ in. (+3 mm, −3 mm) outside dimensions including depth. The above dimensions exclude gaskets, if used.

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

FJ-7100 GENERAL

Low efficiency filters shall be placed in protective cartons with pleats arranged vertically. No more than 12 filters shall be placed in a single carton. All packaging, shipping, receiving, storage, and handling shall meet the requirements of Article AA-7000.

ARTICLE FJ-8000 QUALITY ASSURANCE

FJ-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 quality assurance program acceptable to the Owner or designee and provide required documentation as requested.

FJ-8200 DOCUMENTATION

The following documentation shall be made available to the Owner or designee:

(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 low efficiency filter qualification test report per FJ-5200

(d) certificate of conformance to this Code section and purchase specifications

ARTICLE FJ-9000 LABELS AND MARKINGS

FJ-9100 FILTER MARKINGS

Each filter shall be equipped with a permanent label(s). The marking on the label(s) shall be legible and shall provide the following information as a minimum:

(a) manufacturer's name

(b) manufacturer's designation and part number

(c) date of manufacture (month and year)

(d) rated flow capacity, acfm (m^3/h)

(e) rated initial pressure drop, in. wg (Pa)

(f) recommended maximum pressure drop, in. wg (Pa)

(g) MERV

(h) airflow direction arrow

(i) installation orientation (e.g., "INSTALL THIS SIDE UP" or "INSTALL THIS SIDE VERTICAL")

(j) UL label

(k) temperature operating range, °F (°C)

FJ-9200 PACKAGE MARKINGS

Marking or labeling of each shipping container shall be of a size and type that can be read at a distance of 3 ft (0.9 m). The following information shall be provided as a minimum:

(a) manufacturer's name

(b) manufacturer's designation and part number

(c) arrows and "THIS SIDE UP" indicating orientation for shipping and storage, and "FRAGILE" in letters no less than $^3/_4$ in. (19 mm) high

(d) purchase order number or other identifying markings requested by the Owner

NONMANDATORY APPENDIX FJ-A
DIVISION OF RESPONSIBILITY

This 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.

(19) **Table FJ-A-1000-1 Division of Responsibility**

FJ-	Item	Responsible Party
3000	Materials	Manufacturer/Owner
4000	Design	Manufacturer/Owner
5000	Inspection and testing	Manufacturer
6000	Fabrication	Manufacturer
7000	Packaging, shipping, receiving, storage, and handling	Manufacturer/Owner
8000	Quality assurance	Manufacturer
9000	Labels and markings	Manufacturer

SECTION FK
SPECIAL HEPA FILTERS

ARTICLE FK-1000
INTRODUCTION

FK-1100 SCOPE

This section provides requirements for the performance, design, fabrication, inspection, acceptance testing, and quality assurance for special high efficiency particulate air (HEPA) filters used in air and gas treatment systems in nuclear facilities.

FK-1200 PURPOSE

The purpose of this section is to ensure that special HEPA filters are acceptable in all aspects of design and operation.

FK-1300 APPLICABILITY

FK-1310 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-1311 Types of HEPA Filters. Three types of special HEPA filters are addressed as follows:

(a) *Type 1.* Radial flow filters

(b) *Type 2.* Axial flow circular filters

(c) *Type 4.* Axial flow rectangular filters that are size variations of those addressed in Section FC

Type 1 and 2 filters are depicted in Figures FK-4111-1 through FK-4112-1. Type 4 filters are depicted in Section FC.

FK-1312 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-1320 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-1330 Service Life (19)

HEPA filters are components of a nuclear air treatment system and 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-1340 Division of Responsibility

Nonmandatory Appendix FK-B contains division of responsibility guidelines.

FK-1400 DEFINITIONS AND TERMS (19)

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 end of a radial flow HEPA filter in which the filter pack and filter grille are sealed/ mounted.

filter grille: the perforated or expanded metal tube that forms the outer and inner frame of a radial flow filter.

filter pack depth (d): the typical dimension from the outside surface of the upstream pleat end to the outside surface of the downstream pleat end, in the direction parallel to the airflow for both Type 2 and Type 4 filters.

filter pack diameter (D): the maximum pack design dimension within the circular case and parallel to the vertically oriented pleats for a Type 2 filter.

filter pack height (h): the maximum pack design dimension along the pack face, which is within the case and parallel to the vertically oriented pleats for a rectangular or square Type 4 filter.

filter pack width (w): the maximum pack design dimension across the pack face, which is within the case and perpendicular to the vertically oriented pleats for a rectangular or square Type 4 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: a 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.

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 automated sampling and sizing 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 particle 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: the 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: 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: 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 gelatinuous seals.

Type 4: 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

The codes and standards listed below shall supplement those listed in Article AA-2000. Unless otherwise specified, the latest edition shall apply.

ASME B18.21.1, Washers: Helical Spring-Lock, Tooth Lock, and Plain Washers (Inch Series)
ASME B18.21.2M, Lock Washers (Metric Series)
ASME B18.22M, Metric Plain Washers
Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990 (www.asme.org)

ASTM D3359-09, Standard Test Methods for Measuring Adhesion by Tape Test
ASTM E84C-09, Standard Test Method for Surface Burning Characteristics of Building Materials
ASTM F1267-07, Standard 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 (www.astm.org)

FED-STD-141D-2001, Paint, Varnish, Lacquer and Related Materials: Methods of Inspection, Sampling and Testing
MIL-STD-282, Notice 4 (1995), Filter Units, Protective Clothing, Gas-Mask Components and Related Products: Performance-Test Methods
Publisher: Superintendent of Documents, U.S. Government Publishing Office (GPO), 732 N. Capitol Street, NW, Washington, DC 20401 (www.gpo.gov)

IEST-RP-CC007.2, Testing ULPA Filters
Publisher: Institute of Environmental Sciences and Technology (IEST), 1827 Walden Office Square, Suite 400, Schaumburg, IL 60173 (www.iest.org)

ARTICLE FK-3000 MATERIALS

FK-3100 ALLOWABLE MATERIALS

Materials shall conform to the material specifications listed in Table AA-3100-1.

FK-3110 Cases, End Caps, Grilles, and Flange Materials

The cases, end caps, grilles, and flanges shall be made from stainless steel per ASTM A240.

The case for rectangular axial flow filters, if constructed from wood, shall be made from the following materials:

(a) marine plywood, minimum Grade A (interior side) and minimum Grade B (exterior side), per APA PS-1. The minimum thickness shall be 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 E84.

(b) exterior plywood, minimum Grade A (interior side) and minimum Grade C (exterior side), per APA PS-1. The minimum thickness shall be 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 E84.

FK-3111 Fasteners. Approved fasteners used for the assembly of HEPA filter cases are listed below.

(a) stainless steel bolts, 300 series per ASTM A320 or ASTM A193

(b) stainless steel nuts, 300 series per ASTM A194

(c) stainless steel lock washers, 300 series per ASME B18.22.1/B18.22M

(d) stainless steel plain washers, 300 series per ASME B18.22.1/B18.22M

(e) stainless steel rivets 300 series per ASTM A581

(f) zinc-coated steel nails

Consideration shall be given when selecting the proper filter fasteners serving seismic and other unusual requirements. Uncoated carbon steel fasteners are not allowed.

FK-3120 Gasket Material

FK-3121 Elastomer. Oil resistant, closed cell expanded cellular elastomer in accordance with grade 2C3 or 2C4 of ASTM D1056, with the physical requirements specified for ASTM D1056 cellular rubbers classified as Type 2, Class C, Grade 3 (2C3) or Type 2, Class C, Grade 4 (2C4).

FK-3122 Gelatinous Seal. A self-adhesive and self-healing cured gel seal made of polydimethylsiloxane.

(19) ### FK-3130 Filter Media

The filter media shall conform to the requirements of Section FN.

FK-3140 Face guards

Metallic face guards shall be fabricated from 4 × 4 mesh, wire fabric (hardware cloth) made from 0.025 in. (0.64 mm) minimum steel conforming to either ASTM A740 galvanized steel or ASTM A580 stainless steel.

FK-3150 Adhesives

Adhesives used to fasten gaskets to filter case, and seal the filter pack or face guards to the case, shall be self-extinguishing.

FK-3160 Separators (19)

(a) Aluminum. Aluminum separators shall be made from corrugated aluminum or aluminum alloy 1100-H18, 5052-H38, or 3003-H18 conforming to ASTM B209, 0.0015 in. (0.038 mm) minimum thickness. 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 or aluminum alloy 1100-H18, 5052-H38, or 3003-H18 conforming to ASTM B209, 0.0015 in. (0.038 mm) minimum thickness, coated on both surfaces with a vinyl epoxy coating. The coating shall 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.

FK-3161 Coating. Separators coated in accordance with FK-3160(b) shall meet the following tests after application of the coating to the separator.

(a) The coating shall meet or exceed an adhesion rating of 3A when tested using Method A (X-Cut Tape Test) of ASTM D3359. The X-cut specimen shall be inspected for removal of coating where the 3A adhesion rating equates to jagged removal along the X-cut incision up to 1/16 in. (1.6 mm).

(b) Off-gas volatiles, as determined by thermo-gravimetric analysis, shall not exceed 5% by weight when a 2 in. ± 0 in. (50 mm ± 0 mm) high by 2 in. ± 0 in. (50 mm ± 0 mm) wide sample of the coated separator is subjected to temperatures from 70°F (20°C) to 1,800°F (1 000°C).

(c) The coated separator shall pass a flexibility test in accordance with FED-STD-141D, Method 6221.

FK-3162 Separatorless Filter Packs. Separatorless filter packs shall use formed media to fulfill the function of the separator.

(19) **Table FK-4111-1 Type 1 Radial Flow HEPA Filter — Nominal Rating**

Maximum Rated Airflow		Maximum Resistance	
acfm	m^3/h	in. wg	Pa
40	68	1.3	325
100	170	1.3	325
250	425	1.3	325
500	850	1.3	325
1,000	1 700	1.3	325
1,500	2 550	1.3	325
2,000	3 400	1.3	325

(19) ### FK-3170 Grilles

Type 1 filters shall be fitted with an internal and external perforated grille or flattened expanded metal grilles as shown in Figures FK-4111-1 through FK-4111-4. Flattened expanded metal grilles shall be fabricated from the materials indicated in FK-3110 and conform to ASTM F1267. Grilles shall be 18 gauge (minimum).

FK-3200 GENERAL MATERIAL REQUIREMENTS

All materials used shall have properties and composition suitable for the application as defined by the operating environmental conditions, as defined in FK-4200. When the 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.

The material requirements of Article AA-3000 apply.

FK-3210 Special Limitations of Materials

Materials suitable for the conditions shall be stated in the design specification, with special attention given to the effects of service conditions upon the properties of the materials. The consideration of deterioration of materials caused by service is generally outside the scope of this Code.

It shall be the responsibility of the Owner or Engineer to identify the environment and filter service conditions in which the filter must operate.

Service conditions shall include airstream and gas stream contaminants that can affect the operability, service life, maintainability, or need for special features as to construction or materials of the filter in which the filter must operate.

FK-3220 Alternate Materials

Materials, other than those referenced in this Code section, found acceptable by the qualification tests of Article FK-5000 and the design requirements of Article FK-4000 and Section AA will be acceptable for the fabrication of filters.

ARTICLE FK-4000 DESIGN

FK-4100 GENERAL DESIGN

Three types of HEPA filters are addressed in this Code section as follows:

(a) *Type 1.* Radial HEPA flow filters.

(b) *Type 2.* Axial flow circular HEPA filters.

(c) *Type 4.* Axial flow rectangular HEPA filters that are size variations of those addressed in Section FC.

The total media area provided within the filter pack shall be such that maximum media velocity is 5 ft/min (1.5 m/min) at the rated flow.

HEPA filters not listed above that conform to the performance, material, construction, acceptance, and testing requirements listed in this Code section are acceptable.

FK-4110 Special HEPA Filters

FK-4111 Type 1 Radial Flow Filters. Type 1 radial flow filters shall be made from a media pack formed to produce an annulus with internal and external supporting grilles. The medial pack and grilles shall be sealed into the flange and end cap with adhesive complying with FK-3150. The normal direction of flow shall be from the inside face to the outside face. Optionally, the flow may be from outside face to inside face as may be required for glove box installation or smaller applications. The end cap shall blank off the end of the filter. A handling mechanism will be provided if required by the application. The filter capacity and performance ratings shall be as specified in Table FK-4111-1.

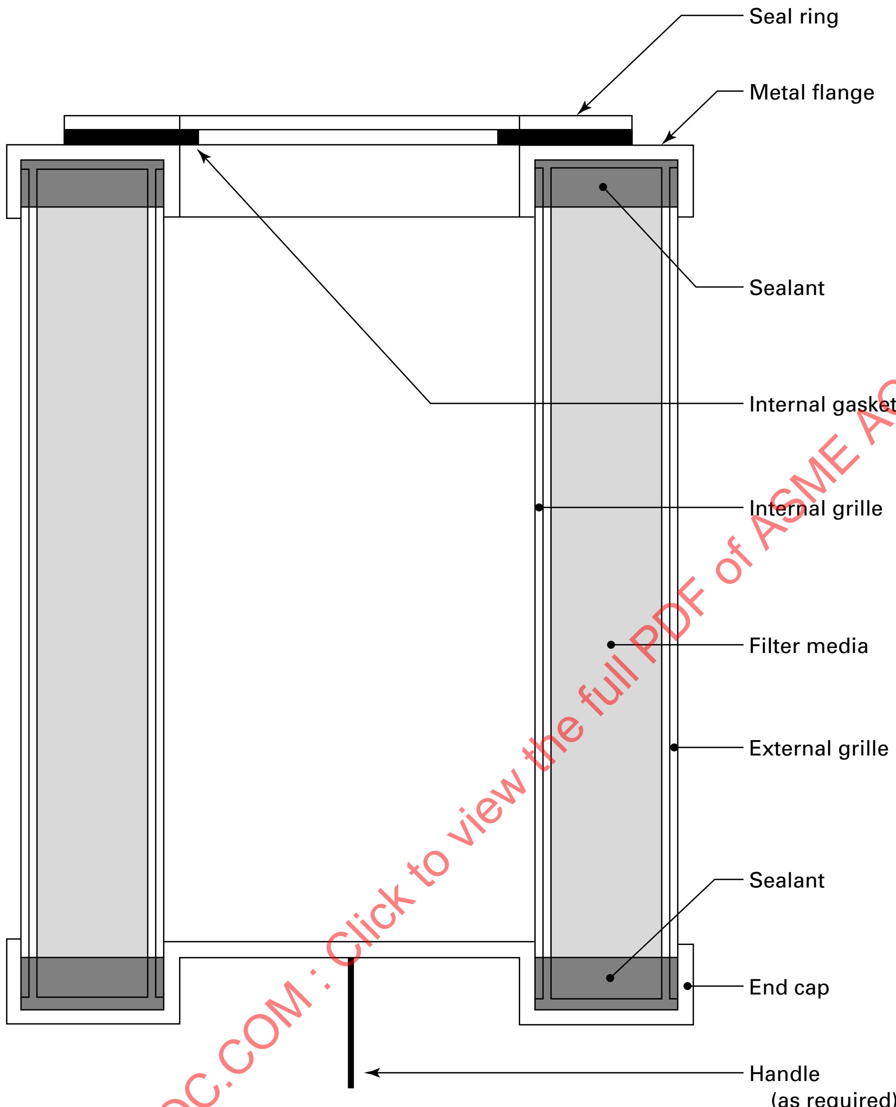
(a) *Type 1 radial flow filters with internal gaskets* shall be constructed as depicted in Figure FK-4111-1. The filter shall accommodate a seal ring connected to the flange to provide a gasket seal between the filter and the sealing face of the housing. Gaskets shall comply with FK-3121.

(b) *Type 1 radial flow filters with internal gelatinous seals* shall be constructed as depicted in Figure FK-4111-2. The filter shall have a circular channel connected to the flange. The circular channel shall contain gelatinous sealant to provide a seal between the filter and a companion circular knife-edge on the housing. Gelatinous seals shall comply with FK-3122.

(c) *Type 1 radial flow filters with external gaskets* shall be constructed as depicted in Figure FK-4111-3. The filter shall accommodate an external seal ring to provide a seal between the filter and the sealing face of the housing. Gaskets shall comply with FK-3121.

(d) *Type 1 radial flow filters with external gelatinous seals* shall be constructed as depicted in Figure FK-4111-4. The filter shall have a circular channel connected to the flange. The circular channel

Figure FK-4111-1 Type 1 Radial Flow HEPA Filter (Internal Gasket), Midsection View



shall contain gelatinous sealant to provide a seal between the filter and a companion circular knife-edge on the housing. Gelatinous seals shall comply with FK-3122.

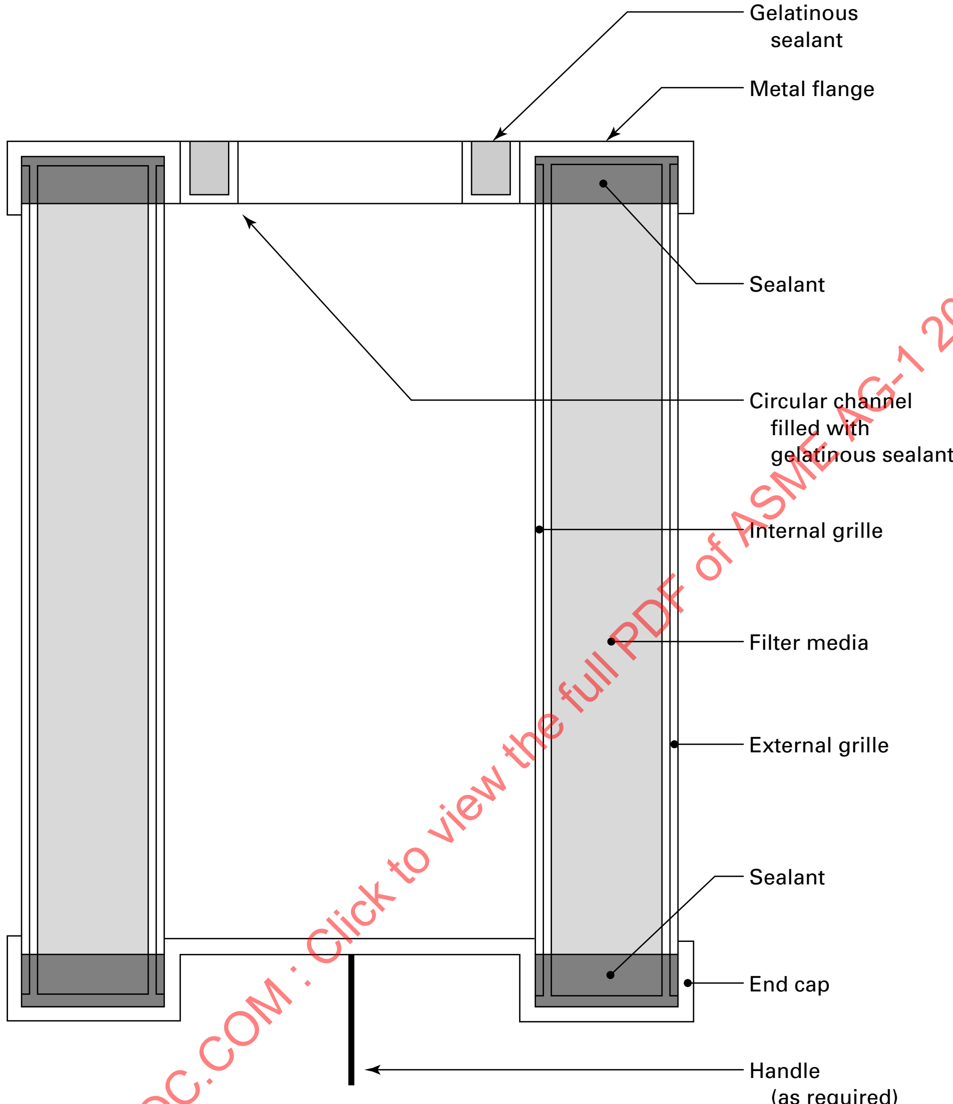
(19) **FK-4112 Type 2 Axial Flow Circular Filters.** Type 2 axial flow circular filters shall be constructed as depicted in Figure FK-4112-1. The filter case shall be one piece, achieved by either cutting piping or tubing of the specified material to the proper length or cutting and rolling material to the desired dimensions. Any required flanges shall be accomplished by either rolling or welding the flange to the case or tube. All welding shall be continuous.

Flanges may be located upstream, downstream, or at both faces. The media pack shall be secured within the entire circumference of the case.

When specified, either elastomer or gelatinous seal gaskets may be used. Gaskets may be located on the face of the flange(s) or on back of the flange(s). Elastomer gaskets shall be fastened to the flange using an adhesive complying with FK-3150. Gelatinous seals shall be accomplished by including a channel on either the flange face or the back of the flange. The filter capacity and performance ratings shall be as specified in Table FK-4112-1.

FK-4115 Type 4 Axial Flow Rectangular Filters. Type 4 axial flow rectangular filters (that are size variations of those addressed in Section FC) shall be constructed as depicted in Article FC-4000. The maximum case dimensions shall be 24 in. (610 mm) high by 30 in. (762 mm) wide. Case materials shall be in accordance with FK-3110. Fabrication shall meet the requirements of Article

Figure FK-4111-2 Type 1 Radial Flow HEPA Filter (Internal Gelatinous Seal), Midsection View



FK-6000. The filter shall be assembled with filter pack Type A, B, C, or D. The entire inside surface of the case shall be coated with adhesive to secure and seal the filter pack to the case. Gaskets shall comply with FK-4140.

FK-4116 Splices and Patches. No splices or patches in the filter media pack are allowed. Joining of the two ends in a Type 1 radial flow filter pack is acceptable.

FK-4120 Filter End Cap, Grilles, and Flange

Filter end cap, grilles, and flanges for Type 1 radial flow HEPA filters are used to contain and support the filter media pack. All joints shall be sealed. End cap and flange materials shall be in accordance with FK-3110. Fabrication shall meet the requirements of Article FK-6000.

FK-4121 End Caps, Grilles, and Flanges for Type 1 Filters. End caps, grilles, and flanges for Type 1 filters shall have a minimum material thickness of 18 gauge.

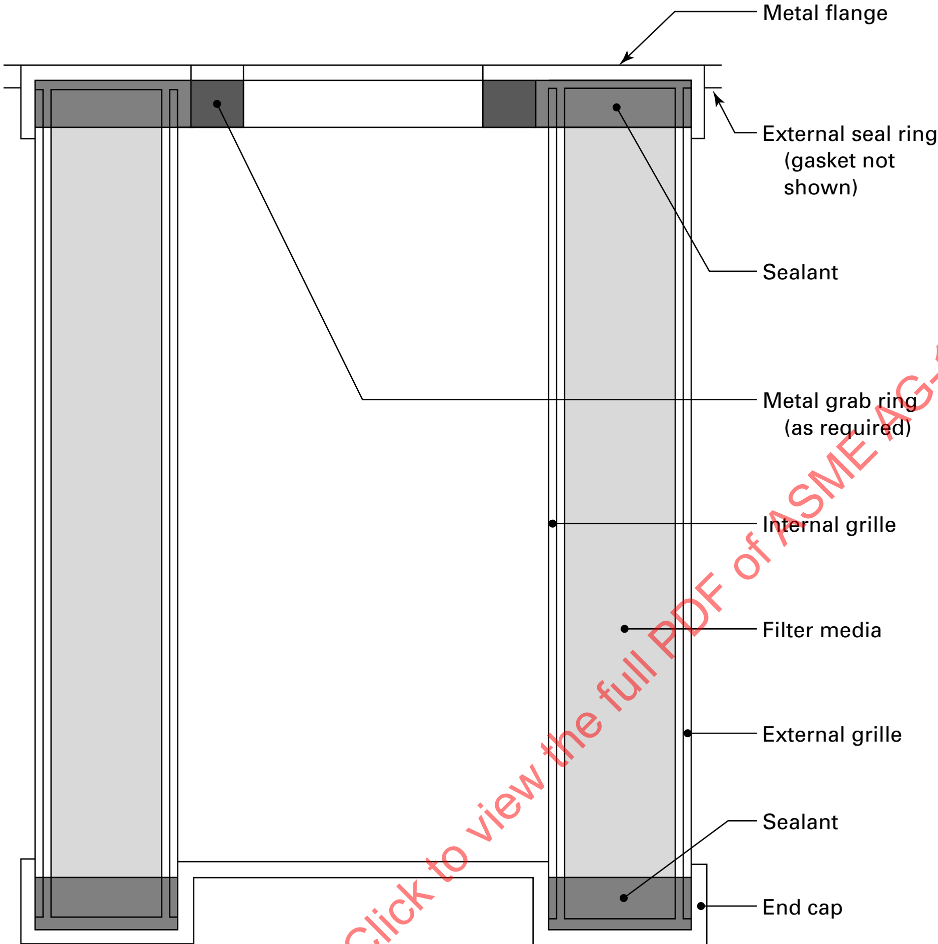
FK-4122 Cases for Type 2 Filters. Cases for Type 2 filters shall have a minimum material thickness of 14 gauge steel.

FK-4123 Cases for Type 4 Filters. Cases for Type 4 filters shall have a minimum material thickness of 14 gauge for steel or $^{3}/_{4}$ in. (19 mm) for wood.

FK-4130 Filter Pack

(a) Type A filter packs shall be made by folding the media to the required depth. The folded filter media shall be supported with corrugated separators. The

Figure FK-4111-3 Type 1 Radial Flow HEPA Filter (External Gasket), Midsection View

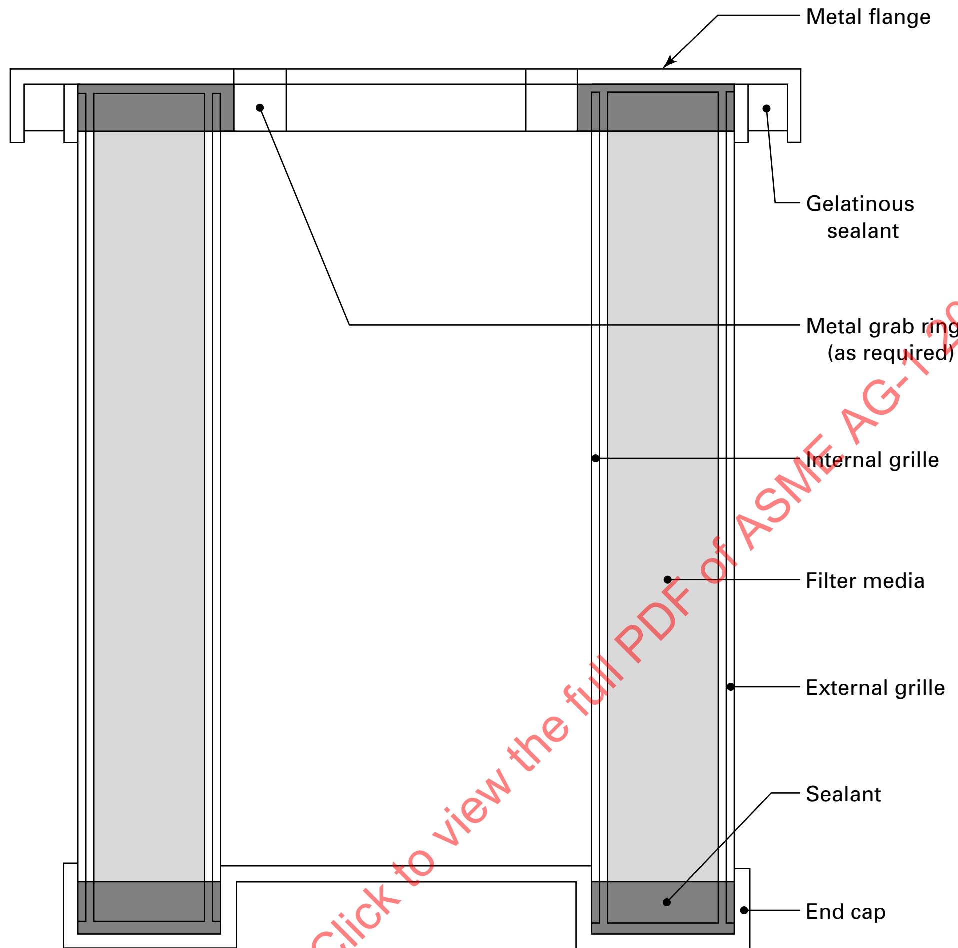


filter media pack shall not extend beyond the exposed ends of the separators. Separator fixed ends, when viewed from the upstream and downstream faces, shall be embedded by the adhesive/sealant. The separators shall not extend beyond the ends of the case when the media pack is bonded to the case. The filter pack shall be rigid within the case and the separators shall be perpendicular to opposite parallel sides of the case; circular filters are exempt from these requirements. Separators and media shall not vary more than $^1/_4$ in. (6 mm) from a straight line connecting the fixed ends.

(b) Type B filter packs shall be made from a series of flat panels of pleated filter media, which are assembled in a V shape. 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. Where two flat panels are assembled to form the V shape, the two flat panels shall be bonded by a common 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 media pack is installed in the filter case, the top and bottom of the media pack shall be embedded in the pack to frame adhesive/sealant. 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; circular filters are exempt from these requirements. The media shall be folded such that the apex created by a media fold does not vary by more than $^1/_{16}$ in. (1.6 mm) when compared to an adjacent media fold apex. 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.

Figure FK-4111-4 Type 1 Radial Flow HEPA Filter (External Gelatinous Seal), Midsection View



(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 opposite parallel sides of the case. The top and bottom of the media pack shall be sealed in a reservoir of potting adhesive at least $^{1}/_{16}$ in. (1.6 mm) deep when the media pack is installed in the filter case.

(19) **FK-4131 Filter Pack Limitations.** Types A, C, and D filter packs for axial flow circular Type 2 filters shall have a ratio of pack diameter, *D*, to pack depth, *d*, of no greater than 2.5 *D*/*d*.

Types A, C, and D filter packs for rectangular Type 4 filters shall have a ratio of pack height, *h*, to pack depth, *d*, of no greater than 2.15 *h*/*d*.

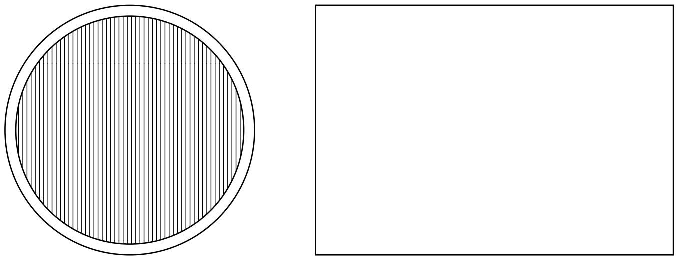
FK-4140 Gaskets

FK-4141 Elastomer. The gasket for Type 1 filters with internal gaskets shall be designed for installation between the seal ring and flange. The seal ring shall uniformly compress the gasket to the flange. The gasket shall be designed to seal against a circular spigot on the filter housing. Gaskets for Type 1 filter with internal gaskets shall not have any joints.

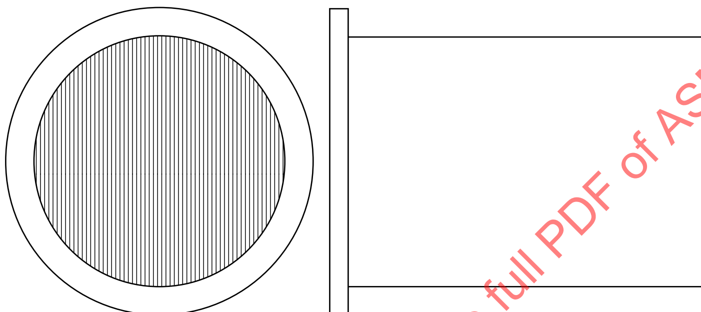
The gasket for Type 1 filters with external gaskets shall be designed for installation in a seal ring groove at the perimeter of the flange. The gasket shall be designed to seal against a tapered machined surface on the filter housing. Gaskets for Type 1 filter with external gaskets shall not have any joints.

The gasket (if required) for Type 2 filters shall be sealed to the filter case with an adhesive per FK-3150. The gasket shall not extend more than $^{1}/_{16}$ in. (1.6 mm) over either side of the seating surface at any point. Type 2 filter gaskets shall not have any joints.

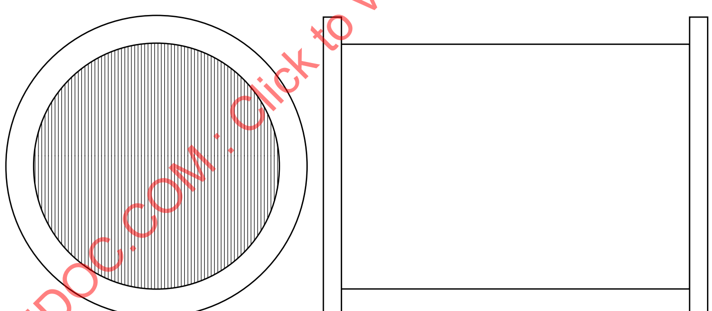
Figure FK-4112-1 Type 2 Axial Flow Circular HEPA Filters



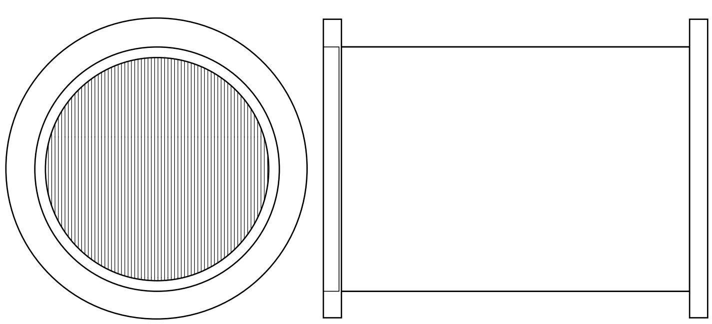
(a) Axial Flow Circular — No Flange



(b) Axial Flow Circular — Single Flange



(c) Axial Flow Circular — Double Flange



(d) Axial Flow Circular — Gelatinous Seal

(19) **Table FK-4112-1 Type 2 Axial Flow Circular HEPA Filter — Nominal Rating**

Maximum Rated Airflow		Maximum Resistance	
acfm	m³/h	in. wg	Pa
20	34	1.0	250
35	60	1.0	250
100	170	1.0	250

The gasket for Type 4 filters shall be sealed to the filter case with an adhesive per FK-3150. The gasket shall not extend more than $^1\!/_{16}$ in. (1.6 mm) over either side of the seating surface at any point (this does not apply to externally mounted seals). If gasket material joints are required for Type 4 filters, they shall be notched or dovetailed and the edges glued in a manner that assures no leakage. There shall be no more than four gasket joints per rectangular HEPA filter gasket-face.

FK-4142 Gelatinous Seal. The gelatinous seal is formed when a continuous knife-edge is inserted into the gelatinous compound. The continuous knife-edge is located on the sealing surface of the holding case or filter housing. The gelatinous compound is located in a continuous channel on the case of the HEPA filter. The continuous channel is integral to the HEPA filter.

The gelatinous compound shall be per FK-3122 and shall conform to the seal knife-edge. The continuous channel, gelatinous seal material, and continuous knife-edge shall be provided with tolerances as required to ensure that the gelatinous compound is deep enough to provide a secure seal.

Space shall be provided between the top of the channel and holding case or filter housing to prevent the gelatinous seal material from sticking to the holding case or filter housing when the continuous knife-edge is inserted into the gelatinous compound.

FK-4150 Grilles

Type 1 filters shall be fitted with internal and external support grilles around the filter media. The support grilles and filter media shall be embedded in adhesive/sealant at the flange and end cap to provide structural strength of the filter. The method of attachment shall be the responsibility of the filter manufacturer.

FK-4160 Face guards

A face guard shall be installed on each face of each filter type excluding Type 1 filters.

FK-4200 PERFORMANCE REQUIREMENTS

The Owner's design specification shall clearly establish the purpose (design function) of the filter and its safety classifications. The Owner's design specification shall include at a minimum the environmental and associated service conditions indicated in Table FK-4200-1.

The Owner or Engineer shall confirm the suitability of the filter media for the specific application.

Designs shall be qualified in accordance with Article FK-5000.

FK-4300 STRUCTURAL REQUIREMENTS

The HEPA filters shall be seismically qualified by test in accordance with AA-4350 when specified by the Owner. The acceptance criteria are as follows:

(a) No structural damage shall be evident by visual examination.

(b) Airflow resistance requirements of FK-5110, FK-5210, and FK-5410 shall be met after the seismic qualification test.

(c) Aerosol particle penetration requirements of FK-5120, FK-5220, and FK-5420 shall be met after the seismic qualification test.

(d) No cracked or warped cases.

(e) No loose joints.

(f) No cracked adhesive.

(g) No loose or deformed media, separators, or grilles.

The HEPA filters shall be mounted on the seismic qualification test machine in the same configuration as the in-service condition with the same sealing or clamping mechanism to provide a valid seismic qualification test.

ARTICLE FK-5000 QUALIFICATION, INSPECTION, AND PRODUCTION TESTING

FK-5100 QUALIFICATION TESTING FOR TYPE 1 RADIAL FLOW FILTERS

New or revised Type 1 filter designs shall require qualification testing prior to acceptance and production. Filter designs shall be requalified at least every 5 yr to verify the consistency of the manufacturing process. Tests shall be performed and certified by an independent test facility.

A qualification sample of 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 qualifies the use of the same gasket or seal on both faces. The test sequence is detailed in Table FK-5100-1. Each Type 1 filter in the qualification sample shall be visually examined for any defects. The acceptance criterion for the filter pack is no visual indication of damage to the filter media, no tears on the surface edge of the filter pleats, and no tears where the filter pack is embedded in the adhesive at the flange and end cap. The acceptance criterion for the flange, grilles, and end cap is no visual indication of dents or deformation. The acceptance criterion for the gel channel and external seal ring is no visual indication of

Table FK-4200-1 Performance Requirements

Parameter	Environmental Service Condition	Units
Temperature	Normal operating	°F (°C)
	Minimum operating	°F (°C)
	Maximum operating	°F (°C)
	Duration for minimum and maximum operating temperatures	...
Air rate	Normal operating at standard conditions	cfm (m^3/h)
	Normal operating at actual conditions	cfm (m^3/h)
	Minimum at standard conditions	cfm (m^3/h)
	Minimum at actual conditions	cfm (m^3/h)
	Maximum at standard conditions	cfm (m^3/h)
	Maximum at actual conditions	cfm (m^3/h)
	Temperature for standard condition	°F (°C)
	Pressure for standard condition	atm (kPa)
Relative humidity	Minimum and maximum operating	%
Chemical exposure	Normal operating condition	...
	Upset condition and duration	...
	Corrosion allowances for filter components that are subject to loss of strength or thinning by corrosion	in. (mm)
	Concentration of each chemical	...
Radiation	Radiological dose level	mrem/h
	Radiation limits	rad (Sv)
	Total integrated dose for the expected life of the filter	rad (Sv)
Biological condition	Biological exposure	...
Penetration	List penetration of particle sizes other than 0.3 micron if required by health physics analysis of filtered medium	%

dents that may interfere with proper sealing. The acceptance criterion for the gelatinous sealant is no visual indication of gouges or separation from the gel channel. The acceptance criterion for the elastomer seal is no visual indication of looseness or tears.

Acceptance shall be contingent on no visual indications of improper assembly, physical damage, structural distress, and no degradation that would impair the ability of a component to perform its intended function. The qualification samples shall be tested for all the requirements for this section. Failure of any filter to comply with the requirements of this section shall be cause for the rejection of the qualification sample.

FK-5110 Resistance to Airflow

The clean filter resistance to airflow shall meet the requirements of Table FK-4111-1 when tested in accordance with FK-5120.

FK-5120 Test Aerosol Particle Penetration

The resistance to airflow and test aerosol particle penetration shall be determined in accordance with Table FK-5100-1. The total aerosol particle penetration through the filter media, frame, and gasket or gelatinous seal shall be no greater than 0.03% of upstream concentration at rated airflow and at 20% of rated airflow when challenged with 0.3 µm particles.

Filters with rated flows less than 125 acfm will be tested at rated flow only.

The Q-76 and Q-107 are suitable penetrometers whose construction and operation are described in MIL-STD-282, Method 102.9. Penetrometers using laser particle counters in accordance with the methods and procedures of IEST-RP-CC007 are also acceptable. 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 penetrometer are dioctylphthalate (DOP), dioctylsebacate (DOS), and 4 centistoke polyalphaolefin (PAO). If using a penetrometer with a particle counter, the aerosol material shall be 4

Table FK-5100-1 Test Groups and Sequence — Type 1 Radial Flow HEPA Filters

Group	Filter Quantity	Requirement	Test Paragraph
I	4	Resistance to rated airflow	FK-5110
		Test aerosol particle penetration at rated airflow	FK-5120
		Resistance to pressure	FK-5140
		Test aerosol particle penetration at 20% of rated airflow only	FK-5120
II	4	Resistance to rated airflow	FK-5110
		Test aerosol particle penetration at rated airflow	FK-5120
		Resistance to rough handling	FK-5130
		Test aerosol particle penetration at rated airflow only	FK-5120
III	1	Resistance to spot flame [see Note (1)]	FK-5160
IV	3	Resistance to heated air at 40% or greater of rated airflow [see Note (1)]	FK-5150
		Test aerosol particle penetration at 40% or greater of rated airflow [see Note (1)]	FK-5120

NOTE: (1) UL 586 qualification is an acceptable substitution for Group III and IV qualification tests. If the filter is qualified to UL 586, then the total filter quantity submitted to the Filter Qualification Test Facility shall be eight filters total.

centistoke polyalphaolefin (PAO) or as defined in IEST-RP-CC007.

FK-5130 Resistance to Rough Handling

Filters shall be tested on a rough handling machine for 15 min at $^3\!/_4$ in. (19 mm) total amplitude at 200 cycles per minute in accordance with Test Method 105.10 of MIL-STD-282. The filter shall be placed on the machine with pleats in a vertical position. 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 joints, cracked adhesive, or loose or deformed media, separators, or grilles. After the rough handling test, the same filter shall meet the requirements in FK-5110 and FK-5120.

FK-5140 Resistance to Pressure (19)

The filter shall be tested for resistance to pressure on a machine capable of testing in accordance with Table FK-5140-1.

Prior to being tested for resistance to pressure, the filter shall be conditioned at atmospheric pressure for a minimum of 24 hr in a chamber at 95°F ± 5°F (35°C ± 3°C) and a relative humidity of 95% ± 5%.

After being conditioned, the filters shall withstand the airflow and water spray environment listed in Table FK-5140-1 without rupture of the filter media. The Type 1 filter shall be installed in the test stand with the filter configured 90 deg from the positions shown in Figures FK-4111-1 through FK-4111-4, with the filter in the horizontal orientation and with the filter inlet facing the airflow stream so that the airflow enters the filter inlet along the centerline of the filter inlet.

Table FK-5140-1 Test Conditions and Requirements

Test Conditions	Test Requirements
Temperature	95°F ± 5°F (35°C ± 3°C)
Relative humidity	95% ± 5%
Rate of airborne water droplets flowing toward the filter [see Note (1)]	1 lb/min ± 0.25 lb/min (0.45 kg/min ± 0.1 kg/min) per 1,000 ft^3/min (1 700 m^3/h)
Pressure differential across filter	10.0 in. water ± 0.2 in. water (2.5 kPa ± 0.05 kPa)
Time to reach pressure	0.5 min, maximum
Time duration at sustained differential pressure	1 hr, minimum
Airflow	That required for producing the above pressure differential

NOTE: (1) Rate of airborne water droplets flowing toward the filter 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 1 in. before the face of the filter.

Within 15 min after completion of the pressure test and while still wet, the filter shall meet the requirement of FK-5120 at 20% airflow.

(19) FK-5150 Resistance to Heated Air

For resistance to heated air, the filter shall be installed in the test chamber and subjected to 40% or greater rated flow of air heated to 700°F ± 50°F (370°C ± 28°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 in accordance with FK-5120 or TA-4634 at rated flow for test aerosol particle penetration through the filter media, case, and gasket or gelatinous seal. The penetration shall not exceed 3%.

Either an Underwriters Laboratories label with its traceable UL control number or a UL 586 designation shall be objective evidence of compliance with FK-5150.

(19) FK-5160 Spot Flame Resistance

The filter is to be mounted in the test duct and the airflow adjusted to rated airflow. A gas flame from a Bunsen burner is to be directed against the upstream face of the unit. The Bunsen burner is to be adjusted to produce a flame with a blue cone $2\frac{1}{2}$ in. (64 mm) long with a tip temperature of 1,750°F ± 50°F (955°C ± 25°C), as measured by a thermocouple inserted in the flame. The tip of the cone is to 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 is to be applied for 5 min at each of three separate locations on the filter face.

The Bunsen burner flame then is to be directed at a location on the filter unit in such a manner that the tip of the blue cone contacts the case, filter pack, and sealing materials. The flame is to be applied for a period of 5 min. The test is to be repeated upon the opposite side 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.

Either an Underwriters Laboratories label with its traceable UL control number or a UL 586 designation shall be acceptable objective evidence of compliance with FK-5160.

(19) FK-5200 QUALIFICATION TESTING FOR TYPE 2 AXIAL FLOW CIRCULAR FILTERS

Type 2 filter designs shall require qualification testing prior to acceptance and production. Filter designs shall be requalified at least every 5 yr to verify the consistency of the manufacturing process. Tests must be performed and certified by an independent test facility.

A qualification sample of 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 qualifies the use of the same gasket or seal on both faces. The test sequence is detailed in Table FK-5200-1.

Each Type 2 filter in the qualification sample shall be visually examined for any defects. The acceptance criterion for the filter pack is no visual indication of damage to the filter media, no tears on the surface edge of the filter pleats, and no tears where the filter pack is embedded in the adhesive at the circular case flange. The acceptance criterion for the case and flange is no visual indication of dents or deformation. The acceptance criterion for the gelatinous sealant is no visual indication of gouges or separation from the gel channel. The acceptance criterion for the gel channel is no visual indication of dents that may interfere with proper sealing. The acceptance criterion for the elastomer seal is no visual indication of looseness and no tears. Acceptance shall be contingent upon no visual indications of improper assembly, physical damage, structural distress, or any degradation that would impair the ability of a component to perform its intended function.

The qualification samples shall be tested for all the requirements for this section. Failure of any filter to comply with requirements of this section shall be cause for the rejection of the qualification sample.

Under constraints specified below, certain eligible Type 2 axial-flow circular filters may be qualified based upon the prior qualification of a filter listed in Table FC-4110-1 to the requirements of Article FC-5000. Under similar constraints below, certain eligible Type 2 axial-flow circular filters may be alternatively qualified to the requirements of Article FK-5000, via qualification of comparable Type 2 axial-flow circular filters of equal or larger diameter. Qualification based upon referenced filter is considered valid only for as long as the referenced filter remains qualified.

For Table FC-4110-1 referenced filters, eligible Type 2 Section FK filters shall have the same materials of construction and pack design as the qualified filter referenced in Table FC-4110-1. They also shall be manufactured using equivalently similar methods and equipment, and rated at an identical usable face velocity. Eligible Type 2 filters shall also have a pack diameter, D, no greater than the pack height of the qualified filter being referenced.

For Section FK referenced filters, eligible Type 2 Section FK filters shall have the same materials of construction and pack design as the qualified referenced filter, as well as have been manufactured using the same methods and equipment and rated at an identical usable face velocity. Eligible Type 2 filters shall also have a pack diameter, D, of the qualified filter being referenced. Moreover, eligible Type 2 filters shall have a ratio of pack diameter, D, to pack depth, d, no greater than the D/d ratio of the qualified Type 2 filter being referenced.

Table FK-5200-1 Test Groups and Sequence — Type 2 Axial Flow Circular HEPA Filters

Group	Filter Quantity	Requirement	Test Paragraph
I	4	Resistance to rated airflow	FK-5210
		Test aerosol particle penetration at rated airflow	FK-5220
		Resistance to pressure	FK-5240
		Test aerosol particle penetration at 20% of rated airflow only	FK-5220
II	4	Resistance to rated airflow	FK-5210
		Test aerosol particle penetration at rated airflow	FK-5220
		Resistance to rough handling	FK-5230
		Test aerosol particle penetration at rated airflow only	FK-5220
III	1	Resistance to spot flame [see Note (1)]	FK-5260
IV	3	Resistance to heated air at 40% or greater of rated airflow [see Note (1)]	FK-5250
		Test aerosol particle penetration at 40% or greater of rated airflow [see Note (1)]	FK-5220

NOTE: (1) UL 586 qualification is an acceptable substitution for Group III and IV qualification tests. If the filter is qualified to UL 586, then the total filter quantity submitted to the filter qualification test facility shall be eight filters total.

For example, a 12 in. high × 12 in. wide × 5⅞ in. deep (305 mm high × 305 mm wide × 149 mm deep) filter listed in Table FC-4110-1 with a 14 gauge steel case qualified to the requirements of Article FC-5000 would qualify a Type 2 axial-flow circular filter 10⅝ in. (270 mm) in diameter and 8 in. (200 mm) deep with a 14 gauge steel case where the media and pack density are the same as the Section FC filter.

Designs that can not be qualified based on the prior qualification of a Type 2 filter, or a filter size listed in Table FC-4110-1, as specified above, shall require qualification testing prior to acceptance and production.

Refer to FK-4131 for the maximum allowable value of the ratio for pack diameter to pack depth, D/d, of Type 2 filters using Type A, C, and D filter packs.

FK-5210 Resistance to Airflow

The clean filter resistance to airflow shall meet the requirements of Table FK-4112-1 when tested in accordance with FK-5220.

FK-5220 Test Aerosol Particle Penetration

The resistance to airflow and test aerosol particle penetration shall be determined in accordance with Table FK-5200-1. The total aerosol particle penetration through the filter media, frame, and gasket or gelatinous seal shall be no greater than 0.03% of upstream concentration at rated airflow and at 20% of rated airflow when challenged with 0.3 μm particles.

Filters with rated flows less than 125 acfm will be tested at rated flow only.

The Q-76 and Q-107 are suitable penetrometers. Penetrometers using laser particle counters in accordance with the methods and procedures of IEST-RP-CC007 are also acceptable. 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 penetrometer are dioctylphthalate (DOP), dioctylsebacate (DOS), and 4 centistoke polyalphaolefin (PAO). If using a penetrometer with a particle counter, the aerosol material shall be 4 centistoke polyalphaolefin (PAO) or as defined in IEST-RP-CC007.

FK-5230 Resistance to Rough Handling

Filters shall be tested on a rough handling machine for 15 min at ¾ in. (19 mm) total amplitude at 200 cycles per minute in accordance with Test Method 105.10 of MIL-STD-282. The filter shall be placed on the machine with pleats in a vertical position. 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, or loose or deformed media, separators, or grilles. After the rough handling test, the same filter shall meet the requirements in FK-5210 and FK-5220.

FK-5240 Resistance to Pressure

The filter shall be tested for resistance to pressure on a machine capable of testing in accordance with Table FK-5140-1.

Prior to being tested for resistance to pressure, the filter shall be conditioned at atmospheric pressure for a minimum of 24 hr in a chamber at 95°F ± 5°F (35°C ± 3°C) and a relative humidity of 95% ± 5%.

After being conditioned, the filters shall withstand the airflow and water spray environment listed in Table FK-5140-1 without rupture of the filter media.

The Type 2 filter shall be installed in the test stand with the filter configured as shown in Figure FK-4112-1, with the filter in the horizontal orientation and with the filter inlet facing the airflow stream so that the airflow enters the filter inlet along the centerline of the filter inlet.

Within 15 min after completion of the pressure test and while still wet, the filter shall meet the requirement of FK-5220 at 20% airflow.

FK-5250 Resistance to Heated Air

For resistance to heated air, the filter shall be installed in the test chamber and subjected to 40% or greater rated flow of air heated to 700°F ± 50°F (370°C ± 28°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 in accordance with FK-5220 or TA-4634 at rated flow for test aerosol particle penetration through the filter media, case, and elastomer or gelatinous seal. The penetration shall not exceed 3%.

Either an Underwriters' Laboratories label with its traceable UL control number or a UL 586 designation shall be objective evidence of compliance with FK-5250.

(19) FK-5260 Spot Flame Resistance

The filter is to be mounted in the test duct and the airflow adjusted to rated airflow. A gas flame from a Bunsen burner is to be directed against the upstream face of the unit. The Bunsen burner is to be adjusted to produce a flame with a blue cone $2^1/_2$ in. (64 mm) long with a tip temperature of 1,750°F ± 50°F (955°C ± 25°C), as measured by a thermocouple inserted in the flame. The tip of the cone is to 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 is to be applied for 5 min at each of three separate locations on the filter face.

The Bunsen burner flame then is to be directed at a location on the filter unit in such a manner that the tip of the blue cone contacts the case, filter pack, and sealing materials. The flame is to be applied for a period of 5 min. The test is to be repeated upon the opposite side 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.

Either an Underwriters Laboratories label with its traceable control number or a UL 586 designation shall be acceptable objective evidence of compliance with FK-5260.

FK-5400 QUALIFICATION TESTING FOR TYPE 4 AXIAL FLOW RECTANGULAR FILTERS

Type 4 filter designs shall require qualification testing prior to acceptance and production. Filter designs shall be requalified at least every 5 yr to verify the consistency of the manufacturing process. Tests must be performed and certified by an independent test facility.

A qualification sample of 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 qualifies the use of the same gasket or seal on both faces. The test sequence is detailed in Table FK-5400-1.

Each Type 4 filter in the qualification sample shall be visually examined for any defects. The acceptance criterion for the filter pack is no visual indication of damage to the filter media, no tears on the surface edge of the filter pleats, and no tears where the filter pack is embedded in the adhesive at the top and bottom of the filter case, or where it is sealed to the two sides of the case. The acceptance criterion for a metal case is no visual indication of dents or deformation. The acceptance criterion for a wood case is no visual indication of cracks at joints, or warping, or of splintering. The acceptance criterion for the gel channel is no visual indication of dents that may interfere with proper sealing. The acceptance criterion for the gelatinous sealant is no visual indication of gouges or separation from the gel channel. The acceptance criterion for the elastomer seal is no visual indication of looseness or tears.

Acceptance shall be contingent upon no visual indications of improper assembly, physical damage, structural distress, or any degradations that would impair the ability of a component to perform its intended function.

The qualification samples shall be tested for all the requirements for this section. Failure of any filter to comply with the requirements of this section shall be cause for the rejection of the qualification sample.

Under the following constraints, certain eligible Type 4 filters may be qualified based upon the prior qualification of a Type 4 filter, or of a filter size listed in Table FC-4110-1 containing the same materials of construction, the same pack design, fabricated using the same manufacturing methods and equipment, and rated at an identical usable face velocity as the filter being referenced for qualification. This is limited to Type 4 Section FK filters with pack face dimensions of height, *h*, and width, *w*, that are no greater than the respective values of the qualified Section FK or Section FC filter being referenced. Qualification based upon a referenced filter is considered valid only for as long as the referenced filter remains qualified.

Refer to FK-4131 for the maximum allowable value of the ratio for pack height to pack depth, D/d, of Type 4 filters using Type A, C, and D filter packs.

Designs that can not be qualified based on the prior qualification of a Type 4 filter, or a filter size listed in Table FC-4110-1 as specified above, shall require qualification testing prior to acceptance and production.

Table FK-5400-1 Test Groups and Sequence — Type 4 Axial Flow Rectangular HEPA Filters

Group	Filter Quantity	Requirement	Test Paragraph
I	4	Resistance to rated airflow	FK-5410
		Test aerosol particle penetration at rated airflow	FK-5420
		Resistance to pressure	FK-5440
		Test aerosol particle penetration at 20% of rated airflow only	FK-5420
II	4	Resistance to rated airflow	FK-5410
		Test aerosol particle penetration at rated airflow	FK-5420
		Resistance to rough handling	FK-5430
		Test aerosol particle penetration at rated airflow only	FK-5420
III	1	Resistance to spot flame [see Note (1)]	FK-5460
IV	3	Resistance to heated air at 40% or greater of rated airflow [see Note (1)]	FK-5450
		Test aerosol particle penetration at 40% or greater of rated airflow [see Note (1)]	FK-5420

NOTE: (1) UL 586 qualification is an acceptable substitution for Group III and IV qualification tests. If the filter is qualified to UL 586, then the total filter quantity submitted to the filter qualification test facility shall be eight filters total.

(19) FK-5410 Resistance to Airflow

The clean filter resistance to airflow shall not exceed 1.3 in. wg (325 Pa) when tested in accordance with FK-5420.

FK-5420 Test Aerosol Particle Penetration

The resistance to airflow and test aerosol particle penetration shall be determined in accordance with Table FK-5400-1. The total aerosol particle penetration through the filter media, frame, and gasket or gelatinous seal shall be no greater than 0.03% of upstream concentration at rated airflow and at 20% of rated airflow when challenged with 0.3 μm particles.

Filters with rated flows less than 125 acfm will be tested at rated flow only.

The Q-76 and Q-107 are suitable penetrometers. Penetrometers using laser particle counters in accordance with the methods and procedures of IEST-RP-CC007 are also acceptable. 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 penetrometer are dioctylphthalate (DOP), dioctylsebacate (DOS), and 4 centistoke polyalphaolefin (PAO). If using a penetrometer with a particle counter, the aerosol material shall be 4 centistoke polyalphaolefin (PAO) or as defined in IEST-RP-CC007.

FK-5430 Resistance to Rough Handling

Filters shall be tested on a rough handling machine for 15 min at $^3/_4$ in. (19 mm) total amplitude at 200 cycles per minute in accordance with Test Method 105.10 of MIL-STD-282. The filter shall be placed on the machine with pleats in a vertical position. 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, or loose or deformed media, separators, or grilles. After the rough handling test, the same filter shall meet the requirements in FK-5410 and FK-5420.

FK-5440 Resistance to Pressure (19)

The filter shall be tested for resistance to pressure on a machine capable of testing in accordance with Table FK-5140-1.

Prior to being tested for resistance to pressure, the filter shall be conditioned at atmospheric pressure for a minimum of 24 hr in a chamber at 95°F ± 5°F (35°C ± 3°C) and a relative humidity of 95% ± 5%.

After being conditioned, the filters shall withstand the airflow and water spray environment listed in Table FK-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 FK-5420 at 20% airflow.

FK-5450 Resistance to Heated Air (19)

For resistance to heated air, the filter shall be installed in the test chamber and subjected to 40% or greater rated flow of air heated to 700°F ± 50°F (370° ± 28°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 in accordance with FK-5420 or TA-4634 at rated flow for test aerosol particle penetration through the filter media, case, and elastomer or gelatinous seal. The penetration shall not exceed 3%.

Either an Underwriters' Laboratories label with its traceable UL control number or a UL 586 designation shall be objective evidence of compliance with FK-5450.

(19) **FK-5460 Spot Flame Resistance**

The filter is to be mounted in the test duct and the airflow adjusted to rated airflow. A gas flame from a Bunsen burner is to be directed against the upstream face of the unit. The Bunsen burner is to be adjusted to produce a flame with a blue cone $2\frac{1}{2}$ in. (64 mm) long with a tip temperature of 1,750°F ± 50°F (955°C ± 25°C), as measured by a thermocouple inserted in the flame. The tip of the cone is to 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 face case. The flame is to be applied for 5 min at each of three separate locations on the filter face.

The Bunsen burner flame then is to be directed at a location on the filter unit in such a manner that the tip of the blue cone contacts the case, filter pack, and sealing materials. The flame is to be applied for a period of 5 min. The test is to be repeated upon the opposite side 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.

Either and Underwriters Laboratories label that with its traceable control number or a UL 586 designation shall be acceptable objective evidence of compliance with FK-5460.

FK-5500 INSPECTION

Each HEPA filter shall be visually inspected to show conformance to size specification, and to verify that the manufacturer's filter label indicates it has been tested at the flow rate of Table FK-4111-1 or Table FK-4112-1 for Type 1 or 2 filters, respectively. Type 4 filters are as specified on the filter label. Additional attributes to be inspected are height, width, depth, squareness, and adherence of gaskets.

Gaskets shall be glued firmly and continuously to the case. Loose, peeling, or distorted gaskets shall be cause for rejection of the filter. The gasket on Type 4 filters shall not extend more than $\frac{1}{16}$ in. (1.6 mm) over either side of the seating surface at any point. Edges of the gasket joint area shall be thoroughly coated with adhesive before assembly.

FK-5600 PRODUCTION TESTING

Each Type 1, 2, and 4 filter manufactured for delivery shall be tested for resistance to airflow and test aerosol particle penetration in accordance with the following:

(a) FK-5110 and FK-5120 for Type 1 filters
(b) FK-5210 and FK-5220 for Type 2 filters
(c) FK-5410 and FK-5420 for Type 4 filters

Results shall be marked on the label of each filter.

ARTICLE FK-6000 FABRICATION

FK-6100 GENERAL

The HEPA filter shall be assembled from the materials designated in Article FK-3000 in accordance with the design requirements established in Article FK-4000. Following assembly, the filter shall be inspected and qualified in accordance with Article FK-5000. Production testing of qualified filters shall conform to FK-5600.

FK-6200 MANUFACTURE AND ASSEMBLY

The general requirements for fabrication and installation are contained in AA-6200 and AA-6300.

FK-6210 Tolerances

FK-6211 Flatness and Squareness

(a) Type 1 filter flange and end cap tolerances shall meet the following criteria: parallel within $\frac{1}{16}$ in. (1.6 mm), square to the filter centerline axis to within $\frac{1}{16}$ in. (1.6 mm) over the total filter length, flat within $\frac{1}{16}$ in. (1.6 mm).

(b) Type 2 filter tolerances shall meet the following criteria: ends parallel within $\frac{1}{16}$ in. (1.6 mm), square to the filter centerline axis to within $\frac{1}{16}$ in. (1.6 mm) over the total filter length, flat within $\frac{1}{16}$ in. (1.6 mm).

(c) Type 4 filters tolerances shall meet the following criteria: faces of the case shall be flat and parallel to within a total allowance of $\frac{1}{16}$ in. (1.6 mm). The case shall be square to within a total allowance of $\frac{1}{8}$ in. (3 mm) when measured diagonally across the corners of both faces.

FK-6212 Overall Dimensions

(a) Type 1 filter length shall be $\pm\frac{1}{16}$ in. (1.6 mm), filter seal ring diameter $\pm\frac{1}{16}$ in. (±1.6 mm), sealing face diameter $+\frac{1}{32}$ in., −0 in. (+0.8 mm, −0 mm), concentricity shall be $\frac{1}{16}$ in. (1.6 mm), all other dimensions $\pm\frac{1}{16}$ in. (±1.6 mm).

(b) Type 2 filters shall have diameters within $+\frac{1}{8}$ in., −0 in. (+3 mm, −0 mm), and depths within $+\frac{1}{16}$ in., −0 in. (±1.6 mm, −0 mm).

(c) Type 4 filters outside dimensions shall be within +0 in., $-\frac{1}{8}$ in. (+0 mm, −3 mm). Depth shall be within $+\frac{1}{16}$ in., −0 in. (+1.6 mm, −0 mm). The above dimensions exclude gaskets.

FK-6220 Media Installation

The filter media shall be fastened to the filter case or end caps 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.

FK-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 face guards; cracks in adhesive; and cracks or holes in exposed portions of the media. All required fasteners shall be securely installed. All the dimensional and performance requirements of this Code section are directed toward achieving the highest quality and level of workmanship possible.

ARTICLE FK-7000 PACKAGING, SHIPPING, AND STORAGE

Packaging, shipping, and storage shall be in accordance with Article AA-7000 and ASME NQA-1 Level B.

HEPA filters shall be individually packaged. Cartons shall have extra shock absorbing material at the corners or edges of the filter that centers the filter within the carton to prevent damage.

Type 1, Type 2, and Type 4 filters shall be placed in the carton with the pleats vertical. The carton should be placed on skids or otherwise packed in such a manner that the pleats remain vertical during shipment.

HEPA filters with gelatinous seals shall be packaged in a manner to prevent the gelatinous compound from sticking to the packaging material. A means shall be provided to prevent the gelatinous seal from being gouged or pulled out of the continuous channel when the filter is removed from the shipping carton/plastic bag.

Cartons for HEPA filters shall not be stacked more than 6½ ft (2 m) high during packaging, shipping, handling, and storage.

The HEPA filter carton shall be clearly marked for proper orientation per FK-9200.

ARTICLE FK-8000 QUALITY ASSURANCE

Quality assurance shall conform to the requirements of Article AA-8000 and the following.

FK-8100 RESPONSIBILITY

The manufacturer shall provide all specified information required by this Code to ensure quality control.

The manufacturer shall perform all detailed examinations and tests required by this Code at the stages of construction necessary to permit them to be meaningful.

FK-8200 CERTIFICATE OF CONFORMANCE

The certificate of conformance shall state that the filters conform to all requirements of Section FK.

ARTICLE FK-9000 NAMEPLATES (19)

FK-9100 FILTER MARKING

Marking or labeling of each filter shall be on the top of the filter when the pleats are vertical. Letter size shall be ⅛ in. (3 mm) minimum.

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 (except Type 1 filters)
(f) pressure drop [in. wg (Pa)] at 100% rated flow
(g) overall penetration at rated flow
(h) UL label indicating successful testing per UL 586 if applicable
(i) date of manufacture

FK-9200 PACKAGE MARKING

Marking or labeling of each shipping container (carton containing one filter) shall provide, as a minimum, the following information:

(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 ⅜ in. (10 mm) high
(c) filter model number
(d) purchase order number or other identifying mark requested by purchaser

NONMANDATORY APPENDIX FK-A DETERMINATION OF HEPA FILTER SERVICE LIFE

Despite the difficulty of determining HEPA filter life based on research data, a conservative interpretation of these data can be used to set age limits. The age limit can be set based on the data derived from the observed decreases in the tensile strength of dry filter media with age and the further reduction in strength due to water exposure.

Although filter life cannot be directly estimated using the data, there is a significant decrease in tensile strength with age for both the unfolded and folded media. Test results also showed a decrease in media tensile strength with age, although the trends were not as distinct because of the scatter in the data.

The extrapolated test data for unfolded media suggests its tensile strength fails at 13 yr. Tests indicate that folded media does not have the required 2.5 lb/in. tensile strength even when new and its tensile strength is extremely low at 7 yr. Research shows that the tensile strength of new filter media is directly proportional to the pressure drop at which the HEPA filter shows structural failure at the pleats. By applying this relationship to aged HEPA filters, the minimum pressure drop for structural damage decreases with age. Similarly, the burst strength data show several filters with very low burst strength after 7 yr to 8 yr. Thus, under dry conditions, the filter media fail the required tensile strength or have very low burst strengths after 7 yr to 13 yr, or an average of 10 yr.

Based on this data, it is recommended that HEPA filter life under dry conditions be set at 10 yr.

When the filter has been exposed to water, the strength of the filter media is further decreased, thereby reducing effective filter life. Even if a demister was used, the high humidity resulting from the water sprays would most likely cause the filter to become wet. Tests have shown the combined effect of both age and water exposure. Water exposure reduces the age limit for the same strength criterion. For example, the occurrence of water exposure would shift the age limit for a dry media from 7 yr to 3 yr. Exposure to water will reduce the HEPA tensile strength to less than the initial acceptance tests. Thus, a filter that could fail at 7 yr to 13 yr when dry could fail at about 3 yr to 7 yr, or an average of 5 yr, when the potential for water exposure exists. Filters that actually become wet should be replaced as soon as possible.

The water repellency of the filter media also appears to decrease with age. However, this decrease may be largely due to water adsorption by deposited particles. Research found that folding the filter media decreases the water repellency even for new filter media. Tests also showed a decrease in water repellency with folded media and found that even the pleats of new media absorb water. The pleat water absorption coupled with its inherent weakness makes the pleats especially prone to structural failure.

Based on this data, it is recommended that HEPA filter life under wet conditions be set at 5 yr.

A 5-yr maximum age of HEPA filters for ventilation systems having in-duct water sprays can be justified because of decreased tensile and burst strengths and decreased water repellency resulting from age and with media folding.

The age limits in this report are based on highly variable data, but more accurate age limits can be derived from controlled experiments in real time over 5 yr to 10 yr using a specific filter media roll. Until such long term studies are conducted, establishing a 5 yr and 10 yr HEPA filter life for wet and dry ventilation systems, respectively, will ensure that most (although not all) HEPA filters will not suffer a significant loss in strength due to age.

The data and recommendations presented in this Appendix have been adapted from Bergman, W., "Maximum HEPA Filter Life," UCRL-AR-134141, Lawrence Livermore National Laboratory, 1999.

NONMANDATORY APPENDIX FK-B
DIVISION OF RESPONSIBILITY

Table FK-B-1000-1 Division of Responsibility

FK-	Item	Responsible Party
3000	Materials	Engineer/Manufacturer
4000	Design	Manufacturer
4300	Structural analysis	Manufacturer
4300	Seismic data	Owner/Engineer
5100, 5200, 5400	Qualification testing	Independent test laboratory
5110, 5210, 5410	Airflow performance	Manufacturer
5120, 5220, 5420	Penetration performance	Manufacturer
5600	Production testing	Manufacturer
6000	Fabrication	Manufacturer
6210	Tolerance	Manufacturer
7000	Packaging, shipping, and storage	Manufacturer/Owner
8000	Quality assurance	Manufacturer
9000	Nameplates	Manufacturer

SECTION FL
DEEP BED SAND FILTERS

ARTICLE FL-1000
INTRODUCTION

FL-1100 SCOPE

This section provides requirements for the materials, design, inspection and testing, fabrication/field construction, packaging, shipping, receiving, storage and handling, quality assurance, and labels and markings for deep bed sand (DBS) filters and DBS filter components used in nuclear air and gas treatment systems. The scope of this section of the Code is limited to DBS filters with vertical airflow.

FL-1200 PURPOSE

The purpose of this section is to ensure that DBS filters used in nuclear applications are acceptable in all aspects of performance, design, construction, acceptance, and testing.

FL-1300 APPLICABILITY

This section applies to DBS filters with vertical airflow. DBS filters are constructed in place. The normal function of these filters is to filter particulate from the air or gas stream prior to exhausting to the atmosphere. The filters are nonflammable.

FL-1310 Limitations

This section of the Code does not cover the integration of a DBS filter into a system.

FL-1320 Division of Responsibility

Nonmandatory Appendix FL-A contains a suggested division of responsibility.

(19) ### FL-1400 DEFINITIONS AND TERMS

Definitions that have common applications are contained in Article AA-1000. The following terms have special meaning in the context of this section.

aggregate: the filter media of a DBS filter, including all grades of rock, gravel, and sand that compose the various layers of the DBS filter bed to provide the filtration function of the DBS filter.

air face velocity: the air face velocity of a DBS filter in feet per minute (m/h). This is the design airflow in cubic feet per minute (m^3/h) divided by the cross-sectional area of the filter media in square feet (m^2) perpendicular to the airflow through the DBS filter.

deep bed sand (DBS) filter: a filter up to several feet thick containing graded layers of rock, gravel, and sand that diminish in granule size as the layers go from bottom to top. Airflow direction is upward so that granules decrease in size in the direction of flow. A top layer of moderately coarse sand is generally added to prevent fluidization of the finest sand layer underneath. The total bed is enclosed in a lined (usually concrete) pit.

deep bed sand (DBS) filter structure: those portions of a DBS filter that house, support, and protect the filter media. This includes the walls, floor, foundation, ceiling, columns, and beams. It also includes the distribution channels that are integral to the foundation or floor and integral to operation of the DBS filter.

design life: the period between initial start-up of the DBS filter and decommissioning of the filter.

distribution blocks: hollow blocks designed with openings to allow air to flow from the distribution channels under the filter bed.

distribution channels: channels which pass under the distribution support structure for airflow into the distribution support structure.

friable material: aggregate that is readily reduced to finer particles by mechanical action or pressure.

special test sections: test sections designed and constructed within the DBS filter that allow the total leak rate of the DBS filter to be calculated based on the leak rate measured.

water extractable material: that material which is dissolved or suspended in the water effluent of thoroughly washed aggregate. This includes common soil.

ARTICLE FL-2000
REFERENCED DOCUMENTS (19)

The codes and standards listed below shall supplement those listed in Article AA-2000. Unless otherwise specified, the latest edition shall apply.

ACI 117, Specifications for Tolerances for Concrete Construction and Materials
ACI 349, Code Requirements for Nuclear Safety-Related Concrete Structures
Publisher: American Concrete Institute (ACI), 38800 Country Club Drive, Farmington Hills, MI 48331 (www.concrete.org)

Industrial Ventilation: A Manual of Recommended Practice, 23rd Edition
Publisher: American Conference of Governmental Industrial Hygienists (ACGIH), 1330 Kemper Meadow Drive, Cincinnati, OH 45240 (www.acgih.org)

AISC 303, Code of Standard Practice for Steel Buildings and Bridges
AISC 326, Detailing for Steel Construction
AISC N690, Specification for Safety-Related Steel Structures for Nuclear Facilities
Publisher: American Institute for Steel Construction (AISC), 130 East Randolph Street, Suite 2000, Chicago, IL 60601 (www.aisc.org)

ASME Code for Pressure Piping, B31
Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990 (www.asme.org)

ASTM A262, Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
ASTM A732, Standard Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures
ASTM A781, Standard Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use
ASTM C136, Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C294, Standard Descriptive Nomenclature for Constituents of Concrete Aggregates
ASTM C295, Standard Guide for Petrographic Examination of Aggregates for Concrete
ASTM C702, Standard Practice for Reducing Samples of Aggregate to Testing Size
ASTM D75, Standard Practice for Sampling Aggregates
ASTM E11, Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves
Publisher: American Society of Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 (www.astm.org)

NAAMM MBG 531, Metal Bar Grating Manual Heavy Duty Metal Bar Grating Manual
Publisher: National Association of Architectural Metal Manufacturers (NAAMM), 800 Roosevelt Road, Building C, Suite 312, Glen Ellyn, IL 60137 (www.naamm.org)

ARTICLE FL-3000 MATERIALS

FL-3100 ALLOWABLE MATERIALS

FL-3110 General Requirements

All materials used shall have properties and composition suitable for the application as defined by the design specification and the operating environmental conditions including structural loads as defined in AA-4213. Materials shall be in conformance with the latest revision of the ASME, ASTM, or other document listed in Table AA-3100-1 or in Article FL-2000 of this section. Substitute materials shall be equivalent to or exceed these requirements and shall be approved by the Owner or the Owner's designee.

Materials that are part of the structure, pressure boundary, or support equipment shall meet the structural requirements of Article AA-4000 as amended by FL-4300 of this section.

FL-3111 Protective Coatings. Carbon steel and concrete surfaces shall be coated or painted to protect against corrosion and to facilitate cleaning and decontamination. Coatings shall comply with the requirements of AA-6500. Coating application shall conform to ASTM D4227 and ASTM D4228.

Coatings shall meet the radiation resistance, chemical resistance, and decontamination requirements in accordance with the design specification.

FL-3120 Filter Media

Filter media shall be made up of multiple layers of aggregate designed and installed in accordance with the requirements of Article FL-4000. The aggregate shall meet the friable material requirements stated in the Owner's specifications (see FL-5114 and FL-B-3140). The aggregate shall be chemically compatible with constituents in the exhaust stream.

FL-3130 DBS Filter Structure and Distribution Channels

The DBS filter structure and distribution channels shall be constructed from material suitable for the environment as specified in Article FL-4000.

Structural steel, filler metal and flux for welding, and steel bolts shall conform to a material standard specification from Table AA-3100-1 or an equivalent approved by the Owner or the Owner's designee.

FL-3140 Distribution Support Structure

The distribution support structure shall be constructed from materials suitable for the environment as specified in Article FL-4000. The distribution support structure shall be constructed to support the weight of the filter media, including vertical and horizontal seismic forces.

The distribution support structure may be either steel, vitrified, or ceramic distribution block, or elevated structural steel grating.

FL-3150 Monitoring, Sampling, and Instrumentation Lines

All tubing for instrumentation shall be stainless steel in accordance with ASTM A269. Tubing wall thickness shall be adequate for the pressure and temperature requirements of the DBS filter and in accordance with ASME B31.3. The monitoring and sampling lines shall be constructed from stainless steel or other corrosion resistant material suitable for the environment as specified in Article FL-4000.

FL-3160 Gaskets

Gasket material, if used, shall be oil and corrosion resistant material suitable for the environment as specified in Article FL-4000.

FL-3200 SPECIAL LIMITATIONS OF MATERIALS

A consideration of material deterioration caused by service is outside the scope of this section of the Code. It is the responsibility of the Owner or the Owner's designee to identify the environment in which the DBS filter shall operate.

FL-3300 CERTIFICATION OF MATERIALS

For structural and steel materials, the supplier shall make available Certified Material Test Reports (CMTRs) of chemical and physical properties.

All other materials used in the construction of DBS filters shall be provided with a manufacturer's certificate of conformance covering the ASME, ASTM, or other material specification, grade, and class, if applicable.

ARTICLE FL-4000 DESIGN

FL-4100 GENERAL DEEP BED SAND FILTER DESIGN

The design described in this section of the Code is provided so that an engineer can review these specific requirements and design a DBS filter to specific needs. Most new designs do not require the very rigid design described in this section of the Code; however, most DBS filters can be designed using this information. Most designs have basic requirements for filter media, the depth of the aggregate layers, airflow design resistance, air distribution, DBS filter capacity, and the location of monitoring, sampling, and instrumentation lines. All DBS filter designs should be proven by a DBS filter mock-up (see FL-B-2000).

FL-4110 DBS Filter Design

DBS filters shall be designed, sized, and constructed to meet the ventilation and filtration needs of the facilities being serviced. Typically, DBS filters are designed to operate for the life of the facility as verified by performance testing. In the event a facility is under review to extend its life, the DBS filter and any needs and requirements that have changed must also be assessed.

Additionally, DBS filters shall be designed with the end-state in mind as identified and agreed upon by the Owner and regulatory authority. (See FL-B-2300 for more information.)

FL-4120 General Arrangement

DBS filters shall be composed of multiple horizontal layers of aggregate with airflow entering through the bottom of the DBS filter bed. Air shall contact the coarsest layer of aggregate first. The air shall flow vertically upward through the bed, passing through progressively finer layers of aggregate. (See Figure FL-4120-1.)

The layers of aggregate shall be evenly distributed across the face of the DBS filter to a uniform depth (see FL-6450 and FL-B-2000). Each layer shall contact the interior side walls of the DBS filter on all sides. A coarse cap layer may be used to prevent the transport of fines into downstream portions of the exhaust system.

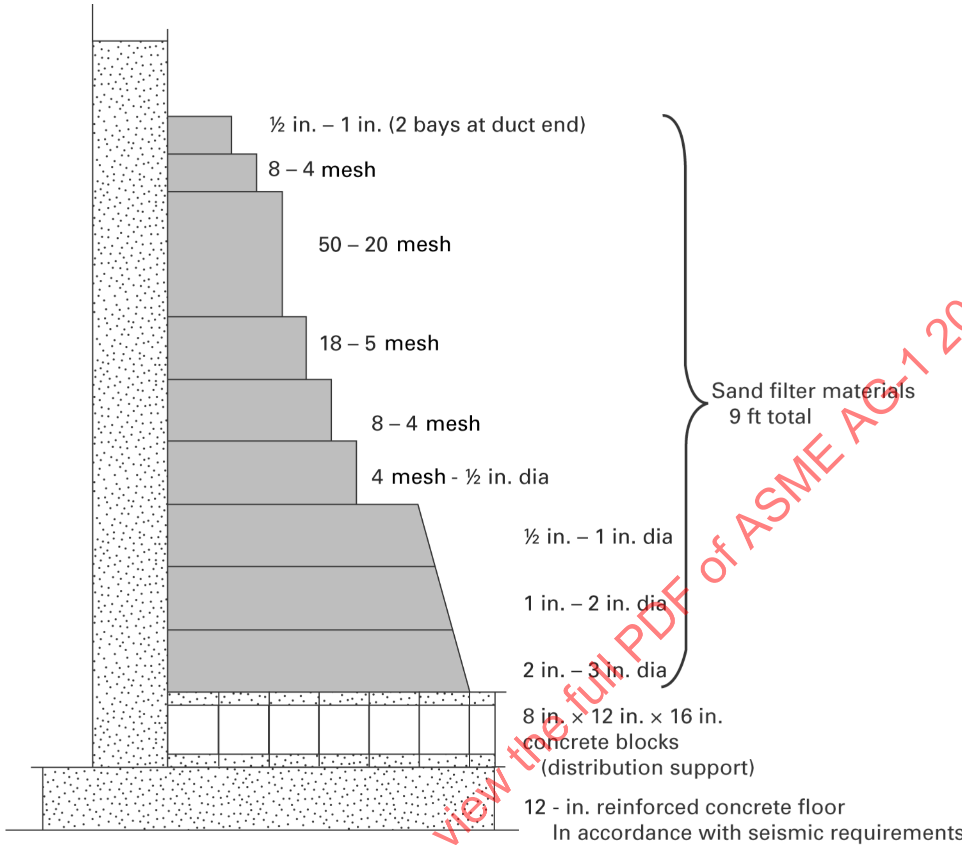
Distribution channels (an air distribution system) shall be provided prior to the first layer of aggregate to ensure uniform distribution of airflow across the bed.

A distribution support structure comprised of a layer of perforated distribution blocks or structural steel grating shall be placed below the bottom layer of aggregate. Distribution blocks, if used, can be fabricated from steel, vitrified, or ceramic materials. The blocks or grating shall allow air to flow up from the distribution channels and prevent the aggregate from falling into the distribution channels, and shall have sufficient load-bearing capacity (as confirmed by analysis and/or testing) so as not to be damaged by the weight of the filter media above in either normal conditions or postulated accident conditions. The blocks or grating aid in the even distribution of airflow through the bed.

FL-4200 DESIGN CRITERIA

Design criteria shall be prepared by the Owner or designee in sufficient detail to provide a complete basis for DBS filter design in accordance with this

Figure FL-4120-1 Typical DBS Filter Cross Section, DOE-HDBK-1169-2003



section of the Code. As a minimum, design criteria shall be specified for the following parameters:

(a) type of trace contaminant in the airflow to be treated (including, but not limited to, corrosive constituents, particulates, and vapors)

(b) rated airflow, nominal, cfm (m^3/h)

(c) design pressure, in. wg (Pa)

(d) temperature operating range, °F (°C)

(e) relative humidity operating range, % RH

(f) contaminants to be removed, including type and concentration

(g) required particulate removal efficiency based on anticipated particle size

(h) initial resistance, in. wg (Pa) at rated flow

(i) final resistance, in. wg (Pa) at rated flow

(j) seismic requirements

(k) number of DBS filter bed layers

(l) depth of each DBS filter bed layer

(m) size/range requirements for individual grains/stones in each DBS filter bed layer

(n) required design life

(o) natural phenomena

(p) amount of water extractable materials

(q) material gradation values

(r) acceptable weighted composition of slate, shale, and friable material in each type of aggregate

(s) loss of weight by leaching

FL-4210 Design Features (19)

The design shall include the following features:

(a) access for interior inspection of the top surface of the DBS filter bed, including an air lock. The space between the surface of the DBS filter bed and the DBS filter roof shall be tall enough for a person to enter and inspect the DBS filter.

(b) special test sections within the bed of the DBS filter for air-aerosol mixing uniformity testing to establish acceptable injection and sampling of aerosols to evaluate DBS filter efficiency per the requirements of Mandatory Appendix FL-I and Mandatory Appendix FL-II. These test sections should be channels approximately 2 ft^2 (0.19 m^2) that pass vertically through the sand bed. They should be filled with the same types and depths of media as the rest of the DBS filter. They should be provided with taps, per FL-4220, to allow the test aerosol upstream and downstream of the test sections to be measured. The number and placement

of the test sections should provide a representative assessment of the entire DBS filter.

(c) provision for remote or robotic inspection if upstream inspections will be needed because radiological conditions upstream of a DBS filter will likely preclude human entry to inspect these locations.

(d) roofing to prevent infiltration of rainwater if the DBS filter is located outside a building.

(e) a balance in the sizing (length × width × height) of the DBS filter bed between efficiency and power consumption and cost and the overall size of the DBS filter. Typical face velocities are 5 ft/min (1.5 m/min) to 7 ft/min (2.1 m/min).

(f) channels, sloped away from the DBS filter bed, to supply and exhaust air from the DBS filter.

(g) sumps located in designed low points to collect condensation and minor water infiltration. The sumps shall be provided with sump pumps and ASME B31 compliant transfer piping to transfer water from the sumps to a designated storage or treatment location. Water collected from the bottom of the DBS filter and channels is potentially contaminated.

FL-4220 Monitoring Capabilities

Means shall be provided, with taps appropriate for the instrumentation required, to obtain the measurements listed below. Instruments may be permanently installed or portable as determined by the Owner or designee.

(a) test aerosol injections

(b) test aerosol measurement (upstream and downstream)

(c) accumulations of radionuclides through the depth of the DBS filter bed at multiple locations in the bed

(d) flow through the DBS filter bed

(e) differential pressure across the DBS filter bed

(f) differential pressure across the individual layers of the DBS filter bed

FL-4221 Test Section Sampling Ports and Seals. Injection and sampling ports shall be located as specified by the Owner or designee. The test section penetration shall have a cap or plug suitable for the pressure and environmental conditions. The penetrations shall be sealed by welding, with a sealant qualified for the environmental conditions, or with adjustable compression or gland type seals. Gland type seals include, but are not limited to, O-rings, gaskets, and other nonmetallic materials.

FL-4230 Particle Removal Efficiency

The DBS filter shall have a particle removal efficiency, specified by the Owner or designee, consistent with its intended function.

FL-4300 STRUCTURAL REQUIREMENTS

AA-4300 does not apply to FL-4300. AA-4300 addresses the structural design of metal equipment appropriate for other sections of ASME AG-1, whereas DBS filters are steel-reinforced concrete structures and the structural requirements are as specified herein.

FL-4310 General

The DBS filter shall be designed in accordance with ACI 349. The DBS filter shall be constructed primarily of steel reinforced concrete. Structural steel, if used, shall comply with AISC N690.

FL-4320 Natural Phenomena

The DBS filter shall be designed to survive and maintain operability through all natural phenomena hazards applicable to the location of the DBS filter (e.g., tornados, earthquakes, and hurricanes).

ARTICLE FL-5000 INSPECTION AND TESTING

The inspection and testing of DBS filters shall conform to the requirements of Article AA-5000 and the specific requirements of this Article. Inspection and testing requirements are specified for filter media (aggregate) and the DBS filter structure, distribution channels, distribution support structure, and monitoring and sampling lines. Personnel performing inspection and testing activities at the supplier's location or DBS filter construction site shall be qualified in accordance with AA-7220.

FL-5100 ACCEPTANCE TESTS

FL-5110 Filter Media Acceptance Tests

FL-5111 Water Extractable Test. This test determines the water extractable materials in the aggregate to be used in the DBS filter. The amount of water extractable materials (dirt and fines) shall not exceed criteria as specified by the Owner's specification.

FL-5112 Particle Size Distribution Test. This test determines the particle size distribution of aggregate. A weighted sample of dry aggregate is separated through a series of sieves or screens having progressively smaller openings for determination of particle size distribution.

The sieve analysis shall be performed in accordance with ASTM C136. Field samples of aggregate shall be reduced to testing quantity in accordance with ASTM C702 employing sieve screens of the standard size specified by ASTM E11. Measured material gradation values shall fall within requirements as specified by the Owner's specifications.

FL-5113 Resistance to Airflow Test. This test determines the resistance to airflow of $\frac{1}{4}$-in. (6.4-mm) and smaller diameter aggregate to be used in the DBS filter and to have this determination made in a manner that is similar to the anticipated "As Installed" condition (matching material type, depth, and compaction of intended design).

Testing shall be conducted on an individual aggregate layer basis for the layer's design depth at various air velocities and conditions of packing as established by the design specification. The acceptability of aggregate shall be based on the measured pressure drop for superficial velocities, aggregate depths, and packing conditions as specified by the Owner.

FL-5114 Friable Material Test. This test determines the extent of shale, slate, and similar friable material in the aggregate.

A sieve analysis of sample aggregate shall be performed in accordance with ASTM C136. Each sieve fraction shall receive a petrographic examination in accordance with ASTM C295 to determine the portion of shale, slate, and friable material as defined by ASTM C294. The calculated weighted average composition of shale, slate, and friable material in each type of aggregate shall fall within the range stated in the Owner's specifications.

FL-5115 Corrosion-Resistance Test. This test is only required for applications involving corrosive fumes. For applications involving exhaust flows having corrosive properties, testing shall be performed in accordance with the weight loss method described in ASTM A262 to determine the corrosive resistance of the aggregate. Corrosive resistance properties shall meet the Owner's acceptance criteria for loss in weight by leaching of the sample mass and the generation of fine particles.

FL-5116 Supplier Sampling for Filter Media Acceptance Test. Sampling of aggregate for acceptance tests shall be in accordance with ASTM D75. At the supplier's site, all samples shall be collected from the conveyor belt or free flowing stream (bins or belt discharge) immediately before loading into the common carrier's equipment. All sampling shall be available to be witnessed by the Owner.

FL-5117 Supplier Filter Media Acceptance Test. The supplier shall submit to the Owner certified copies of all applicable filter media tests (FL-5111 through FL-5115) at the time of each shipment for each type of material being shipped. At a minimum, test report information shall include the type and weight of materials, sources of materials, sample numbers and date of samples, and test results. Acceptance criteria shall be in accordance with the Owner's specifications and procedures.

FL-5120 Distribution Support Structure Acceptance Tests (19)

Structural steel, filler metal and flux for welding, and steel bolts shall have CMTRs or certificates of conformance per AISC N690 and the Owner's specifications.

If the distribution support structure is steel, vitrified, or ceramic distribution block a certificate of conformance shall be issued by the manufacturer to the Owner stating the castings conform to ASTM A27, ASTM A732, or ASTM A781.

FL-5130 DBS Filter Structure Acceptance Tests

Tests of DBS filter structure materials including cements, concrete, and steel reinforcement shall be performed and shall be in conformance with the requirements of the Owner's specifications and ACI 349.

FL-5200 INSPECTION PLAN

FL-5210 Plan

An inspection plan shall be established for the DBS filter. The plan shall incorporate a checklist of inspection and acceptance criteria for the receipt and fabrication/placement of filter media, the DBS filter structure, distribution channels, the distribution support structure, and monitoring and sampling lines. This plan shall be approved by the Owner or designee.

FL-5220 Minimum Filter Media Inspection Requirements

FL-5221 Receipt Inspection. Certified filter media acceptance tests conducted per FL-5100 shall be reviewed prior to shipment of the material to the DBS filter construction site. The Owner shall confirm that the material meets the criteria in Article FL-3000 and the Owner's specification. The reviews shall be documented in accordance with Article AA-8000.

FL-5222 Fabrication/Placement Inspection. Adequate precautions shall be taken in accordance with Article FL-6000 and the Owner's specifications to assure as clean, dry, and low dust environment as practicable during placement of filter media and that the filter media is not compacted (e.g., use of a plywood walkway during placement of the filter media).

Each layer of material shall be checked to ensure the depth is within design tolerances as identified in Article FL-6000 and the Owner's specification across the filter media.

FL-5230 Minimum Distribution Support Structure Inspection Requirements

FL-5231 Receipt Inspection. Distribution support structure components (i.e., DBS filter distribution blocks, grates) shall be visually inspected for damage and conformance with the design criteria of Article FL-4000 and the Owner's specifications prior to placing the first layer of aggregate.

Inspections and reviews shall be documented in accordance with Article AA-8000.

(19) **FL-5232 Fabrication Inspection.** Inspections shall verify that the fabrication and erection of distribution support structure steel components comply with AISC 303 and the Owner's specifications regarding tolerances for fitting, fastening, positioning, alignment, and general work quality. Additionally, field welded and steel bolted connections shall be examined per AISC N690 and the Owner's specification.

Inspections shall confirm that distribution support structure components (i.e., DBS filter distribution blocks, grates) are installed on clean surfaces, that they remain in an undamaged condition, and that they are placed such that tolerances comply with the Owner's specifications.

FL-5240 Minimum Monitoring and Sampling Line Inspection Requirements

FL-5241 Receipt Inspection. Monitoring and sampling lines shall be visually inspected for damage and conformance with the design criteria of Article FL-4000 and the Owner's specifications.

FL-5242 Fabrication Inspection. Inspections shall confirm that radiation monitoring and pressure tap pipes, including positioning devices, are placed as shown on design drawings, prior to placement of filter media. A visual inspection of pipe ends shall verify that radiation-monitoring pipes have closed ends and pressure tap pipes have open ends. The ends shall be above the DBS filter bed.

FL-5250 Minimum DBS Filter Structure Inspection Requirements

FL-5251 Receipt Inspection. Inspection of DBS filter structure materials prior to construction shall be performed to confirm materials are in conformance with the Owner's design drawings and specifications.

FL-5252 Fabrication Inspection. Inspection of the DBS filter structure throughout all fabrication stages shall be performed to confirm work is in conformance with the Owner's design drawings and specifications. Documentation of inspections shall comply with the Inspection Plan and shall include the minimum installation/construction lifetime retention record requirements of ACI 349, including quality and proportions of concrete materials, concrete design mix and placement records, concrete cylinder test reports, reinforcing steel material property reports, and sequence of erection and connection of precast members.

FL-5260 Rejection and Reinspection

Noncompliant conditions (such as, but not limited to, poor workmanship, damaged components, work environment, tests) shall be corrected or resubmitted and reinspected prior to continuation of related fabrication activities.

FL-5300 QUALIFICATION AND VERIFICATION TESTING

FL-5310 Filter Media Verification Testing

Verification testing of each filter media aggregate type shall be performed by the Owner to confirm each shipment meets the design requirements. Verification testing of representative shipment samples shall be done using samples taken by the supplier at the supplier site. The Owner shall have the option to witness supplier sampling.

Testing for water extractable materials, particle size distribution, resistance to airflow, friable material, and corrosion resistance (if required) shall be conducted by the Owner in accordance with FL-5111 through FL-5115 to verify the "As Supplied" filter media test results. Notice of acceptance or failure of the sample to meet specification requirements will be conveyed to the supplier.

The supplier may furnish and deliver new samples for retesting after receiving notice of failure of sample. The Owner shall have the option to witness the resampling.

FL-5320 DBS Filter Performance Qualification and Verification Testing

FL-5321 Initial Operation Qualification Testing. The rated performance of the DBS filter shall be established at airflow rate(s) selected by the Owner or designee for flow resistance and particulate matter removal efficiency. Air-aerosol mixing shall be measured in accordance with Mandatory Appendices FL-I and FL-II to establish acceptable injection and sampling of aerosols to evaluate filter efficiency.

FL-5322 Requalification Testing. Testing shall be conducted to reestablish the rated performance to the DBS filter after design changes (i.e., filter media modifications) or changes in applications (i.e., flow rate, corrosive characteristics of airflow).

FL-5323 Periodic Verification Testing. DBS filter airflow resistance and particulate matter removal efficiency may change with time. Periodic testing of these parameters shall be conducted to trend changes and to verify they fall within the rated performance range. The Owner or designee shall determine the applicable frequency for periodic verification testing.

ARTICLE FL-6000
FABRICATION/FIELD CONSTRUCTION

FL-6100 GENERAL

The DBS filter shall be fabricated and assembled from the materials designated in Article FL-3000 in accordance with the design requirements established in Article FL-4000. The DBS filter shall be tested in accordance with Article FL-5000. The media placement shall be in accordance with FL-6350.

FL-6200 FABRICATION AND ASSEMBLY

FL-6210 Reinforcing Steel and Concrete

Reinforcing steel shall be free of loose mill scale, loose rust, paint, grease, oil, mud, and any other foreign material, which will prevent or reduce bonding. Reinforcing steel shall be free of twists, kinks, and other defects. Reinforcing steel shall be bent cold without fractures or cracking in the steel.

Concrete and reinforcing steel shall be fabricated in accordance with ACI 349, including tolerances.

FL-6220 Distribution Support Structure

Steel, vitrified, or ceramic distribution block shall be cast in accordance with ASTM A27, ASTM A732, or ASTM A781 as applicable.

Elevated structural steel grating, if used in lieu of distribution blocks, shall be fabricated in accordance with metal bar grating manual NAAMM MBG 532.

FL-6230 Structural Steel

Structural steel, if used, shall be fabricated in accordance with AISC 303 and AISC N690.

FL-6300 INSTALLATION

FL-6310 Concrete Installation

Concrete installation shall be in accordance with ACI 349. Areas of concrete pours shall be adequately and continuously ventilated to prevent trapped moisture and mold formation.

FL-6320 Distribution Support Structure Installation

Distribution blocks or elevated steel grating shall be installed as shown on construction drawings. No material shall be dropped or laid down on the distribution blocks or elevated steel gratings, which would damage or leave dust or residue on or in the distribution support structure. Any debris that falls into a pocket of the distribution block shall be removed. Any distribution block that is damaged shall be replaced with a new one.

FL-6330 Monitoring and Sampling Line Installation

Radiation monitoring and pressure tap pipes, including positioning devices, shall be placed as shown on design drawings prior to placement of filter media. The supplier shall perform a visual inspection of the pipe ends to verify that radiation monitoring pipes have closed ends and pressure tap pipes have open ends as shown on design drawings. The supplier shall submit a verification report prior to installation of the filter media.

FL-6340 Structural Steel Installation (19)

Installation shall be in accordance with the following: AISC 303, AISC 325, and AISC 326.

FL-6350 Filter Media Installation

Precautions shall be taken during placement operations to assure as clean and low dust an environment as practicable. The filter media shall not be compacted. It shall not contain foreign material or dust caused by crushing or materials infiltrated from either layer above or below.

Clean work platforms (i.e., plywood or other suitable material) shall be used while placing and handling materials during construction of the DBS filter. Multiple layers of filter media may be placed based on the ability to maintain tolerances and avoid mixing of the layers of the filter media.

FL-6351 Moisture Prevention. The coarse materials comprising the lower layers shall be worked clean of rock dust prior to placement of each layer by washing with water meeting the requirements of drinking water as defined by the United States Environmental Protection Agency. These materials should be surface dry prior to placement of upper layers of fine materials. Provisions shall be made to remove water from the trench and from the sumps.

Condensation of moisture within the DBS filter should be avoided. Humidity control is required during the placement of upper layers of fine materials to prevent any dripping water that would wet the media and cause uneven settlement. Frequent checks shall be made for any visual sign of surface moisture or wetness.

FL-6400 TOLERANCES

FL-6410 Concrete Tolerances

Tops of piers, pedestals, and foundations shall be within the tolerance limits of the design specifications. Finished floor slabs shall be within the tolerances limits of the design specifications. All other tolerances shall be in accordance with ACI 117.

FL-6420 Distribution Support Structure Tolerances

Distribution blocks or the elevated steel grating shall be placed so that noncumulative tolerances are within the limits per design specifications.

FL-6430 Monitoring and Sampling Line Tolerances

Monitoring and sampling lines shall be placed in accordance with the limits per design specification.

FL-6440 Reinforcing Steel Placing Tolerances

Reinforcing steel placing tolerances shall be in accordance with ACI 349.

FL-6450 Filter Media Tolerances

Tolerances in the depth and uniformity of the filter media shall be in accordance with design specifications.

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

FL-7100 GENERAL REQUIREMENTS

DBS filters are constructed in place at the facility being serviced. As applicable, packaging, shipping, receiving, storage, and handling of materials of construction shall meet the requirements of Article AA-7000 and ASME NQA-1 and shall be so as to retain the original quality of the materials.

FL-7200 FILTER MEDIA

Packaging, shipping, receiving, storage, and handling of the filter media shall meet the requirements of packaging Level C in accordance with ASME NQA-1, Part 2.2.

ARTICLE FL-8000 QUALITY ASSURANCE

FL-8100 GENERAL

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 as well as 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.

Quality assurance shall conform to the requirements of Article AA-8000 and FL-8110.

FL-8110 Scope and Applicability

This Article contains general requirements for the quality assurance of DBS filters and filter media (aggregate), the DBS filter structure and the distribution channels, the distribution support structure, and the monitoring, sampling, and instrumentation lines. The requirements of ASME NQA-1 apply to DBS filters and the filter media, the DBS filter structure and distribution channels, the distribution support structure, and the monitoring, sampling, and instrumentation lines.

FL-8200 IDENTIFICATION AND COMPLETED MATERIAL

Identification of filter media from the Material Supplier shall be traceable by matching the marking on the shipping container (e.g., railcar) with the accompanying bill of lading.

ARTICLE FL-9000 LABELS AND MARKINGS

FL-9100 DEEP BED SAND FILTER MARKINGS

DBS filters shall be marked per the Owner's direction.

FL-9200 PACKAGE MARKING

Marking or labeling of the shipping cartons of small items (i.e., those components used in the construction of the DBS filter and packaged in shipping cartons) shall be of a size and type that can be read at a distance of 3 ft (0.9 m). The following information shall be provided:

(a) manufacturer's name
(b) manufacturer's designation and part number
(c) as applicable for fragile items, arrows and "THIS SIDE UP" orientation indication for shipping and storage, and "FRAGILE" in letters no less that $^3/_4$ in. (19 mm) high
(d) purchase order number or other identifying markings required by the purchaser

FL-9300 FILTER MEDIA

Marking or labeling of the filter media (aggregate) shipping container (e.g., railcar) shall be of a size and type that can be read at a distance of at least 3 ft (0.9 m). The following information shall be provided:

(a) supplier's name
(b) type of aggregate
(c) amount (weight) of aggregate

MANDATORY APPENDIX FL-I
AIR-AEROSOL MIXING TEST PROCEDURES

ARTICLE FL-I-1000
(19) ## INTRODUCTION

The procedures in this Appendix are used to prepare specific test procedures to ensure that the challenge aerosol or gas injection ports used for the in-place leak tests of Mandatory Appendix FL-II provide a uniform challenge across the test faces of the DBS filter. Uniform air-aerosol mixing provides a representative sample of the leak rate of the whole DBS filter during these in-place tests. Once an injection port is qualified by this procedure, it shall be used in all subsequent in-place leak tests as outlined in the acceptance tests of FL-4210(b) and FL-5320.

FL-I-1100 SYSTEM TEST

Special test sections shall be located so that the leak rate of the entire system can be represented by assuming the leak rate measured from the special test sections and rationing the leak rate measured to determine the projected leak rate for the whole DBS filter. Any bypass ducts and associated dampers shall be verified to be bubble tight.

FL-I-1200 SUMMARY OF METHOD

The system is operated at ±10% of the design flow rate. Challenge aerosol or gas is injected through a pre-installed injection port upstream of the special test sections arranged in such a way that all the discharged aerosol will enter the special test section. Challenge aerosol or gas concentration readings are obtained at equal cross-sectional areas in front of the special test section. Each reading is then compared to the average for the other special test sections. Dioctylphthalate (DOP) aerosol is the preferred challenge agent for this test. However, use of a challenge gas may be useful in some cases.

FL-I-1300 INJECTION PORT SELECTION CRITERIA

Injection ports should be located upstream of a flow disturbance to maximize mixing. The challenge gas will pass through the special test sections. It is not necessary that all special test sections be tested at the same time.

FL-I-1400 DOWNSTREAM SAMPLE PORT SELECTION CRITERIA

Downstream sample ports not serviced by a qualified sample manifold shall have an air-aerosol mixing uniformity test performed at the preselected location.

ARTICLE FL-I-2000
PREREQUISITES

The system is operating within ±10% of design flow rate. The airflow distribution has been verified in accordance with Mandatory Appendix FL-II.

If the system is designed to operate at more than one specified flow rate, the air-aerosol mixing test and subsequent in-place leakage tests shall be performed at each flow rate (±10%).

ARTICLE FL-I-3000
TEST EQUIPMENT

Test equipment includes the following:

(a) challenge aerosol or gas generator

(b) challenge aerosol or gas-measuring instrument

ARTICLE FL-I-4000
PROCEDURES (19)

FL-I-4100 GENERAL

Procedural guidelines are as follows:

(a) Connect challenge aerosol or gas generator to the injection port to be qualified in this test.

(b) Place the challenge aerosol or gas-measuring instrument sample probe upstream of the special test section to be tested. Because of the arrangement of the DBS filter inlet, it will be necessary to install the piping and instrumentation at the inlet prior to placing the aggregate in the DBS filter.

(c) Start the challenge aerosol or gas injection and establish a constant injection rate.

(d) Concentration readings shall be taken upstream of and at the approximate centers of the special test sections.

(e) The average concentration, C_{avg}, readings shall be calculated using the following equation:

$$C_{avg} = \frac{\sum_{1}^{n} C_i}{n}$$

where

C_i = individual readings

n = number of readings

$\sum_{1}^{n}$ = sum of readings from 1 to n

(f) The highest and lowest concentration readings shall be identified and used to calculate the percentage they vary from the average concentration.

$$\Delta\% = \frac{C_{\text{highest or lowest}} - C_{avg}}{C_{avg}}$$

FL-I-4200 DOWNSTREAM SAMPLE PORT QUALIFICATION (19)

(a) Connect challenge aerosol or gas generator in a location that will provide adequate challenge agent to be introduced to the sample port to be qualified.

(b) Place the challenge aerosol or gas-measuring instrument sample probe at the preselected location to be tested with adequate length to reach all areas of the traverse plane as established by ACGIH Industrial Ventilation, Chapter 9.

(c) Start the challenge aerosol or gas injection and establish a constant injection rate.

(d) Concentration readings shall be taken at each traverse location.

(e) The average concentration, C_{avg}, shall be calculated using the equation in FL-I-4100(e).

(f) The highest and lowest concentration readings shall be identified and used to calculate the percentage they vary from the average concentration, using the equation in FL-I-4100(f).

(g) The downstream sample point shall be considered acceptable when the challenge aerosol concentrations across the sampling plane do not exceed ±20% of the average concentration.

MANDATORY APPENDIX FL-II DEEP BED SAND FILTER IN-PLACE LEAK TEST PROCEDURES (19)

ARTICLE FL-II-1000 INTRODUCTION

The procedures in this Appendix are used to prepare specific test procedures for leak testing DBS filters.

FL-II-1100 SUMMARY OF METHOD

The system is operated at ±10% of the design flow rate. Challenge aerosol is injected upstream of each special test section through injection ports qualified in Mandatory Appendix FL-I.

The concentration of the challenge aerosol is measured upstream and downstream of the special test section. The ratio of the downstream and upstream concentrations represents the DBS filter leak rate.

If the system is designed to operate at more than one specified flow rate, the air-aerosol mixing test and subsequent in-place leakage tests shall be performed at each flow rate (±10%).

ARTICLE FL-II-2000 PREREQUISITES

The injection ports shall be qualified to provide uniform air-aerosol mixing in accordance with Mandatory Appendix FL-I.

ARTICLE FL-II-3000 TEST EQUIPMENT AND PROCEDURES

(19) FL-II-3100 TEST EQUIPMENT

Test equipment includes the following:

(a) challenge aerosol generator

(b) challenge aerosol-measuring instrument

(c) challenge aerosol (e.g., dioctylphthalate (DOP) aerosol) for in-place leak testing of installed DBS special test sections, which shall be a polydisperse liquid aerosol having an approximate light scattering droplet size distribution as follows:

(1) 99% less than 3.0 μm diameter

(2) 50% less than 0.7 μm diameter

(3) 10% less than 0.4 μm diameter

FL-II-3200 PROCEDURES (19)

Procedural guidelines are as follows:

(a) Connect challenge aerosol generator to the qualified injection port.

(b) Connect to the already placed challenge aerosol-measuring instrument sample probes upstream and downstream of the special test section to be tested. The upstream and downstream sample points shall be located at the qualified locations as determined by Mandatory Appendix FL-I.

(c) Start the system and verify stable flow within ±10% of design flow rate.

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

(e) Start the challenge aerosol injection.

(f) Record the upstream and downstream concentrations. Repeat until at least two of the readings are stable (within 5%).

(g) Stop the injection.

(h) Using the final set of readings meeting the stability and tolerance criteria, calculate the special test section leak rate using the equation below:

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

where

C_d = downstream concentration

C_u = upstream concentration

L = percentage leak

NONMANDATORY APPENDIX FL-A
DIVISION OF RESPONSIBILITY

This 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 FL-A-1000-1 Division of Responsibility

FL-	Item	Responsible Party
3000	Materials	Owner or designee
4100	General design	Owner or designee
4200	Design criteria	Owner or designee
4300	Structural requirements	Owner or designee
5000	Inspection and testing	Supplier/Manufacturer/Owner or designee
6000	Fabrication/field construction	Manufacturer
7000	Packaging, shipping, receiving, storage, and handling	Supplier/Manufacturer/Owner or designee
8000	Quality assurance	Supplier/Manufacturer/Owner or designee
9000	Labels and markings	Supplier/Manufacturer/Owner or designee

NONMANDATORY APPENDIX FL-B GUIDELINES FOR DEEP BED SAND FILTERS

ARTICLE FL-B-1000 DBS FILTER MATERIAL SELECTION

FL-B-1100 GENERAL

All materials used to construct DBS filters should have properties and composition suitable for the application as defined by the design specification and the operating environmental conditions. Substitute materials should be equivalent to or exceed the requirements of specified materials.

FL-B-1200 FILTER MEDIA

Filter media should be made up of multiple layers of aggregate from the types presented herein. Aggregate should be resistant to abrasion and fracture, and chemically compatible with constituents in the exhaust system. Research has shown that irregular shaped grains of sand provide better filtration than more spherically shaped grains.

FL-B-1210 Purity

Filter media should be durable high purity silica, free of silt, organic matter, acid soluble components, and other deteriorating material. Filter media should not contain greater then 3% shale, slate, or other friable materials when tested in accordance with ASTM C295.

FL-B-1220 Aggregate Types

FL-B-1221 Type A Media. Type A media should be between $1\frac{1}{4}$ in. and 3 in. (32 mm to 76.1 mm) in diameter. Type A media should pass through a 3 in. (76.1 mm) sieve with less than 2% by weight passing through a $1\frac{1}{4}$ in. (32 mm) sieve.

FL-B-1222 Type B Media. Type B media should be between $\frac{5}{8}$ in. and $1\frac{1}{2}$ in. (16 mm to 38.1 mm) in diameter. Type B media should pass through a $1\frac{1}{2}$ in. (38.1 mm) sieve with less than 2% by weight passing through a $\frac{5}{8}$ in. (16 mm) sieve.

FL-B-1223 Type C Media. Type C media should be between $\frac{1}{4}$ in. and $\frac{5}{8}$ in. (6.4 mm to 16 mm) in diameter. Type C media should pass through a $\frac{5}{8}$ in. (16 mm) sieve with less than 5% by weight passing through a $\frac{1}{4}$ in. (6.4 mm) sieve.

FL-B-1224 Type D Media. Type D media should be between US No. $3\frac{1}{2}$ mesh and $\frac{3}{8}$ in. (9.5 mm) in diameter. Type D media should pass through a $\frac{3}{8}$ in. (9.5 mm) sieve with less than 5% by weight passing through a US No. $3\frac{1}{2}$ mesh sieve.

FL-B-1225 Type E Media. Type E media should be between US No. 8 (2.36 mm) mesh and $\frac{1}{4}$ in. (6.35 mm) in diameter. Type E media should pass through a $\frac{1}{4}$ in. (6.35 mm) sieve with greater than 75% passing through a US No. 4 (4.75 mm) mesh sieve and less than 5% by weight passing through a US No. 8 mesh (2.36 mm) sieve.

FL-B-1226 Type F Media. Type F media should be between US No. 8 mesh (2.36 mm) and US No. 20 (0.85 mm) mesh in diameter. Type F media should pass through a US No. 8 (2.36 mm) mesh sieve with less than 5% by weight passing through a US No. 20 (0.85 mm) mesh sieve.

FL-B-1227 Type G Media. Type G media should be between US No. 20 (0.85 mm) mesh and US No. 50 (0.30 mm) mesh in diameter. Type G media should pass through a US No. 20 (0.85 mm) mesh sieve with less than 5% by weight passing through a US No. 50 (0.30 mm) mesh sieve.

FL-B-1228 Type H Media. Type H media should be between US No. 30 (0.60 mm) mesh and US No. 70 (0.212 mm) mesh in diameter. Type H media should pass through a US No. 30 (0.60 mm) mesh sieve with less than 35% by weight passing through a US No. 40 (0.425 mm) mesh sieve and less than 5% by weight passing through a US No. 70 (0.212 mm) mesh sieve.

FL-B-1300 DBS FILTER STRUCTURE AND DISTRIBUTION CHANNELS

Historically, the distribution support structure has been constructed of steel, vitrified, or ceramic distribution block or elevated steel grating.

ARTICLE FL-B-2000
DESIGN GUIDELINES

FL-B-2100 GENERAL

The dimensions of the DBS filter structure are dependent on the airflow requirements of the application. The cross section of the DBS filter bed is determined by maintaining a face velocity of 5 ft/min (1.5 m/ min). The supply air channel plenum at the bottom of the DBS filter structure and the discharge air plenum at the top of the DBS filter structure are sized based on the airflow requirements. The top of the DBS filter structure also interfaces with the exhaust channel.

There are no universal criteria for the number and depth of aggregate layers in a DBS filter. It is the Owner's or the Owner's designee's responsibility to specify the number and thickness of each layer to achieve the facility's specific filtration requirements. Additionally, each media type identified in this section of the Code is not necessarily used in each DBS filter. DOE-HDBK-1169 contains information about previous DBS filters, including total bed depth, and the number, type, and thickness of individual media layers.

A large-scale DBS filter mock-up can assist with the sizing analysis and the number, composition, and depth of aggregate layers necessary to achieve the desired filtration performance.

FL-B-2200 DESIGN ATTRIBUTES

FL-B-2210 Provision for Inspections and Maintenance

Provision for permanent or temporary lighting of the interior of the DBS filter and breathing air will facilitate ongoing inspections and maintenance of a DBS filter.

FL-B-2220 Allowance of Bypass Channel

If the main facility exhaust system will be placed in service while construction of the facility supported by the DBS filter is still in progress, the inclusion of a channel bypassing the DBS filter is recommended. Otherwise, the dust and debris generated during construction may shorten the life of the DBS filter.

FL-B-2300 EXAMPLES OF SUPPORT STRUCTURE ARRANGEMENT

There are several approaches to the design of the support structure that have been used in existing DBS filters.

Figure FL-B-2300-1 shows a cross-sectional view of a typical support structure and the DBS filter media (circa 1955). Exhaust air is brought into the DBS filter bed via inlet air channels and then diverted vertically utilizing a block type support structure with openings for airflow.

A more recent design (circa 2005) uses stainless steel grating in place of support blocks, upon which the DBS filter media is placed. The design has proven to be more durable in corrosive environments as well as capable of sustaining seismic loads.

FL-B-2400 END OF LIFE

DBS filters should be designed with the end-state in mind (e.g., abandon in place) as identified and agreed upon by the Owner and the regulatory authority. On a case-by-case basis, the Owner and the regulatory authority will need to address and agree upon the application of abandon in place (e.g., double wall containment, remote inspection techniques, groundwater collection system), 10 C.F.R. § 61.56 requirements for waste stabilization (e.g., potential mixing of cement and water with the filter media), 10 C.F.R. 61 Subpart C long-term performance objectives, and 10 C.F.R. 61 Subpart D technical requirements for land disposal facilities.

ARTICLE FL-B-3000
INSPECTION AND TESTING GUIDELINES

FL-B-3100 FILTER MEDIA ACCEPTANCE TEST PROCEDURES

This Article presents test procedures to perform filter media acceptance tests per FL-5100.

FL-B-3110 Water Extractable Test

Purpose: This test determines the amount of water extractable materials (dirt and fines) in the aggregate.

Procedure: Determination of the dirt and fines content can be performed as follows:

(a) Place 3.2 qt (3L) of water containing 2 oz (59 mL) of 1.057 oz/1.057 qt (30 g/L) sodium pyrophosphate decahydrate ($Na_4P_2O_7 \cdot 10H_2O$) solution in shallow pan or tray.

(b) Place a 1.8 oz (51 g) sample of aggregate (dried to a constant weight) on a US No. 50 mesh testing sieve.

(c) Immerse the screening surface and aggregate sample from 1 in. to 4 in. (25 mm to 102 mm) below the surface of the water and agitate for a period of 3 min.

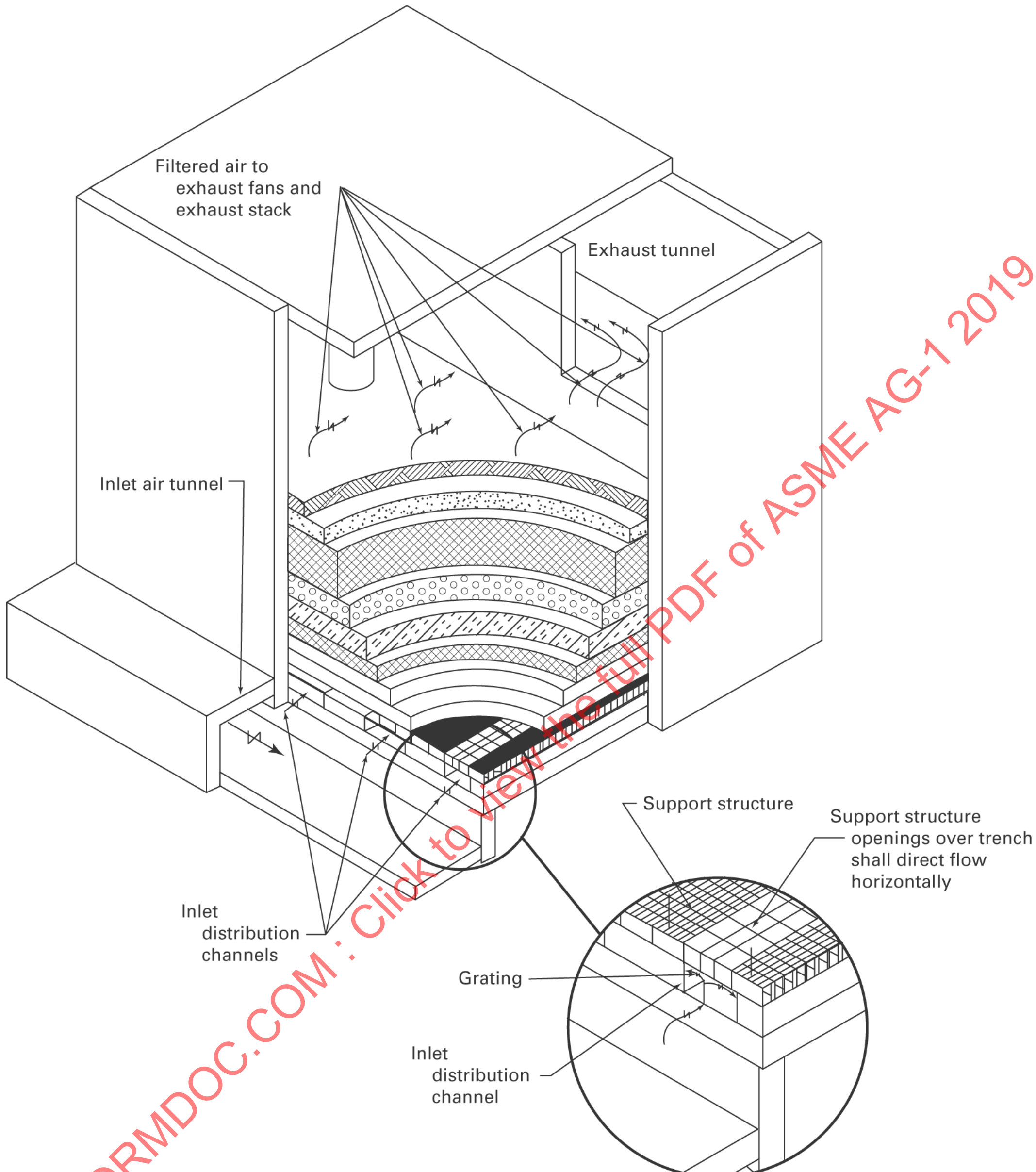
(d) Allow the screen and contents to drain for 30 sec and rinse for 2 min under a spray of cold water.

(e) Dry the screen and aggregate contents to a constant weight in an oven at 212°F to 250°F (100°C to 121°C).

(f) Weigh the residue on the screen. The amount of dirt and fines is determined based on the weight difference of the residue and original sample.

Acceptance Criteria: The amount of dirt and fines as determined by the water extractable procedures should not exceed the Owner's specification (typically 1%).

Figure FL-B-2300-1 Sand-Filter Cross Sections



FL-B-3120 Particle Size Distribution Test

Purpose: This test determines the particle size distribution of aggregate.

Procedure: Determination of the particle size range of the various categories of aggregate is conducted using a series of sieves of progressively smaller openings following ASTM procedures. Suggested sample quantities and sampling techniques are also summarized.

(a) Field samples should be reduced to testing size in accordance with ASTM C702 using sieve screens of the standard size specified by ASTM E11.

(b) Refer to ASTM C136 for recommended frames for use with coarse aggregate materials.

(c) The recommended number and weight of samples for each filter media category is

(1) Types A, B, and C — 50 samples of approximately equal weight for a total of 165 lb (75 kg) for Type A, 110 lb (55 kg) for Type B, and 35 lb (16 kg) for Type C

(2) Types D, E, F, G, and H — 25 samples of approximately equal weight for a total of 25 lb (11.4 kg) of each type

(d) Sieve analysis should be performed in accordance with ASTM C136.

Acceptance Criteria: Measured material gradation values should fall within requirements of the Owner's specifications.

FL-B-3130 Resistance to Airflow Test

Purpose: This test determines the resistance to airflow (pressure drop) of $\frac{1}{4}$-in. (6.4-mm) and smaller diameter aggregate.

Procedure: Determination of the resistance to airflow of the aggregate can be performed as follows and should be conducted for two packing conditions:

– the anticipated "As Installed" condition (matching material type, design, and compaction of intended design)

– a packed condition achieved by vigorously vibrating the aggregate

(a) The apparatus used to conduct the test should have a minimum inside diameter of 6 in. (152 mm) and be long enough to accommodate the greatest design depth of aggregate to be used, with a small plenum chamber under the aggregate for air distribution. Typically, transparent materials are used to construct the apparatus.

(b) Mount the tube on a baseplate and orient in a vertical configuration. Use a US No. 50 mesh screen over a US No. 10 mesh screen to support the aggregate in the tube and locate the screens approximately 6 in. (152 mm) above the base of the tube to form an inlet plenum chamber.

(c) Connect a calibrated, 1 in. (25 mm) I.P.S. compressed air supply in the center of the baseplate, supporting the tube.

(d) Locate a pressure tap through the baseplate and connect to a manometer, with the other end open to atmosphere to measure the pressure drop.

(e) Initially load the aggregate into the tube so that it is not compacted. To minimize compacting, tilt the tube when loading so that the aggregate slides down the inside wall of the tube; then upright the tube and level to appropriate depth of aggregate.

(f) Generate a flow resistance curve: establish and control the airflow to maintain the air face velocity at multiple flows around the design air face velocity, including 5 ft/min (1.5 m/min), and observe and record the manometer readings.

(g) Subsequently compact the aggregate by vibrating vigorously and until no further increase of pressure drop at a given rate.

(h) Typical aggregate types and depths to be tested are:

(1) Type F — 12 in. (0.3 m)

(2) Type G — 36 in. (0.9 m)

(3) Type H — 8 in. (0.2 m)

Acceptance Criteria: The pressure drop based on a superficial velocity of 5 ft/min (1.5 m/min) for typical aggregate types and packing conditions should fall within the following range:

– Type F — 0.1 in. wg to 0.4 in. wg (24.82 Pa to 99.28 Pa)

– Type G — 4.0 in. wg to 6.0 in. wg (995.6 Pa to 1493 Pa)

– Type H — 1.0 in. wg to 2.2 in. wg (248.9 Pa to 547.6 Pa)

FL-B-3140 Friable Material Test

Purpose: This test determines the extent of shale, slate, and friable material in the aggregate.

Procedure: Determination of the extent of friable material in the filter media is made by performing a petrographic examination of representative samples of aggregate.

(a) Field samples should be reduced to testing size in accordance with ASTM C702 using sieve screens of the standard size specified by ASTM E11.

(b) Refer to ASTM C136 for recommended frames to be used for coarse aggregate material.

(c) Sieve analysis should be performed in accordance with ASTM C136.

(d) Petrographic examination should be performed in accordance with ASTM C295.

Acceptance Criteria: The friable material content should fall within the requirements of Owner's specifications.

FL-B-3150 Corrosion-Resistance Test

Purpose: This test determines the corrosion resistance of filter media for applications where filtered exhaust air may have corrosive properties.

Procedure: Testing is similar to ASTM A262 Practice C for stainless steel corrosion testing where the prepared samples are refluxed in a nitric acid solution to determine their service life. Aggregate must be cleaned, crushed, and quartered to prepare the samples for testing while sand media can be prepared without crushing.

(a) Refer to ASTM A262 Practice C for details of apparatus and preparation of acid test solution.

(b) Representative samples should be selected and have US 50 mesh fines removed.

(c) Use a separate flask for each sample and 5 oz (147.9 mL) of acid test solution.

(d) Place the prepared 1.8 oz (50 g) sample weighed to the nearest 0.0001 oz (0.0028 g) in the flask along with a Teflon coated agitator.

(e) Place the charged flask on a magnetic stirring motor hot plate to keep the acid solution boiling and to motivate the aggregate agitator. During testing, the acid vapors are captured, condensed, and returned to the flask.

(f) After 22 hr of reflux, pour off the acid, wash the flask contents, and retain all fines.

(g) Dry the flask contents to a constant weight in an oven at 221°F to 230°F (105°C to 110°C).

(h) Perform a screen analysis of the fines using a US No. 50 mesh screen and weigh the screen fractions to the nearest 0.0001 oz (0.0028 g).

Acceptance Criteria: The loss in weight by leaching should be substantially nil and the generation of minus US No. 50 mesh fines should be less than 1%.

FL-B-3200 SEISMIC

A large-scale DBS filter mock-up is needed to support seismic calculations. The mock-up should be the full height of the actual DBS filter and contain each aggregate layer (matching type and depth). The mock-up should be as long and wide as can be supported by a shake table apparatus. The mock-up should include the corresponding portion of the distribution and support structure. Testing of the mock-up will provide validation of the response of the DBS filter structure and media to a design basis earthquake. The mock-up will also provide information needed to analyze the load exerted on the DBS filter structure by the filter media.

FL-B-3300 SMOKE LOADING

A smoke loading test can be conducted with a mock-up such as that described in FL-B-3200, or a unit with smaller length and width, but still having the full height of the media layers. Smoke should be injected into the airstream until the DBS filter fails (presumably by clogging the DBS filter beyond the ability of the exhaust fans to overcome the load). Testing will provide an understanding of smoke loading capacity based upon testing using representative combustible materials for the facility. The use of mock-ups can also be used to validate the selection of specific media for the DBS filter.

ARTICLE FL-B-4000 FABRICATION GUIDELINES

FL-B-4100 GENERAL

Materials for constructions should be shipped and stored in a container or environment to preclude dust adhering to or settling on the material.

Dust control mechanisms should include

(a) sprinkling of roads

(b) washing of equipment, e.g., trucks, conveyors, chutes

(c) enclosure of handling trucks

(d) limiting equipment to specific activities

(e) personnel control

Access roads to be used hauling materials of construction should be maintained free of dust, and should be sprinkled with water. All material handling equipment such as trucks, conveyors, and chutes, etc. should be kept clean and free of dust by brooming or, if necessary, washing. Material handling trucks should be either enclosed or equipped with tarpaulin covers, which should be kept in place at all times except when actually loading or unloading. Trucks used should be restricted to handling DBS filter material only. All personnel entering the DBS filter structure building should thoroughly clean their shoes prior to entering.

Traffic in the DBS filter structure should not be concentrated in special areas, but should be distributed to prevent local compaction, dust accumulation, infiltration into local layers, or other undesirable conditions.

FL-B-4200 FILTER MEDIA PLACEMENT

The hopper railcars should be placed over the unloading concrete pit and the material discharged via an unloading conveyor system into a vibrating screen conveyor. The vibrating screen should be arranged to discharge the material into trucks that carry the material to the DBS filter structure building. The material should be unloaded from the trucks onto a conveyor system, discharging the material into the DBS filter structure.

The filter media once installed should not be directly walked on at any time without the use of plywood walkways. Routing of walkways should be changed periodically to prevent concentration of traffic loads.

FL-B-4210 Type A Media (19)

Hand placement should be required for the initial 4 in. (102 mm) depth of Type A media to prevent the small rocks from falling into or damaging the distribution support structure. No load should be placed on this 4 in. (102 mm) layer; doing so will cause damage or displacement of the distribution support structure. The remaining 8 in. (203 mm) depth should be placed by wheelbarrows or plywood runways and raked to the required grade.

FL-B-4220 Types B and C Media

In the DBS filter structure building, the conveyor system should deposit the material at the desired location. The conveyor system should be supported from inserts embedded in the roof slab. All work should be performed from 4 ft × 8 ft × 1 in. (1.2 m × 2.4 m × 25 mm) plywood panel walkways, including raking to the required grade.

FL-B-4230 Types D, E, F, G, and H Media

These materials should be unloaded from covered hopper cars by the unloading conveyor system into covered trucks and brought to the DBS filter structure building. Particular care should be exercised to keep the materials dry. Placement inside the DBS filter structure building should be by the methods described in FL-B-4220.

SECTION FM
HIGH-STRENGTH HEPA FILTERS

(In the Course of Preparation)

SECTION FN
FILTER MEDIA: HIGH EFFICIENCY

(19)

ARTICLE FN-1000
INTRODUCTION

FN-1100 SCOPE

This section establishes requirements for the manufacture of high-efficiency, fire-resistant filter media for use in the construction of HEPA filters as described in Sections FC and FK. This section replaces Mandatory Appendix FC-I that was originally derived from and also supersedes the military specification MIL-F-51079D for fire-resistant, high efficiency filter media.

FN-1110 PURPOSE

The purpose of this section is to ensure that filter media are acceptable in all aspects of design and operation.

FN-1120 Applicability

FN-1121 Filter Media. This section applies to filter media for use in HEPA filters, as defined in Sections FC and FK, that meet the requirements defined by subsections listed in Table FN-5330-1.

FN-1122 Limitations. This section does not cover media used in filters other than those covered in Sections FC and FK.

FN-1130 Definitions and Terms

medium: a porous material that separates the solid particles or liquid droplets from the air or the gas passing through it. The plural form is media.

medium velocity: the linear velocity of air or gas into the filter medium.

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 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 HEPA filter media and fabricated HEPA filters.

test aerosol: the dispersion of particles in air for testing the penetration of filter media or filters.

ARTICLE FN-2000
REFERENCE DOCUMENTS

ASTM D737, Test Method for Air Permeability of Textile Fabrics
ASTM D1193-06 (2018), Standard Specification for Reagent Water
Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 (www.astm.org)

IEST-RP-CC021.4, Testing HEPA and ULPA Filter Media
Publisher: Institute of Environmental Sciences and Technology (IEST), Arlington Place One, 2340 South Arlington Heights Road, Suite 620, Arlington Heights, IL 60005-4510 (www.iest.org)

MIL-STD-282, Notice 4 (1995), Filter Units, Protective Clothing, Gas-Mask Components and Related Products: Performance-Test Methods
Publisher: Superintendent of Documents, U.S. Government Printing Office (GPO), 732 N. Capitol Street, NW, Washington, DC 20401 (www.gpo.gov)

MIL-STD-810G, Environmental Engineering Considerations and Laboratory Tests, Method 508.6, Fungus (U.S. test fungus — Aspergillus flavus, Aspergillus versicolor, Penicillium funiculosum, Chaetomium globosum, Aspergillus niger)
Publisher: Department of Defense, Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094

TAPPI T 402, Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets, and Related Products
TAPPI T 411, Thickness (Caliper) of Paper, Paperboard, and Combine Board
TAPPI T 494, 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 (www.tappi.org)

Q101, Water Repellency Indicator (125-8-1)
Publisher: U.S. Army Chemical and Biological Defense Command, Edgewood Research, Development, and Engineering Center, Aberdeen Proving Ground, MD 21010 (www.cbc.ccdc.army.mil)

ARTICLE FN-3000 MATERIALS

FN-3100 ALLOWABLE MATERIALS

Materials used in the HEPA filter media construction must allow the finished product to meet all the design parameters in Article FN-4000.

FN-3110 Fiber

Fiber used in filter media must allow the finished product to meet all the design parameters in Article FN-4000.

FN-3120 Binder

The binders used in the filter media must allow the media to meet the requirements in Article FN-4000.

FN-3130 Water Repellent

The water repellent used in the media must allow the media to meet design requirements in Article FN-4000.

FN-3140 Additional Fibers

Any additional fiber used, whether inorganic or organic, must allow the end product to meet the design parameters in Article FN-4000.

FN-3150 Nonpermissable Materials

Use of the following materials is prohibited in the construction of filter media:

(a) mercury
(b) radiologically unstable fluorinated polymers
(c) asbestos

ARTICLE FN-4000 DESIGN

FN-4100 GENERAL DESIGN REQUIREMENTS

FN-4110 Form

The filter media shall be furnished in rolls. The media shall be tightly and evenly wound on nonreturnable fiber or paperboard cores with a minimum inside diameter of 3.07 in. ± 0.12 in. (78 mm ± 3 mm) and a minimum wall thickness of 0.375 in. (9 mm).

FN-4120 Size

The width of the roll shall be specified at the time of procurement. The tolerance on the specified width shall be +0.25 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.

FN-4130 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).

FN-4200 PHYSICAL AND CHEMICAL

FN-4210 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 (5.33 cm/s), when tested as specified in FN-5210.

FN-4220 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 tested in accordance with FN-5210 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 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.

FN-4230 Tensile Strength

FN-4231 Tensile Strength and Elongation. The average tensile breaking strength of the media shall be not less than 2.5 lb/in. (0.44 kN/m) of width in the machine direction and not less than 2.0 lb/in. (0.35 kN/m) of 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 FN-5221.

FN-4232 Tensile Strength After Heated Air. The average tensile strength of the media shall be not less than 0.6 lb/in. (0.1 kN/m) of width in the cross direction after exposure to heated air at 700°F ± 50°F (370°C ± 10°C) in a forced draft oven for 5 min when tested as specified in FN-5222.

FN-4233 Wet Tensile Strength. The average wet tensile breaking strength of the media after being soaked for 15 min in ASTM D1193-06 Type II water at 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 FN-5223.

FN-4234 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 (6.0×10^5 grays) to 6.5×10^7 rads (6.5×10^5 grays) at a dosage rate not to exceed 2.5×10^6 rads (2.5×10^4 grays) per hour when tested as specified in FN-5224.

FN-4240 Water Repellency

FN-4241 Initial Water Repellency. 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 FN-5231.

FN-4242 Water Repellency 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 in. wg (1.2 kPa) after the media is exposed to an integrated dose of 6.0×10^7 rads (6.0×10^5 grays) to 6.5×10^7 rads (6.5×10^5 grays) at a dose rate not to exceed 2.5×10^6 rads (2.5×10^4grays) per hour when tested in accordance with FN-5232.

FN-4250 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 FN-5240.

FN-4260 Combustible Material

The combustible material in the filter media shall not exceed 7% by weight when tested as specified in FN-5250.

FN-4270 Flexing Characteristics

FN-4271 Examination After 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 moving through an arc of at least 180 deg when tested as specified in FN-5261.

FN-4272 Test Aerosol Penetration After Flexing. 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 MPPS after the media is drawn back and forth as required in FN-4271 when tested as specified in FN-5210.

FN-4280 Mildew Resistance

If mildew resistant media is required, the media shall show no growth when tested as specified in FN-5270. This test is only required if requested explicitly by the media purchaser.

FN-4300 WORKMANSHIP

Media shall be free from contamination (foreign matter), thick or thin spots, wrinkles, and damage, such as tears, cracks, holes, abrasions, and punctures, as specified in FN-5280.

ARTICLE FN-5000 INSPECTION AND TESTING

FN-5100 QUALIFICATION TESTING

FN-5110 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. This sample shall be tested for the properties specified in Table FN-5330-1.

FN-5111 Material Change. Any change in materials or source of materials after qualification shall require a new qualification sample.

FN-5112 Reverification of Qualification. Media shall be requalified at least every 5 yr. Tests shall be performed and certified by an independent test facility.

FN-5200 TEST PROCEDURES

FN-5210 Airflow Resistance and Test Aerosol Penetration

Three test specimens shall be tested for airflow resistance and aerosol penetration at a medium velocity of 10.5 ft/min (5.33 cm/s) using a penetrometer according to ASTM D737 and MIL-STD-282. Optionally, the MPPS penetration may be determined according to IEST-RP-CC021.4.

FN-5220 Tensile Strength

FN-5221 Tensile Strength and Elongation. Ten test specimens, five taken in each direction, shall be tested for tensile strength and elongation in accordance with

TAPPI T 494, except that the test specimens shall be 1.00 in. ± 0.05 in. (25 mm ± 1 mm) wide with sides parallel within 0.004 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 any slack can be removed from the strip before clamping. A motorized tensile testing machine that has a constant rate of elongation and a flat jaw clamping device shall be used. 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, whichever is greater. The rate shall be constant to ±4%.

FN-5222 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 T 402. One test strip taken in the cross direction, 1.00 in. ± 0.05 in. (25 mm ± 1 mm) wide with sides parallel within 0.004 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, shall be tested for tensile strength in accordance with FN-5221.

FN-5223 Wet Tensile Strength. Three test specimens taken in the cross direction width, 1.00 in. ± 0.05 in. (25 mm ± 1 mm) wide with sides parallel within 0.004 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, 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 FN-5221.

FN-5224 Tensile Strength After Gamma Irradiation. Six test specimens 7 in. × 3 in. ± 0.2 in. (175 mm × 76 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 FN-4234. A test strip taken from each of these specimens, 1.00 in. ± 0.05 in. (25 mm ± 1 mm) wide with sides parallel within 0.004 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, shall be tested for tensile strength in accordance with FN-5221.

FN-5230 Water Repellency

FN-5231 Initial Water Repellency. Three test specimens 2.75 in. ± 0.125 in. × 5.5 in. ± 0.25 in. (70 mm ± 3 mm × 140 mm ± 6 mm) shall be conditioned in accordance with TAPPI T 402 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 2.25 in. ± 0.125 in. × 2.25 in. ± 0.125 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.

FN-5232 Water Repellency After Gamma Irradiation. Three test specimens 7 in. ± 0.25 in. × 5 in. ± 0.25 in. (175 mm ± 6 mm × 75 mm ± 6 mm) shall be exposed to irradiation in a ventilated chamber as specified in FN-4234 and subsequently tested in accordance with FN-5231.

FN-5240 Thickness

The thickness of the media shall be determined in accordance with TAPPI T 411.

FN-5250 Combustible Material

The percentage of material combusted from the sample shall be determined as specified in IEST-RP-CC-0021.4, section 4.10.

FN-5260 Flexing Characteristics

FN-5261 Examination After Flexing. Eight test specimens 6 in. ± 0.25 in. × 12 in. ± 0.25 in. (150 mm ± 6 mm × 300 mm ± 6 mm) in the machine direction shall be bent perpendicular to the machine direction over a 0.1875 in. ± 0.03125 in. (5 mm ± 1 mm) mandrel so that 10 in. ± 0.5 in. (250 mm ± 12 mm) of media are drawn five times through an arc of 180 deg. Four specimens shall be bent with the screen/wire side against the mandrel, and four specimens shall be bent with the felt side against the mandrel. The flexed media 10 in. ± 0.5 in. (250 mm ± 12 mm) section shall be examined for compliance with FN-4271.

FN-5262 Test Aerosol Penetration After Flexing. After examination as specified in FN-5261, the center of each test specimen shall be tested for penetration in accordance with the procedure of FN-5210 for compliance with FN-4272.

FN-5270 Mildew Resistance

When mildew resistance is required, the filter media shall be tested in accordance with MIL-STD 810, Method 508.7.

Table FN-5330-1 Filter Media Qualification and Production Tests

Property	Test Requirement	Test Procedure	Qualification Test	Production Test
Airflow resistance	FN-4210	FN-5210	X	X
Test aerosol penetration	FN-4220	FN-5210	X	X
Tensile strength and elongation	FN-4231	FN-5221	X	X
Tensile strength after heated air	FN-4232	FN-5222	X	...
Wet tensile strength	FN-4233	FN-5223	X	X
Tensile strength after gamma irradiation	FN-4234	FN-5224	X	...
Initial water repellency	FN-4241	FN-5231	X	X
Water repellency after gamma irradiation	FN-4242	FN-5232	X	...
Thickness	FN-4250	FN-5240	X	X
Combustible material	FN-4260	FN-5250	X	X
Examination after flexing	FN-4271	FN-5261	X	...
Test aerosol penetration after flexing	FN-4272	FN-5262	X	...
Mildew resistance	FN-4280	FN-5270	X [Note (1)]	...
Workmanship	FN-4300	FN-5280	X	X

NOTE: (1) This test is only required if requested explicitly by the media purchaser.

FN-5280 Workmanship

Each roll of media shall be inspected for defects. Defects such as abrasions greater than 0.25 in. (6 mm) diameter; burn holes, charring or scorching from the drying operation; and deviations outside the width tolerance shall be cause for rejection.

FN-5300 PRODUCTION TESTING

FN-5310 Production Lot

A production lot shall consist of the rolls of filter media produced sequentially by one manufacturer using the same methods, materials, equipment, processes, and design. Each roll of filter media shall be assigned an identifier to permit traceability to test results and reports.

FN-5320 Sampling

A full width sample shall be taken at the beginning of a production lot for testing. Subsequent samples shall be taken at a minimum of every 16,404 ft (5 000 m), or in accordance with a sampling plan as prescribed by the purchaser. Inspection level may vary by test property and shall be based on known measures of process capability.

FN-5330 Testing

Samples taken as described in FN-5320 shall be tested for the properties specified in Table FN-5330-1 as production tests.

ARTICLE FN-6000 FABRICATION

FN-6100 GENERAL REQUIREMENTS

The media shall be manufactured from the materials designated in FN-3100 in accordance with the design requirements established in Article FN-4000. Following construction, the media shall be inspected and qualified in accordance with FN-5100. Production testing of qualified media shall conform to FN-5300.

FN-6200 MANUFACTURE AND ASSEMBLY

The general requirements for fabrication and installation are contained in AA-6200 and AA-6300.

FN-6210 Tolerances

The media shall be manufactured in accordance with the tolerances specified in FN-4100 and FN-4250.

FN-6300 WORKMANSHIP

The media shall be free from foreign matter (dirt, oil, or viscous material) and damage, cracks, or holes.

ARTICLE FN-7000 PACKAGING, SHIPPING, AND STORAGE

FN-7100 PACKAGING

Packaging shall conform to ASME NQA-1 Level B.

FN-7200 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 used.

FN-7300 STORAGE

Media shall be in accordance with ASME NQA-1 Level B.

ARTICLE FN-8000 QUALITY ASSURANCE

Quality assurance shall conform to the requirements of Article AA-8000 and FN-8110 and FN-8120.

FN-8100 RESPONSIBILITY FOR INSPECTION

FN-8110 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.

FN-8120 Objective Evidence

The supplier shall provide objective evidence acceptable to purchaser that the requirements of FN-4000 and FN-5000 have been satisfied.

ARTICLE FN-9000 NAMEPLATES

FN-9100 MEDIA ROLL MARKING

Marking or labeling of each media roll shall be on the inside core, of such size and legibility that it can be read at a distance of 3 ft (1 m). An optional label can be placed on the outside of each roll.

As a minimum, the following information shall be provided:

(a) manufacturer's name or symbol

(b) grade number and unique identification for lot, roll, and slit number

FN-9200 PACKAGE MARKING

Marking or labeling of each shipping container (carton containing one media roll) 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 $\frac{1}{8}$ in. (3.2 mm) high

(c) grade number and unique identification for lot, roll, and slit number

(d) purchase order number or other identifying marking requested by purchaser

NONMANDATORY APPENDIX FN-A DIVISION OF RESPONSIBILITY

This Appendix is intended to identify the roles normally assumed by the organizations responsible for fulfilling code requirements when these roles are 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 FN-A-1000-1 Division of Responsibility

FN-	Item	Responsible Party
3000	Materials	Manufacturer
4000	Design	Manufacturer
4210	Airflow resistance	Manufacturer
4220	Test aerosol penetration	Manufacturer
5000	Inspection and testing	Manufacturer
5100	Qualification testing	Independent test laboratory
5300	Production testing	Manufacturer
6000	Fabrication	Manufacturer
6210	Tolerances	Manufacturer
7000	Packaging, shipping, and storage	Manufacturer/Owner
8000	Quality assurance	Manufacturer
9000	Nameplates	Manufacturer

SECTION IA INSTRUMENTATION AND CONTROLS

ARTICLE IA-1000 INTRODUCTION

IA-1100 SCOPE

This section provides requirements for the performance, design, fabrication, installation, inspection, acceptance testing, and quality assurance for instrumentation, control components, and control panels used in air and gas treatment systems in nuclear facilities.

IA-1200 PURPOSE

The purpose of this section is to ensure that instrumentation, control components, and control panels are acceptable in all aspects of design and operation.

IA-1300 APPLICABILITY

This section applies only to permanently installed instrumentation and control systems.

This section does not cover the requirements for portable instrumentation or controls used for in-place testing or inspection of nuclear air and gas treatment systems. This section does not cover the requirements of temporary instrumentation and controls used for testing or inspection of nuclear air and gas treatment systems during fabrication or installation.

The responsibility for meeting the requirements of this section shall be assigned by the Owner or designee using Nonmandatory Appendix IA-A as a guide.

IA-1400 DEFINITIONS AND TERMS

accuracy: the ratio of the error to the full-scale output, or the ratio of the error to the output expressed as a percent.

ambient temperature: the temperature surrounding the device. For example, in the case of a remote bulb controller, the ambient temperature is the air temperature surrounding the controller and not the temperature at the bulb (sensing element).

calibration: the comparison of a measurement standard or instrument of known accuracy with another standard or instrument to adjust the output of the instrument (for a particular value of the input) within a specified tolerance.

channel: an arrangement of components and modules as required to generate a single signal. A channel loses its identity where single signals are combined.

component: an item from which the system or device is assembled (e.g., transmitters, gauges, switches, resistors, wires, transistors, tubing, etc.).

control panel: an enclosure for mounting of instrumentation, controls, and associated wiring and tubing.

controlled device: a device that reacts to the signal received from a controller and changes the required parameter of the controlled medium. Examples are valves, dampers, and motors.

electromagnetic interference (EMI): a disturbance that affects an electrical circuit due to either electromagnetic conduction or electromagnetic radiation emitted from an external source. The disturbance may interrupt, obstruct, or otherwise degrade or limit the effective performance of the circuit. This is also known as radio frequency interference (RFI).

local: the vicinity of equipment being controlled.

margin (instrument set point): the difference between a normal operating condition and a trip set point.

Megger test: a test performed with an instrument (Megger tester) to measure the insulation resistance of wires, power cables, motors, generators, transformers, switchboards, and electrical controls. Application of Megger testing can be either low voltage, high resistance, or high voltage.

raceway: an open or closed cable tray or conduit used to support cable or wire installation on nuclear air or gas treatment components.

sensing element: the element directly responsive to the value of the measured variable.

verification and validation (V&V): a process of checking that a product, service, or system meets specifications and that it fulfills its intended purpose.

ARTICLE IA-2000 REFERENCED DOCUMENTS

The codes and standards listed below shall supplement those listed in Article AA-2000. Unless otherwise specified, the latest editions shall apply.

ASTM D635-06, Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
Publisher: American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 (www.astm.org)

IEEE 7-4.3.2-2003, Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations
IEEE 100-2000, The Authoritative Dictionary of IEEE Standard Terms
IEEE 323-2003, Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations
IEEE 336-2005, Guide for Installation, Inspection, and Testing for Class 1E Power, Instrumentation, and Control Equipment at Nuclear Facilities[1]
IEEE 379-2000 (R2008), Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems[1]
IEEE 383-2003, Qualifying Class IE Electric Cables and Field Splices for Nuclear Power Generating Stations[1]
IEEE 384-2008, Standard Criteria for Independence of Class IE Equipment and Circuits
IEEE 420-2001, Standard for the Design and Qualification of Class IE Control Boards, Panels, and Racks Used in Nuclear Power Generating Stations
IEEE 603-2009, Standard Criteria for Safety Systems for Nuclear Power Generating Stations
IEEE 690-2004, Standard for the Design and Installation of Cable Systems for Class IE Circuits in Nuclear Power Generating Stations
IEEE 1012-2004, Standard for Software Verification and Validation
IEEE 1050-2004, Guide for Instrumentation and Control Equipment Grounding in Generating Stations[1]
IEEE C37.20, IEEE Standard for Metal Enclosed Low Voltage Power Circuit Breaker Switchgear
Publisher: Institute of Electical and Electronics Engineers (IEEE), 445 Hoes Lane, Piscataway, NJ 08854 (www.ieee.org)

ISA 7.0.01-1996, Quality Standard for Instrument Air
ISA RP60.3-1985, Human Engineering for Control Centers
ISA RP60.4-1990, Documentation for Control Centers
ISA RP60.6-1984, Nameplates, Labels and Tags for Control Centers
ISA RP60.8-1978, Electrical Guide for Control Centers
ISA RP60.9-1981, Piping Guide for Control Centers
ISA RP60.11-1991, Crating, Shipping and Handling for Control Centers
ISA S67.02.01-1999, Nuclear Safety-Related Instrument Sensing Line Piping and Tubing Standard for Use in Nuclear Power Plants[1]
ISA S67.04.01-2006, Setpoints for Nuclear Safety-Related Instrumentation[1]
ISA TR20.00.01-2006, Specification Forms for Process Measurement and Control Instruments, Part 1: General Considerations
Publisher: International Society of Automation (ISA), 67 T. W. Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709 (www.isa.org)

NEMA ICS 1-2000 (R2008), Industrial Control and Systems: General Requirements
NEMA ICS 6-1993 (R2006), Industrial Control and Systems: Enclosures
Publisher: National Electrical Manufacturers Association (NEMA), 1300 North 17th Street, Rosslyn, VA 22209 (www.nema.org)

NFPA 70-2008, National Electrical Code
Publisher: National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02269-9101 (www.nfpa.org)

Regulatory Guide 1.168, 2004, Rev. 1 , Verification, Validation, Reviews and Audits for Digital Computer Software Used in Safety Systems of Nuclear Power Plants
Regulatory Guide 1.180, 2003, Rev. 1, Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems
Publisher: Distribution Services Section, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001 (www.nrc.gov)

ARTICLE IA-3000 MATERIALS

IA-3100 MATERIALS OF CONSTRUCTION

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 IA-4120.

Materials shall be in conformance with the latest revision of the ASME and ASTM materials listed in Table AA-3100-1 and Table IA-3100-1.

Materials that are part of the pressure boundary or support equipment shall meet the structural requirements of Article AA-4000.

IA-3200 NONPERMISSIBLE MATERIALS

Use of the following materials is prohibited in the manufacture and installation of instrumentation and controls in nuclear air and gas treatment systems:

(a) mercury
(b) radiologically unstable fluorinated polymers

[1] May also be obtained from the American National Standards Institute (ANSI), 25 West 43rd Street, New York, NY 10036 (www.ansi.org).

Table IA-3100-1 Allowable Materials

ASTM Designator	Publication Title
D3485	Smooth-Wall Coilable Polyethylene (PE) Conduit (Duct) for Preassembled Wire and Cable
D2802	Ozone-Resistant Ethylene-Alkene Polymer Insulation for Wire and Cable
D4246	Ozone-Resistant Thermoplastic Elastomer Insulation for Wire and Cable, 90°C Operation

(c) asbestos

IA-3300 RESTRICTED MATERIALS

All material shall be compatible with the operating environment. The following material shall not be used unless approved by the Owner or designee:

(a) aluminum and zinc in the presence of corrosive vapors

(b) adjoining materials that may cause galvanic corrosion

(c) chlorine-producing materials, e.g., polyvinylchloride (PVC)

IA-3400 CERTIFICATION OF MATERIAL

The manufacturer shall make available a certificate of conformance for panel structural material and tubing to the ASTM numbers listed in Table IA-3100-1. For those materials that do not have ASTM ratings, testing should be performed per ASTM A370.

All other components used in the construction of the panel assembly shall be provided with a manufacturer's certificate of conformance to the requirements in the design specification.

ARTICLE IA-4000 DESIGN REQUIREMENTS

IA-4100 GENERAL DESIGN

(19) IA-4110 Purpose

This section establishes design requirements for instrument and control systems and the selection of instrumentation and control components used air and gas treatment systems used in nuclear facilities.

IA-4120 Design Specification

The design specification shall establish the purpose (function) of the instrumentation and control components. The design specification shall identify the instrumentation and control components, and establish their functions. The design specification shall also identify the instrumentation and control component classifications. For guidance in determining instrumentation and controls for nuclear air and gas treatment systems, refer to Nonmandatory Appendix IA-C. The design specification shall provide requirements for the design, fabrication, and selection of instrumentation and control systems in accordance with the safety system design basis requirements of IEEE 603 and of this Code, and shall include the following, as applicable:

(a) performance requirements for all plant operating modes (accident and normal) wherein the equipment is expected to perform an intended function

(b) ambient and process operating conditions, including the measured variable for each of the applicable operating modes described in (a)

(1) *temperature:* the minimum and maximum temperatures to which the instrumentation and control system devices will be subjected.

(2) *pressure:* the minimum and maximum pressures to which the instrumentation and control system devices will be subjected.

(3) *relative humidity:* the minimum and maximum relative humidities to which the equipment will be subjected.

(4) *radiation — alpha, beta, and gamma:* the cumulative dosage levels and maximum dose rates to which the equipment will be subjected.

(5) *chemicals:* concentration and duration of chemical exposure to which the equipment will be subjected.

(6) *electrical:* all electrical power transients, EMI/RFI conditions outlined in Regulatory Guide 1.180 and power surges to which the instrumentation and control system devices may be subjected. Variations in parameters such as voltage, frequency, and current shall include minimum and maximum values and their duration.

(7) *structural:* structural loads to which the instrumentation and control system components will be subjected. The loads shall include, as a minimum, the applicable loads listed in AA-4211.

IA-4130 Manufacturer's Documentation Requirements

When required by the design specification, documentation provided by the manufacturer to the Owner or 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) materials of construction.

(e) design life.

(f) environmental and seismic qualifications.

(g) mounting restrictions and instructions.

(h) loop and logic diagrams.

(i) electrical schematic and wiring drawings.

(j) panel general arrangement and construction drawings.
(k) instrument piping and tubing drawings.
(l) certificate of conformance.
(m) calibration procedures and data.
(n) panel-mounted instrument list including nameplate engraving.
(o) maintenance and surveillance requirements.
(p) recommended spare parts listing.
(q) specification data sheets for components, parts, or systems. ISA TR20.00.01 may be used for process measurement and control instrument specification forms.

IA-4140 Clarification of Code Applicability

Pressure-retaining parts whose design, materials, manufacture, test, and documentation are covered by ASME BPVC, Section III shall be in accordance with the applicable requirements of that Code. When conflict exists between this section and ASME BPVC, Section III, the latter shall take precedence.

IA-4200 SINGLE-FAILURE CRITERIA

Where redundant channels are required by the design specification, they shall meet the single-failure requirements of IEEE 603. IEEE 379 provides guidance in the application of the single-failure criteria.

IA-4210 Common Cause Failure

Digital instrumentation and computers in safety systems of nuclear power generating stations shall meet the requirements of IEEE 7-4.3.2.

IA-4300 SEPARATION CRITERIA

IA-4310 Circuits and Devices

IA-4311 Physical separation of circuits and devices shall be in accordance with IEEE 7-4.3.2.

IA-4312 Instrument cables, including but not limited to computer, transducer, thermocouple, resistance temperature detector, or other low-level signal cables shall be installed in separate raceways from power-carrying cables.

IA-4320 Instrument-Sensing Lines

IA-4321 Instrument-sensing lines and interconnecting tubing for redundant channels shall be in accordance with the requirements of ISA 67.02.01 and shall be routed a minimum of 18 in. (450 mm) apart from each other, in areas free of or protected from missiles, high-energy jet streams, and pipe whips.

IA-4322 Where 18 in. (450 mm) of separation cannot be maintained, each line shall be separated by a barrier extending at least 1 in. (25 mm) beyond the line of sight between redundant sensing lines. The design and installation of separation barrier shall be in accordance with the requirements of Article AA-4000.

IA-4323 Tubing shall not rest against surfaces that can cause wear or mechanical damage.

IA-4324 Sensing lines shall be routed to ensure that the intended function is not jeopardized due to high vibration, abnormal temperature, or stresses due to thermal expansion. Separation and isolation of the data processing functions of interconnected digital components shall be in accordance with IEEE 384.

IA-4325 Divisional separation of permanently filled capillaries, sensing lines, and interconnecting tubing for devices shall be identified by color coding and tagging, as a minimum, at both ends.

IA-4326 Redundant tubing inside panels shall be separated by a minimum of 1 in. (25.4 mm).

IA-4400 QUALIFICATION OF EQUIPMENT

All components shall be operable when exposed to the range of operating conditions specified during normal and accident conditions. Manufacturer installation and maintenance requirements that are needed to maintain qualification of the equipment shall be identified by the manufacturer and followed in the qualification program.

IA-4410 Normal Operating Conditions

All components shall be specified, manufactured, and qualified to ensure operation within performance limits (e.g., accuracy) when exposed to their normal operating conditions. Normal operating conditions include but are not limited to exposure to the following:
(a) temperature
(b) pressure
(c) humidity
(d) vibration
(e) chemicals
(f) power levels and fluctuations
(g) radiation

IA-4420 Environmental Qualification

Components operating in a harsh environment (as defined in 10 C.F.R. § 50.49) shall be qualified in accordance with IEEE Standard 323.

Digital computer software used in safety systems of nuclear power plants shall be verified and validated per Regulatory Guide 1.168.

IA-4430 Seismic Qualification

Components and mountings shall be seismically qualified using the guidelines of IEEE Standard 344 to the Owner's required response spectra, plus applicable amplification factors, for the components' location and mounting.

Components that must retain their structural integrity so as not to damage, degrade, or interfere with the performance of functions by any equipment or component shall maintain their structural integrity when subjected to applicable seismic loads.

IA-4440 Qualification Documentation

The Owner shall have documentation demonstrating the qualification of components and showing the Owner's acceptance of the qualification testing and results.

IA-4500 PANELS

IA-4510 General

IA-4511 Control panels shall be designed to support and protect the instrumentation and controls and to facilitate the monitoring and control of the mechanical equipment operation and performance.

IA-4512 Instrumentation and control devices on the front and the inside of control panels shall be arranged in accordance with the requirements of ISA RP60.3.

IA-4513 Temperature limits inside a control panel shall be maintained within the allowable specified design temperature range for all components mounted inside the panel.

IA-4520 Structures and Enclosure Materials

IA-4521 Material for enclosures, stiffeners, braces, supports, and frames shall be selected to meet the structural design requirements of Article AA-4000.

IA-4522 Support shall be provided for incoming cables, wiring, piping, and other appurtenances.

IA-4523 Subpanels and brackets for mounting instruments shall meet the structural loads and load combinations set forth by the design specification.

IA-4524 Panels weighing over 200 lb (91 kg) shall be provided with removable lifting eyes or other means as required for loading, unloading, and moving the panels to their final installation location.

IA-4525 All tubing, wire troughs, or raceways used in the panel shall be of the metallic type or shall be manufactured from fire retardant or self-extinguishing material. Nonmetallic components and devices shall be manufactured from self-extinguishing materials, as classified by ASTM D635.

IA-4526 Panels shall be provided with an integral mounting plate or a separate structural channel member, as required by the design specification, to facilitate the mounting of panels on imbedment plates or anchor bolts provided in walls or floors.

IA-4530 Panel Wiring

IA-4531 Wiring of control boards, panels, and racks used in safety systems shall comply with the requirements of IEEE 420 and as supplemented herein.

Wiring bundles shall be supported by such devices as clamps, straps, wire ties, wire wrap, etc. Uninsulated metallic/wire ties shall not be used.

IA-4532 Insulating grommets shall be installed through all openings provided in partitions for the passage of wires or cables.

IA-4533 Where a cable crosses a panel hinge, multistrand flexible wire shall be used. The cable shall also be secured on each side of the hinge, protected from damage.

IA-4534 Both ends of each wire shall be marked with color coded wire markers as required by the design specification.

IA-4535 All wiring shall have current capacity, mechanical strength, thermal rating, and insulation characteristics to meet the circuit and installation requirements required by the design specification and NFPA 70, para. 384-9. The wire insulation and Class 1E cables shall meet the requirements of IEEE 383.

IA-4536 Terminal blocks shall be installed on subpanels for terminating cables entering and leaving the panels, except that wire leads from thermocouples and certain other temperature-detecting devices may be brought directly to the terminal blocks in the instrument cases.

IA-4537 Terminal blocks shall be provided with a marking strip, and terminals shall be clearly identified.

IA-4538 The terminal blocks used for the termination of power voltage circuits, the control voltage circuits, and signal circuits (low voltage or current) shall be physically separate from each other.

IA-4539 The control panel and its appurtenant equipment shall be connected to a ground bus inside the panel for personal safety. The method of grounding shall not compromise the independence of the redundant instruments and shall be in accordance with IEEE 1050. A method of terminating to the Owner's station ground bus shall be provided.

IA-4540 Power Supply and Fuses

IA-4541 Power supplies within control panels shall be provided with branch circuit overload protection and a means to disconnect incoming power.

IA-4542 Fuses shall be installed in locations free from obstructions.

IA-4543 Fuses shall be sized to limit fault currents within the requirements of the cable insulation.

IA-4550 Panel Piping, Tubing, Valves, and Fittings

IA-4551 Process sensing lines, fittings, and valves installed within panels shall meet the requirements of IA-4600.

IA-4552 All non-process piping, tubing, or valves installed inside panels shall be in accordance with ASME B31.1 unless otherwise required by the design specification.

IA-4553 Tubing bends shall be smooth and formed to avoid flattened, kinked, or wrinkled bends.

IA-4554 Panel piping or tubing installation shall not interfere with panel-mounted instrument removal or access to the instrument for maintenance purposes.

IA-4555 Isolation valves and test connections shall be installed in an easily accessible location to allow in-place calibration of all instrumentation.

IA-4556 Isolation valves shall not be solely supported by the instrument tubing. Isolation valve supports shall be secured to the panel structure or substructure to prevent torque being applied to the tubing.

IA-4557 Bulkhead fittings shall be used for termination of the control tubing from inside and outside of the panel.

IA-4558 Instrument lines shall have permanent tags on both ends where required to assure proper identification. The type of material, color coding, and method of tagging shall be as required by the design specification.

IA-4560 Instrument Air-Supply Header Assembly

IA-4561 Where required, pressure reducing valves, complete with isolation valves, relief valves, and gauges, shall be installed inside the panel to provide a regulated instrument air supply to an instrument air header.

IA-4562 The instrument air header shall be provided with isolation valves for each branch supply line.

IA-4570 Instrument Tags

Permanent nameplates shall be installed on control panels to designate instrument function and tag number. Nameplates shall be in accordance with ISA RP60.6 or the Owner's requirements.

IA-4600 MOUNTED INSTRUMENTS AND SENSORS

Instruments shall not be mounted in locations where their performance will be adversely affected by equipment vibration. Instrument chassis and attached capillary tubing shall be supported to meet the seismic requirements for their particular location.

IA-4700 INTERCONNECTING WIRING FOR SKID-MOUNTED COMPONENTS

Interconnecting circuits between components mounted on a skid shall meet the requirements of the National Electric Code, Sections 250-59 and 250-95, and IA-4534 and IA-4535.

IA-4800 INSTRUMENT-SENSING LINES AND FIELD-INSTALLED TUBING

IA-4810 Pressure Boundary and Mechanical Design Requirements

IA-4811 Instrument piping, tubing, isolation valves, and permanently filled capillaries in systems designed to ASME BPVC, Section III shall be designed and constructed to the requirements of ISA S67.02, as supplemented herein.

(a) Instrument-sensing lines that are connected to Class 2 process piping or vessels shall not be less than Class 2 Seismic Category I from their connections to the process piping or vessel to and including the accessible isolation valve.

(b) Instrument-sensing lines that are connected to Class 2 processing piping or vessels and that are used to actuate or monitor systems shall not be less than Class 2 Seismic Category I from their connections to the process piping or vessel to the sensing instrumentation.

(c) Instrument-sensing lines that are connected to Class 3 process piping and vessels and that are used to actuate or monitor systems shall not be less than Class 3 Seismic Category I from their connection to the process piping or vessel to the sensing instrumentation.

IA-4812 Instrument-sensing lines not connected to ASME BPVC, Section III Class 2 or 3 piping, vessels, or ductwork shall meet the requirements of ASME B31.1.

IA-4813 Fitting material shall be compatible with the tube or pipe material to avoid galvanic corrosion and provide acceptable soldering or brazing joints.