

SECTION FK

SPECIAL HEPA FILTERS

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ARTICLE FK-1000

INTRODUCTION

FK-1100 SCOPE

This Section of the Code provides requirements for the performance, design, construction, acceptance testing, and quality assurance for special High Efficiency Particulate Air (HEPA) filters constructed for radial flow, circular axial flow, rectangular duct-connected configurations, and rectangular axial flow.

FK-1110 PURPOSE

The purpose of this Code is to assure that special HEPA filters used in nuclear applications are acceptable in all aspects of performance, design, construction, acceptance, and testing.

FK-1120 APPLICABILITY

FK-1121 Special HEPA Filters

This section applies to extended media dry-type filters for use in air and gas streams with a 250°F (121°C) maximum continuous temperature.

Four types of special HEPA filters are addressed:

- (a) Type 1: Radial flow filters
- (b) Type 2: Axial flow circular filters
- (c) Type 3: Axial flow rectangular or circular filters with inlet and/or outlet connections
- (d) Type 4: Axial flow rectangular filters that are size variations of those addressed in Section FC

Type 1, 2, and 3 filters are depicted in Figure FK-4100-1 through Figure FK-4100-8. Type 4 filters are depicted in Section FC.

Four types of filter pack are addressed:

- (a) Type A: Folded filter media with corrugated separator/supports
- (b) Type B: Mini-pleat medium with glass fiber or noncombustible thread separators
- (c) Type C: Continuous corrugated filter media folded without separators
- (d) Type D: Folded filter media with glass fiber ribbon separators of glass fiber media or noncombustible threads glued to the filter media

FK-1122 Limitations

This Section does not cover the following items:

- (a) Filter mounting frames
- (b) Integration of HEPA filters into air cleaning systems
- (c) Filter housings and ducting, including ducting and housing related pressure boundary and structural capability requirements.
- (d) Filters listed in Section FC

FK-1123 Service Life

HEPA filters are components of a nuclear air treatment system that degrade with service. The user/owner of the facility shall incorporate written specifications on the service life of the HEPA filters for change-out criteria. Non-Mandatory Appendix FK-A provides guidance on determining the acceptable service life for each application of HEPA filters.

FK-1130 DEFINITIONS AND TERMS

This Code section delineates definitions and terms unique to this code section. Definitions and terms that have common applications are listed in Article AA-1000.

Axial flow: flow in a direction essentially perpendicular to the filter face.

Filter Case: The outer frame of an axial flow filter in which the filter pack is sealed.

Filter End Cap: The circular ends of a radial flow HEPA filter in which the filter pack and filter grille are sealed/mounted.

Filter Grille: Perforated or expanded metal tube that forms the outer and inner frame of a radial flow filter.

HEPA filter: High Efficiency Particulate Air filter. A throwaway, extended-media dry type filter in a rigid casing enclosing the full depth of the pleats, having a minimum efficiency of 99.97% (that is, a maximum particle penetration of 0.03%) for 0.3 micrometer diameter test aerosol particles.

Independent Filter Test Laboratory: an autonomous body not affiliated with a HEPA filter manufacturer or supplier subject to this Code Section but capable of performing the tests necessary to demonstrate the ability of HEPA filters to meet this Code Section.

Mechanical or Metal Grab Ring: Circular metal ring provided at the inlet of a Type 1 radial flow HEPA filter used to facilitate filter insertion and removal by remote mechanical handling systems.

Media velocity: the linear velocity of the air or gas into filter media.

Most Penetrating Particle Size: that particle size for which the penetration of the filter medium by the test aerosol is a maximum at a specified velocity.

Particle Size: the apparent linear dimension of the particle in the plane of observation as observed with an optical microscope; or the equivalent diameter of a particle detected by automatic instrumentation. The equivalent diameter is the diameter of a reference sphere having known properties and producing the same response in the sensing instrument as the particle being measured.

Penetrometer: a device for generating a test aerosol and for evaluating the aerosol penetration and air resistance of fabricated HEPA filters.

Radial flow: flow in essentially a perpendicular direction outward from a centerline, or conversely flow in essentially a perpendicular direction inward to a centerline.

Rated airflow: designated airflow capacity of a HEPA filter at a not to exceed initial filter resistance.

Spigot: a fitting connected to the housing that serves as a seating surface for a radial flow HEPA filter.

Test aerosol: a dispersion of particles in air for testing the penetration of filter media or filters.

Type 1: Type 1 is the special HEPA filter type assigned to a radial flow HEPA filter. Radial flow HEPA filters are made from a media pack formed to produce an annulus with internal and external supporting grilles. The media pack and grilles are sealed into the flange and end cap with adhesive. The normal direction of flow is from the inside face to the outside face. Type 1 filters may use an internal gasket seal, external gasket seal, or gelatinous seal.

In some applications, a mechanical or metal grab ring may be employed.

Type 2: Type 2 is the special HEPA filter type assigned to axial flow circular filters. The Type 2 filter case is formed from pipe, tube, or by rolling material to the desired dimension. Type 2 filters may use flanges, gasket seals, or gelatinous seals.

Type 3: Type 3 is the special HEPA filter type assigned to an axial flow rectangular filter with inlet and/or outlet connections, or an axial flow circular filter with inlet and/or outlet connections.

Type 4: Type 4 is the special HEPA filter type assigned to axial flow rectangular filters that are size variations of those HEPA filters addressed in Section FC (e.g., 24 in. high by 30 in. wide, 610 mm high by 762 mm wide).

ARTICLE FK-2000

REFERENCED DOCUMENTS

Common application documents referenced in this Code Section are detailed in Article AA-2000. Where ASTM materials are specified, the equivalent ASME material specification may be substituted. Unless otherwise shown, the latest edition and addenda are applicable.

AMERICAN PLYWOOD ASSOCIATION

Voluntary Product Standard PS-1-95 for Construction and Industrial Plywood (APA PS-1)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM A 193/A 193M-04c, Specification for Alloy – Steel Stainless Steel Bolting Materials for High Temperature Service

ASTM A 194 /A 194M-04a, Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure and High Temperature Service

ASTM A 240/A 240M-04a, Specification for Heat Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

ASTM A 320-04, Specification for Alloy – Steel Bolting Materials for Low Temperature Service

ASTM A 580/A 580M-98 (Reapproved 2004), Standard Specification for Stainless Steel Wire

ASTM A 581/A 581M-95b (Reapproved 2004), Standard Specification for Free Machining Stainless Steel Wire and Wire Rods

ASTM A 740-98 (Reapproved 2003), Specification for Hardware Cloth (Woven or Welded Galvanized Steel Wire Fabric)

ASTM B 209-04, Specification for Aluminum and Aluminum Alloy Sheet and Plate

ASTM D 1056-00, Standard Specification for Flexible Cellular Materials - Sponge or Expanded Rubber

ASTM D 3359-02, Test Methods for Measuring Adhesion by Tape Test

ASTM E 84-04, Test Methods for Surface Burning Characteristics of Building Materials

ASTM F 1267-01, Specification for Metal, Expanded, Steel

ASTM D 1056-00, Standard Specification for Flexible Cellular Materials - Sponge or Expanded Rubber

ASTM D 3359-02, Test Methods for Measuring Adhesion by Tape Test

ASTM E 84-04, Test Methods for Surface Burning Characteristics of Building Materials

ASTM F 1267-01, Specification for Metal, Expanded, Steel

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B18.21.1-1999, Internal Tooth Lock Washer

ASME B18.22.1-1965 (Reapproved 1981), Plain Washer

FEDERAL SPECIFICATIONS

FF-N-105B, Nails, Brads, Staples, and Spikes, Cut and Wrought

FEDERAL STANDARDS

FED-STD-141D-2001, Paint, Varnish, Lacquer, and Related Materials; Method of Inspection, Sampling and Testing

INSTITUTE OF ENVIRONMENTAL SCIENCES AND TECHNOLOGY (IEST)

IEST-RP-CC007, Testing ULPA Filters, 1992 Edition

MILITARY STANDARDS

MIL-STD-282, Filter Units, Protective Clothing, Gas Mask Components, and Related Products: Performance Test Methods

UNDERWRITER LABORATORIES

UL-586, Standard for Safety High Efficiency, Particulate Air Filter Units, 2004 Edition

ARTICLE FK-3000

MATERIALS

FK-3100 ALLOWABLE MATERIALS

FK-3110 CASES, END-CAPS, GRILLES, AND FLANGE MATERIALS

The case, end-caps, grilles, and flanges shall be made from stainless steel Type 409, 304, 304L, 316, or 316L per ASTM A 240.

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), APA PS-1. The minimum thickness shall be $\frac{3}{4}$ in. (19 mm). The grade shall be fire retardant treated. The plywood shall have a flame spread classification of 25 or less when tested as specified in ASTM E84. This material is not allowed for Type 3 circular filters.
- (b) Exterior plywood, minimum Grade A (interior side) and minimum Grade C (exterior side, APA PS-1). The minimum thickness shall be $\frac{3}{4}$ in. (19 mm). The grade shall be fire retardant treated. The plywood shall have a flame spread classification of 25 or less when tested as specified in ASTM E 84. This material is not allowed for Type 3 circular filters.

FK-3111 Fasteners

Approved fasteners used for the assembly of HEPA filter cases are listed below:

- (a) Stainless steel bolts, 300 series per ASTM A 320 or ASTM A 193
- (b) Stainless steel nuts, 300 series per ASTM A 194
- (c) Stainless steel lock washers, 300 series per ANSI B18.21.1
- (d) Stainless steel plain washers, 300 series per ANSI B18.22.1
- (e) Stainless steel rivets 300 series per ASTM A 581
- (f) Zinc-coated carbon steel nails per FF-N-105B.

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 D 1056, with the physical requirements specified for ASTM D 1056 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.

FK-3130 FILTER MEDIA

The filter media shall conform to the requirements of ASME AG-1 Mandatory Appendix FC-I.

FK-3140 FACEGUARDS

Metallic faceguards shall be fabricated from 4 x 4 mesh, wire fabric (hardware cloth) made from 0.025 in. (0.64 mm) minimum steel conforming to either ASTM A 740 galvanized steel or ASTM A 580 Type 304 stainless steel.

FK-3150 ADHESIVES

Adhesives used to fasten gaskets to filter case, and seal the filter pack or faceguards to the case shall be self extinguishing.

FK-3160 SEPARATORS

- (a) Aluminum – Aluminum separators shall be made from corrugated aluminum, 0.0015 in. (0.038 mm) minimum thickness, conforming to ASTM B 209, Alloy 5052, 3003, 1100, or 1145 aluminum. To protect the filter media, the separators shall be provided with a hemmed edge.
- (b) Acid-Resistant Aluminum – Acid resistant aluminum separators shall be made from corrugated aluminum, 0.0015 in. (0.038 mm) minimum thickness, conforming to ASTM B 209, Alloy 5052, 3003, or 1145 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 non-combustible material bonded to the filter media.
- (e) Hot Melt – Hot melt separators shall be a non-combustible 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 D 3359. 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 thermogravimetric analysis, shall not exceed 5% by weight when a 2 in. \pm 0 in. (50 mm \pm 0 mm) high by 2 in. \pm 0 in. (50 mm \pm 0 mm) wide sample of the coated separator is subjected to temperatures from 70°F (20°C) to 1800°F (1000°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.

FK-3170 GRILLES

Type 1 filters shall be fitted with an internal and external perforated grille or flattened expanded metal grilles as shown in Figure FK 4100-1 through Figure FK-4100-4. Flattened expanded metal grilles shall conform to ASTM F 1267 fabricated from the materials indicated in FK-3110. 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 being 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 air stream 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 FK-5000, and the design requirements of FK-4000 and Section AA will be acceptable for the fabrication of filters.

ARTICLE FK-4000

DESIGN

FK-4100 GENERAL DESIGN

Four types of HEPA filters are addressed in this code section:

- Type 1: Radial flow HEPA filters
- Type 2: Axial flow circular HEPA filters
- Type 3: Axial flow rectangular or circular HEPA filter with inlet and/or outlet connections
- 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 which 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 media 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 glovebox installations or similar 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-4000-1.

- (a) **Type 1 Radial flow filters with internal gaskets** shall be constructed as depicted in Figure FK-4100-1. 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 gelatinous seals** shall be constructed as depicted in Figure

FK-4100-2. 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-4100-3. 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 gelatinous seals** shall be constructed as depicted in Figure FK-4100-4. 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.

FK-4112 Type 2 Axial Flow Circular Filters

Type 2 Axial flow circular filters shall be constructed as depicted in Figures FK-4100-5 and FK-4100-6. The filter case shall be one-piece, achieved by either cutting piping or tubing of the specified material to the proper length or by cutting and rolling material to the desired dimensions. Any required flanges shall be accomplished either by rolling or by 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 either on the flange face or back of the flange. The filter capacity and performance ratings shall be as specified in Table FK-4000-2.

FK-4113 Type 3 Axial Flow Rectangular Filters with Inlet and/or Outlet Connections

Type 3 Axial flow rectangular filters with inlet and/or outlet connections shall be constructed as depicted in Figure FK-4100-7. Filters shall be assembled by fastening top, bottom, and side cases together and securing top, bottom, and sides of the filter media within the case. Cut edges shall be firmly embedded in the pack to frame sealant. All joints shall be welded or sealed with adhesive complying with FK-3150.

Flange connections may be located upstream, downstream or at both faces. The flange connection may be on the open face or on the nipple connection. Flange connections shall have bolt holes in a standard pattern equally spaced and centered on the filter face flange or on the nipple connected flange as required by the Owner.

The filter shall be designed to allow factory testing for penetration and resistance prior to attachment of inlet and/or outlet connections without damage to the connections. The filter size and performance ratings shall be as specified in Table FK-4000-3.

The inlet and/or outlet connection configurations shall be specified by the Owner. The Owner shall specify pressure drop and pressure boundary leakage requirements for the completed assembly with end plates and nipple connection(s).

FK-4114 Type 3 Axial Flow Circular Filters with Inlet and/or Outlet Connections

Type 3 Axial flow circular filters with inlet and/or outlet connections shall be constructed as depicted in Figure FK-4100-8. The filter case shall be one-piece, fabricated from pipe or tubing cut to the proper length, or fabricated from sheet and rolled into a cylinder with a single welded seam. Any required flanges shall be accomplished either by rolling or by welding the flange to the case. All welding shall be continuous.

Filters shall be assembled by joining inlet and/or outlet connections to the circular filter case. The filter media shall be secured to the perimeter of the circular filter case. All joints shall be welded or sealed with adhesive complying with FK-3150.

Flange connections may be located upstream, downstream or at both faces and may be drilled if required by the Owner. The filter shall be designed

to allow factory testing for penetration and resistance prior to attachment of inlet and/or outlet connections without damage to the connections. These filters are custom designed. Therefore, the sizes and ratings shall be as specified by the Owner. The maximum resistance shall be 1.3 inches WC (325 Pa) when tested per FK-5621.

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 Section 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 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 3 and 4 Filters

Cases for Type 3 and Type 4 filters shall have a minimum material thickness of 14 gauge for steel or $\frac{3}{4}$ 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 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 $\frac{1}{4}$ in. (6 mm) from a straight line connecting the fixed ends. Type A filter packs, for axial-flow, circular Type 2 and Type 3 circular filters, shall have a ratio (D/d) of pack diameter (D) to pack depth (d) no greater than 3 to assure pack structural reliability.
- (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 $\frac{1}{4}$ in. (6 mm). No ribbons or media supports shall vary from a straight line by more than $\frac{1}{4}$ 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 $\frac{3}{8}$ 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 $\frac{1}{16}$ 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.

- (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 $\frac{1}{16}$ in. (1.6 mm) deep when the media pack is installed in the filter case.

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 $\frac{1}{16}$ in. (1.6 mm) over either side of the seating surface at any point. Type 2 filter gaskets shall not have any joints.

The gasket for Type 3 (Enclosed Rectangular) filters shall be sealed to the filter case with an adhesive per FK-3150. The gasket shall not extend more than $\frac{1}{16}$ 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 3 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.

The gasket for Type 3 (Enclosed Circular) filters shall be sealed to the filter case with an adhesive per FK-3150. The gasket shall not extend more than $\frac{1}{16}$ in. (1.6 mm) over either side of the seating surface at any point (this does not apply to externally mounted seals). Type 3 filter gaskets shall not have any joints.

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 $\frac{1}{16}$ 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 FACEGUARDS

A faceguard shall be installed in 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-4000-4.

The Owner is cautioned that the most penetrating particle size may be less than 0.3 micrometers. If the most penetrating particle size is not 0.3 micrometers, it shall be the responsibility of the Filter Designer/Manufacturer to test for and to identify the most penetrating particle size for the filter media to be installed. The Owner or Engineer shall confirm the suitability of the filter media for the specific application.

Designs shall be qualified in accordance with Section 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:

- (a) No structural damage shall be evident by visual examination
- (b) Airflow resistance requirements of FK-5110 shall be met after the seismic qualification test
- (c) Aerosol penetration requirements of FK-5120 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.

TABLE FK-4000-1
TYPE 1 RADIAL FLOW HEPA FILTER – NOMINAL RATINGS

Maximum Rated Air Flow		Maximum Resistance	
(acfm)	(m ³ /hr)	Inches WC	Pa
40	68	1.3	325
100	170	1.3	325
250	425	1.3	325
500	850	1.3	325
1000	1700	1.3	325
1500	2550	1.3	325
2000	3400	1.3	325

TABLE FK-4000-2
TYPE 2 AXIAL FLOW CIRCULAR HEPA FILTER – NOMINAL RATING

Maximum Rated Air Flow		Maximum Resistance	
(acfm)	(m ³ /hr)	Inches WC	Pa
20	34	1.0	250
35	60	1.0	250
100	170	1.0	250

TABLE FK-4000-3
TYPE 3 AXIAL FLOW RECTANGULAR HEPA FILTER
WITH INLET/OUTLET CONNECTION(S)
NOMINAL SIZES AND RATINGS

Size (1)		Maximum Rated Air Flow		Maximum Resistance (2)	
(Inches)	(mm)	(acfm)	(m ³ /hr)	Inches WC	Pa
8 x 8 x 10	203 x 203 x 254	80	136	1.3	325
12 x 12 x 12	305 x 305 x 305	125	212	1.3	325
12 x 12 x 16	305 x 305 x 406	250	425	1.3	325
24 x 24 x 12	610 x 610 x 305	500	850	1.3	325
24 x 24 x 16	610 x 610 x 406	1000	1700	1.3	325

Notes:

1. Dimensions are height by width by depth. Depth includes the casing only and does not include the length of the nipple connection(s).
2. Maximum resistance shall be as measured in FK-5621.

TABLE FK-4000-4
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	
Airflow Rate	Normal operating at standard conditions	cfm (m ³ /hr)
	Normal operating at actual conditions	cfm (m ³ /hr)
	Minimum at standard conditions	cfm (m ³ /hr)
	Minimum at actual conditions	cfm (m ³ /hr)
	Maximum at standard conditions	cfm (m ³ /hr)
	Maximum at actual conditions	cfm (m ³ /hr)
	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/hour
	Radiation limits	rads (Sv)
	Total integrated dose for the expected life of the filter	rads (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	%

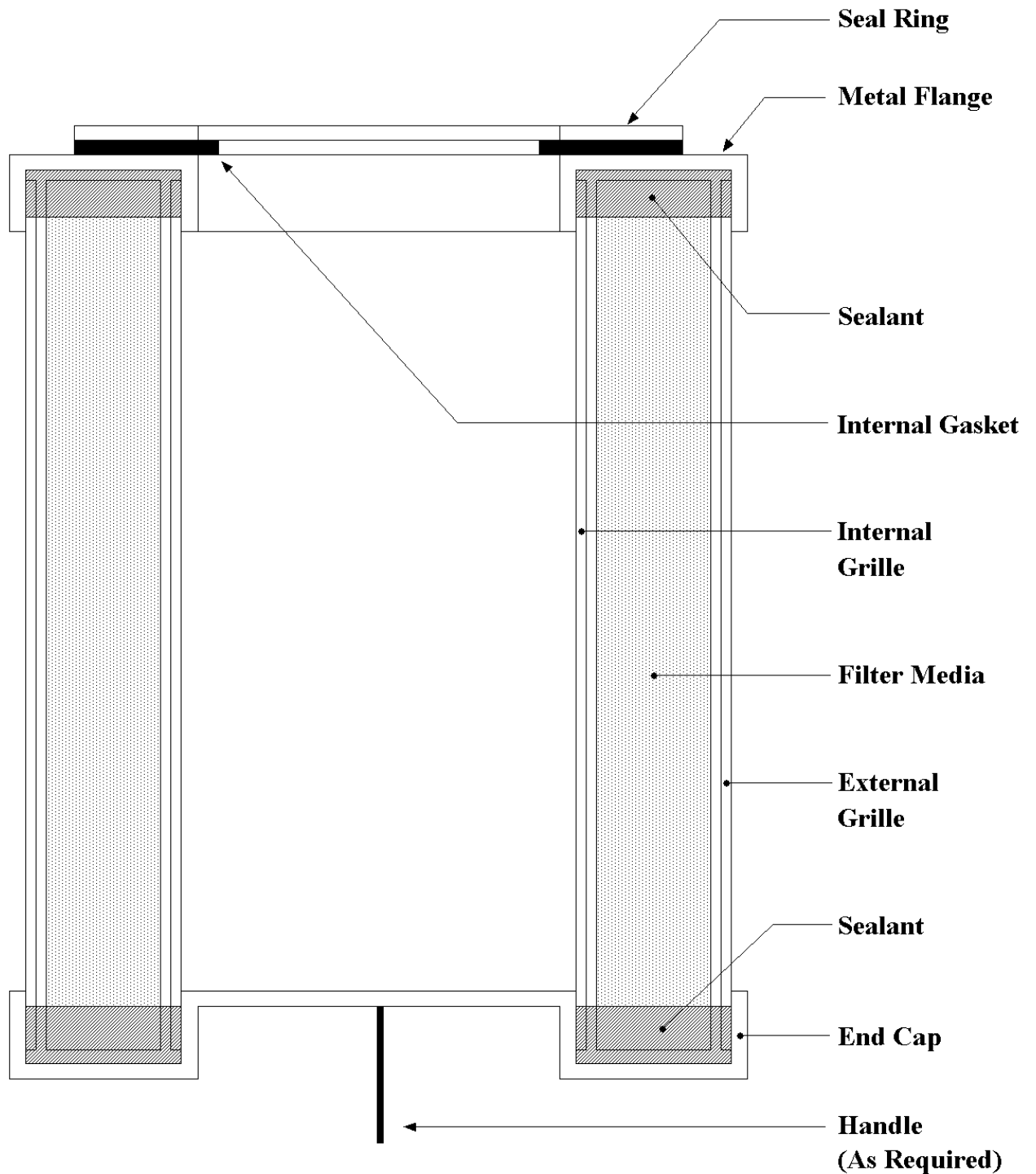
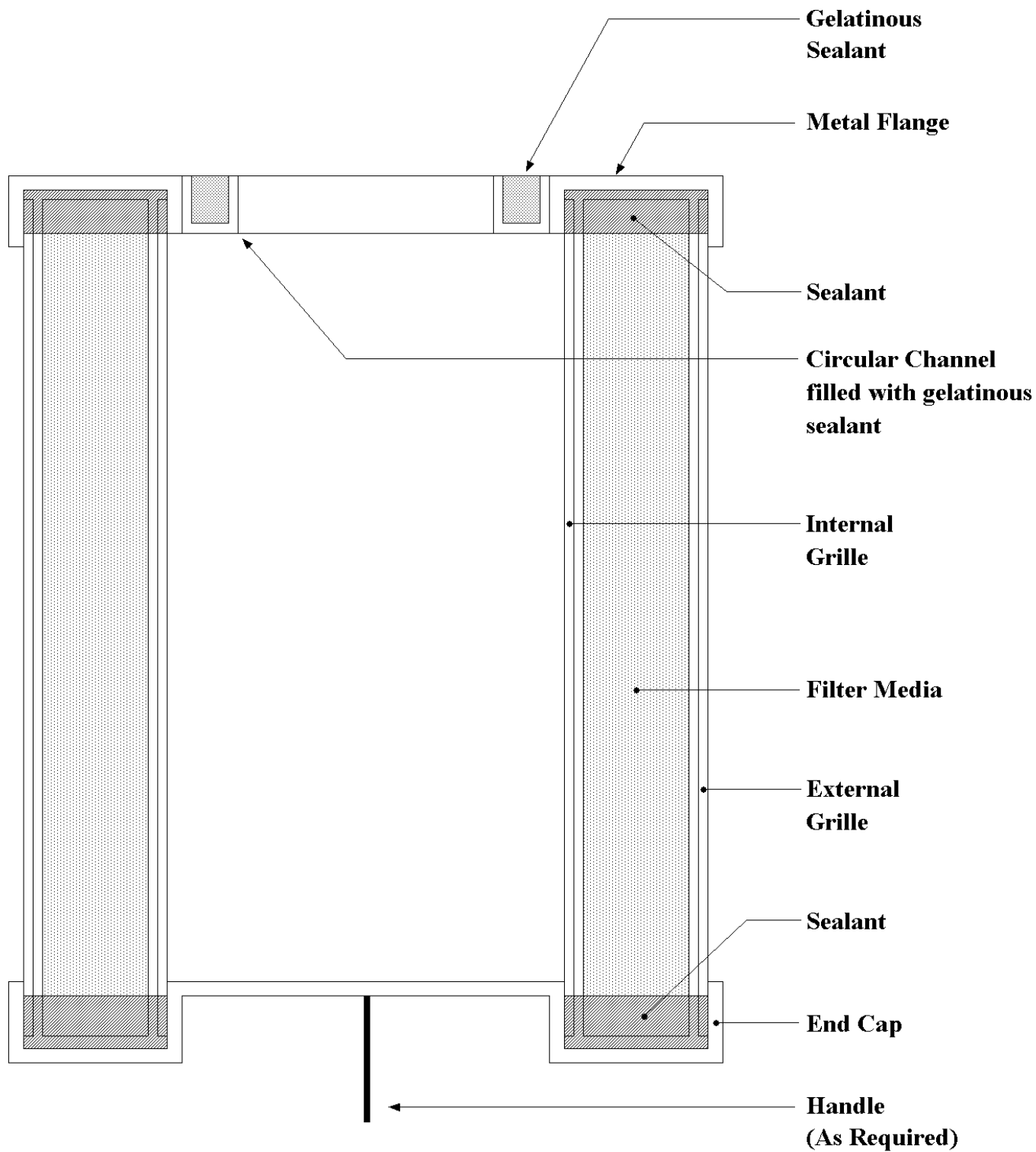


FIGURE FK-4100-1
TYPE 1 RADIAL FLOW HEPA FILTER (INTERNAL GASKET)
MID-SECTION VIEW



**FIGURE FK-4100-2
TYPE 1 RADIAL FLOW HEPA FILTER (GELATINOUS SEAL)
MID-SECTION VIEW**

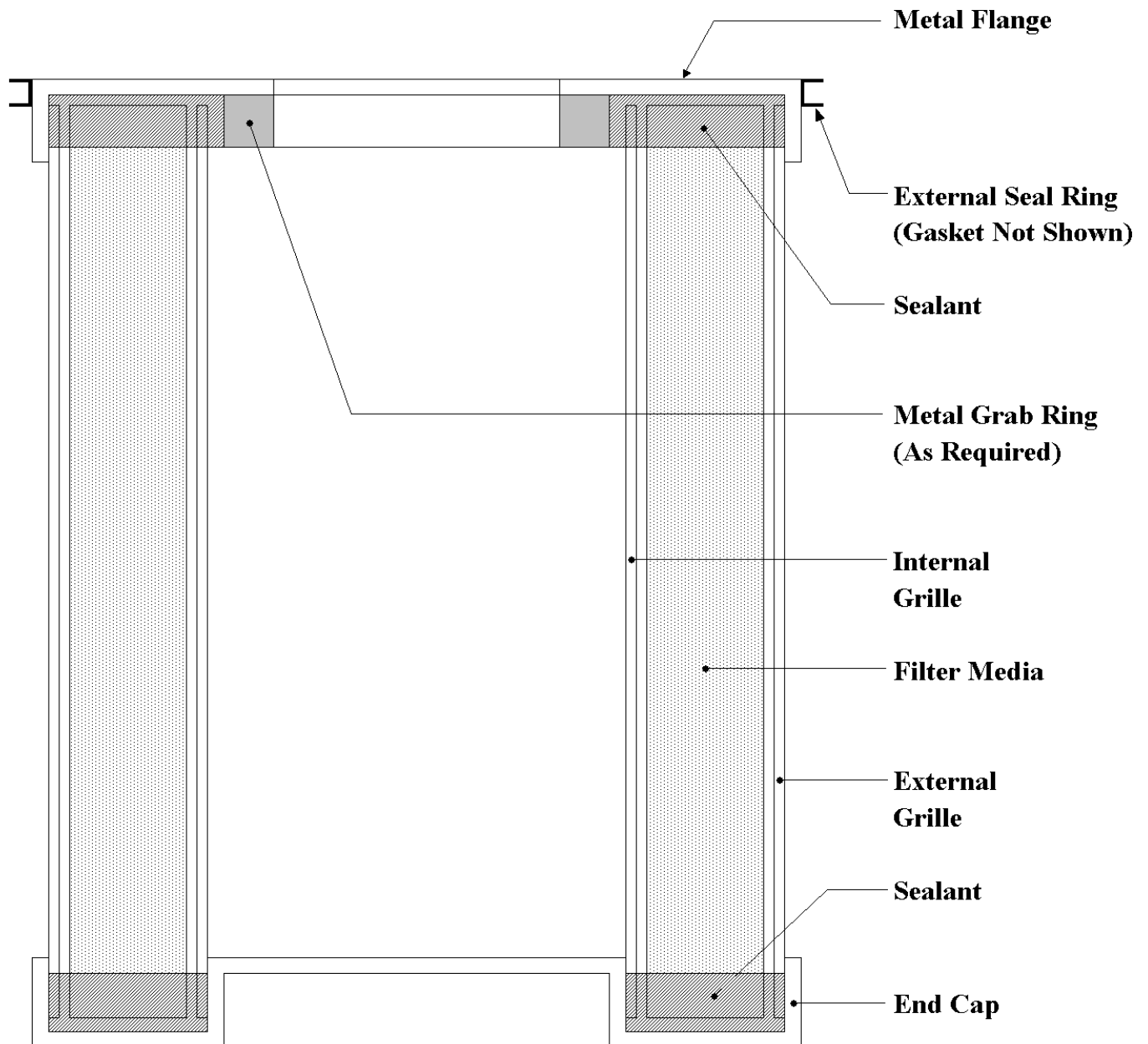


FIGURE FK-4100-3
TYPE 1 RADIAL FLOW HEPA FILTER (EXTERNAL GASKET)
MID-SECTION VIEW

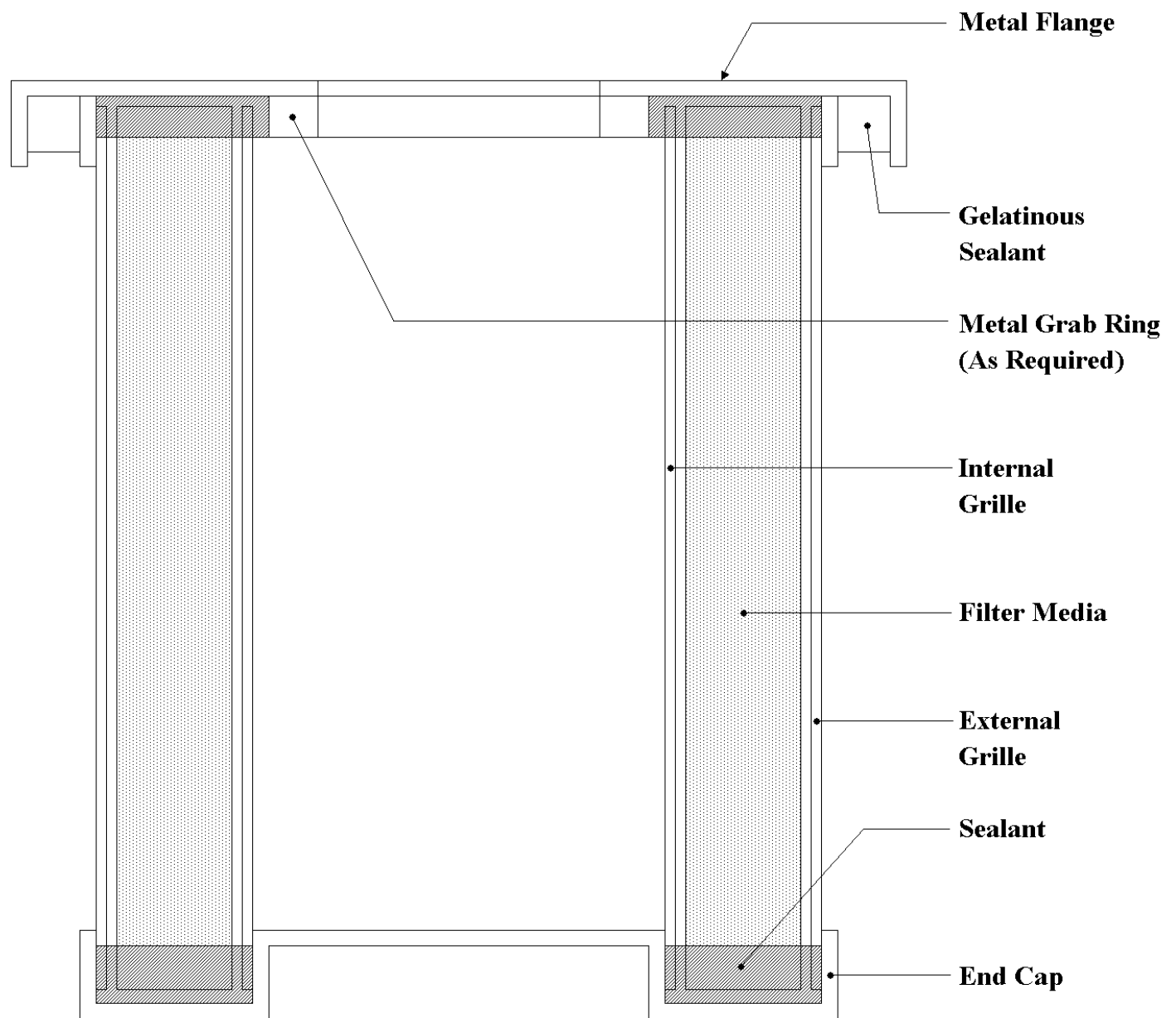
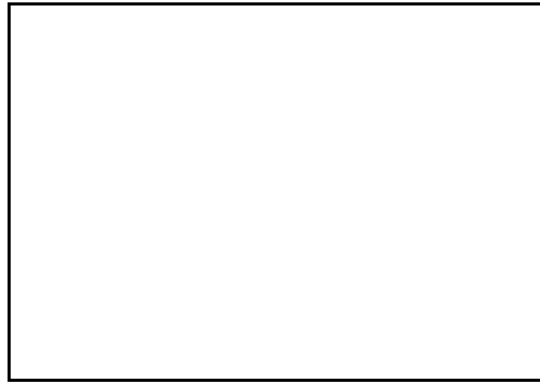
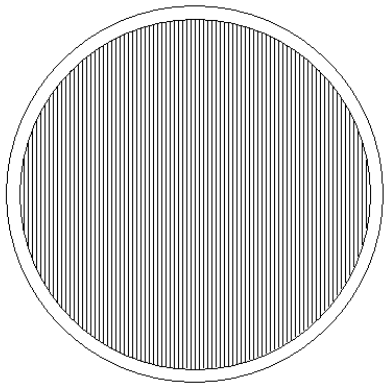
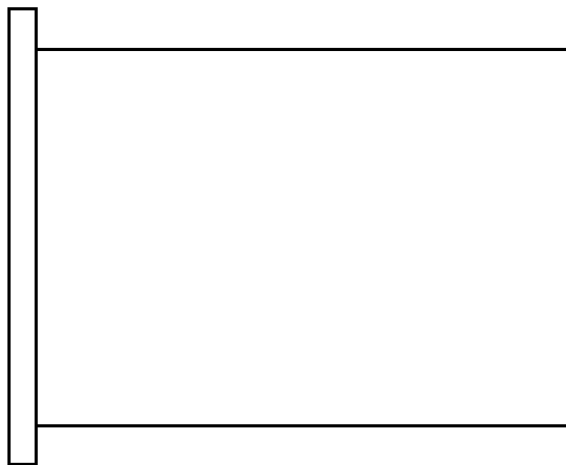
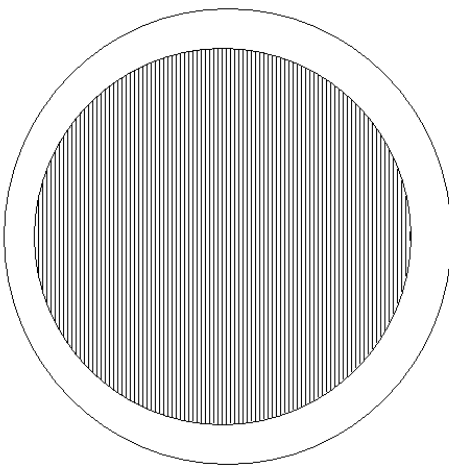


FIGURE FK-4100-4
TYPE 1 RADIAL FLOW HEPA FILTER (GELATINOUS SEAL)
MID-SECTION VIEW

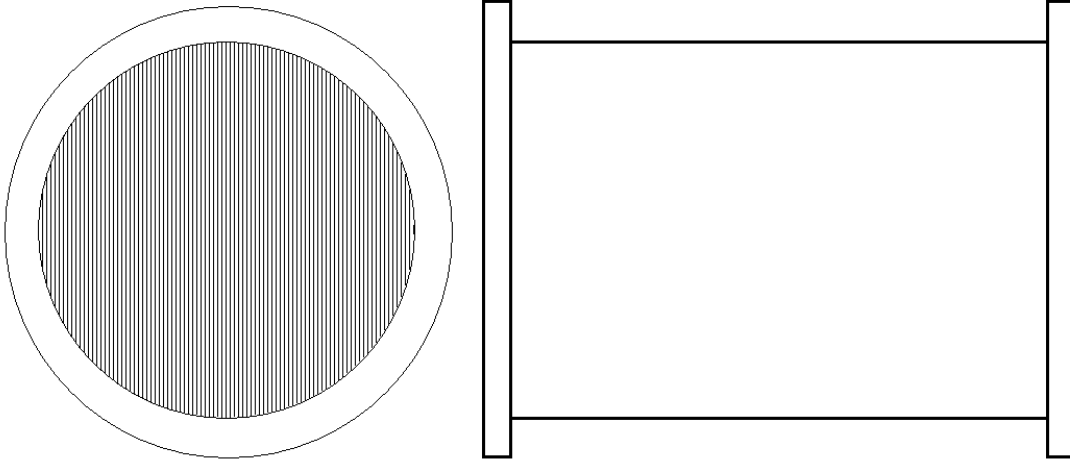


Axial Flow Circular - No Flange

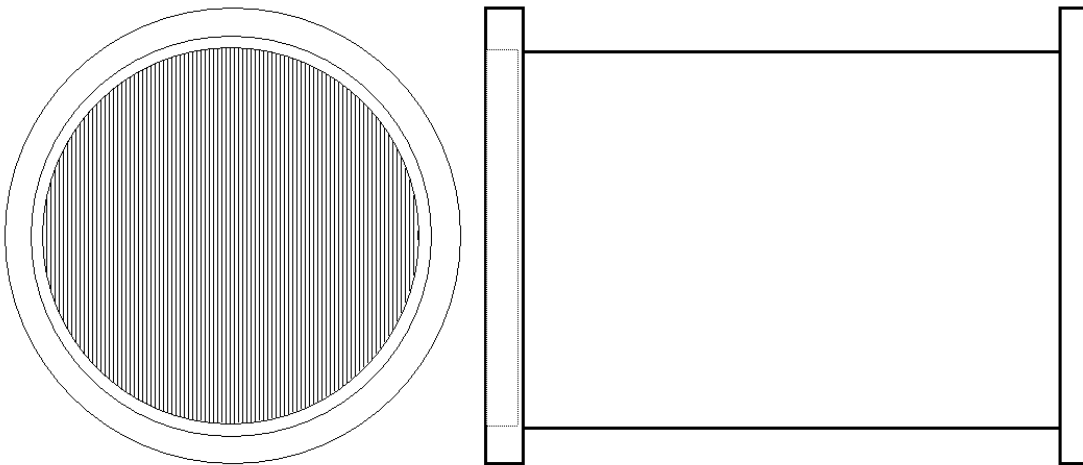


Axial Flow Circular - Single Flange

**FIGURE FK-4100-5
TYPE 2 AXIAL FLOW CIRCULAR HEPA FILTER**



Axial Flow Circular - Double Flange



Axial Flow Circular - Gelatinous Seal

**FIGURE FK-4100-6
TYPE 2 AXIAL FLOW CIRCULAR HEPA FILTER**

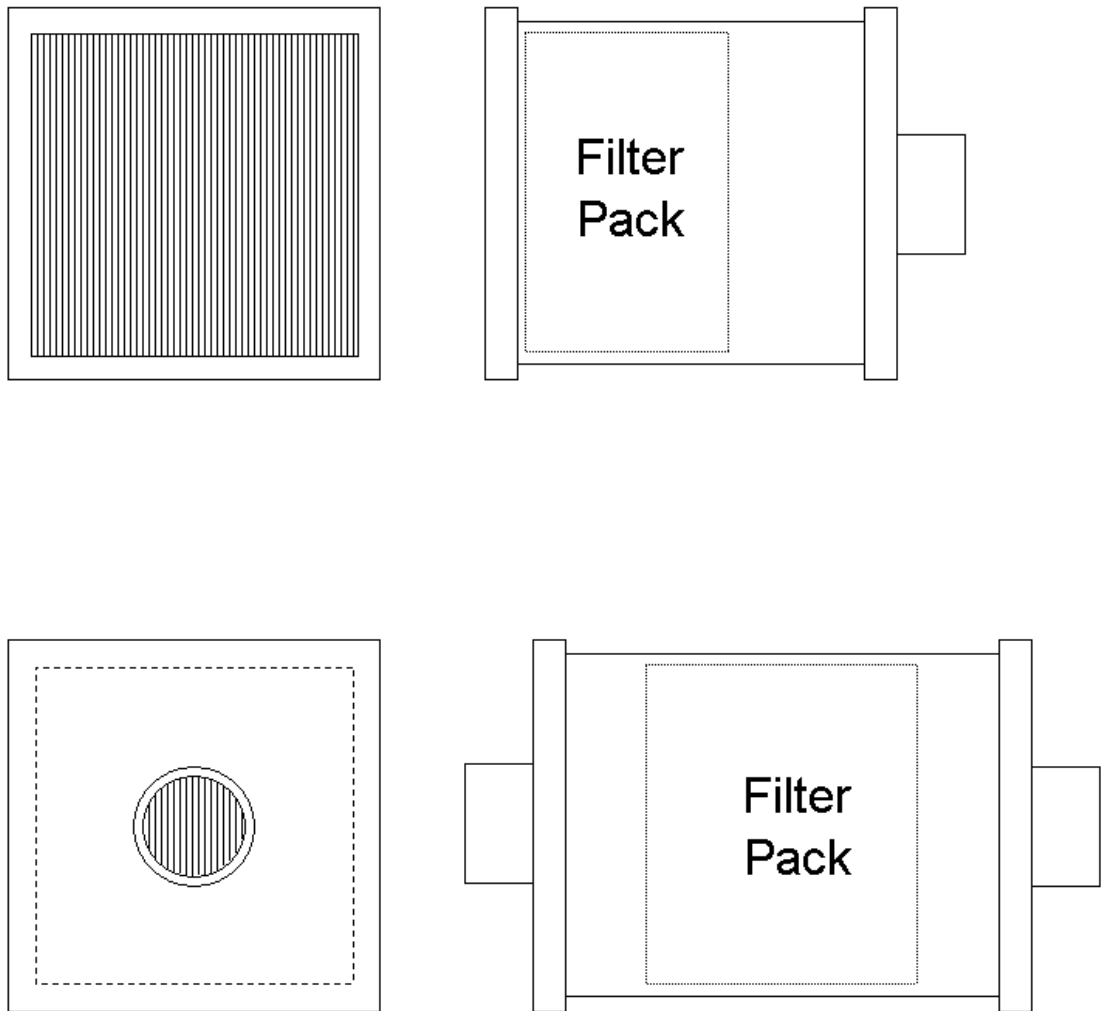
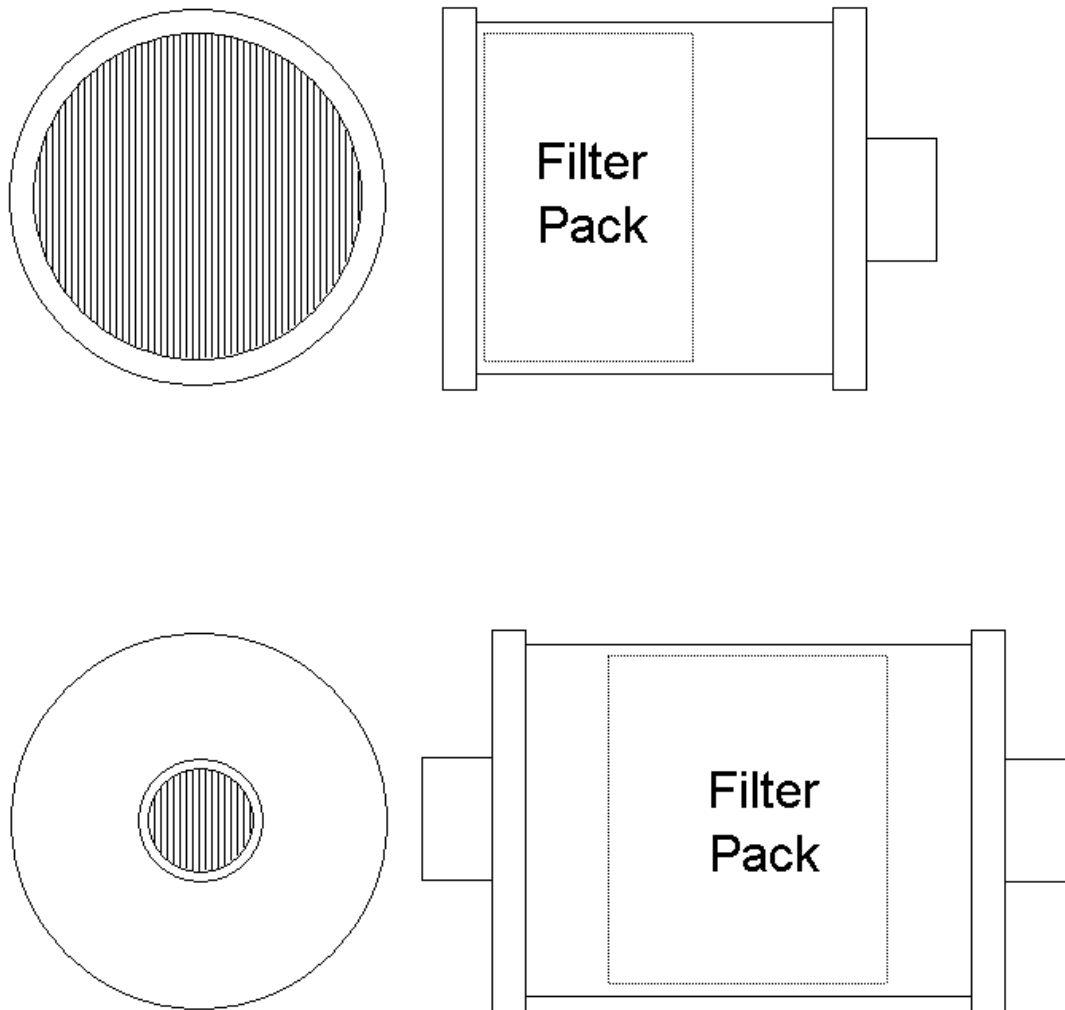


FIGURE FK-4100-7
TYPE 3 AXIAL FLOW RECTANGULAR HEPA FILTER
WITH INLET AND/OR OUTLET CONNECTIONS



**FIGURE FK-4100-8
TYPE 3 AXIAL FLOW CIRCULAR HEPA FILTER
WITH INLET AND/OR OUTLET CONNECTIONS**

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 years. 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-5000-1.

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 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-4000-1 when tested in accordance with FK-5120.

FK-5120 TEST AEROSOL PENETRATION

The test aerosol penetration shall be determined in accordance with Table FK-5000-1. The total aerosol 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 micrometer 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 micrometer 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-5130 RESISTANCE TO ROUGH HANDLING

Filters shall be tested on a rough handling machine for 15 minutes at $\frac{3}{4}$ 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, 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

The filter shall be tested for resistance to pressure on a machine capable of testing in accordance with Table FK-5000-4.

Prior to being tested for resistance to pressure, the filter shall be conditioned at atmospheric pressure for 24 hours minimum in a chamber at $95^{\circ}\text{F} \pm 5^{\circ}\text{F}$ ($35^{\circ}\text{C} \pm 3^{\circ}\text{C}$) and a relative humidity of $95\% \pm 5\%$.

After being conditioned, the filters shall withstand the airflow and water spray environment listed in Table FK-5000-4 without rupture of the filter media.

Within 15 minutes after completion of the pressure test and while still wet, the filter shall meet the requirement of FK-5120 at 20% airflow.

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 $700^{\circ}\text{F} \pm 50^{\circ}\text{F}$ ($370^{\circ}\text{C} \pm 28^{\circ}\text{C}$) for no less than 5 minutes. Ramping to this temperature shall be accomplished in no more than 15 minutes.

Following exposure to heated air and cooling of the filter in place, the filter shall be tested in accordance with FK-5120 at rated flow for test aerosol penetrations through the filter media, case, and gasket or gelatinous seal. The penetration shall not exceed 3% when tested in accordance with TA-4634.

A label showing the traceable UL control number shall be objective evidence of compliance with FK-5150.

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 $1750^{\circ}\text{F} \pm 50^{\circ}\text{F}$ ($955^{\circ}\text{C} \pm 25^{\circ}\text{C}$), 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 minutes 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 minutes. 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 which through its traceable control number or UL-586 designation shall be acceptable objective evidence of compliance with FK-5160.

FK-5200 QUALIFICATION TESTING FOR TYPE 2 AXIAL FLOW CIRCULAR FILTERS

Type 2 axial flow circular filters may be qualified based on the prior qualification of a filter size listed in Table FC-4000-1 using the same methods, materials, and equipment.

Type 2 axial flow circular filters may be qualified by testing comparable size filters listed in Table FC-4000-1 to the requirements of Article FC-5000. Type 2 axial flow circular filters shall have the same media and pack as those filters listed in Table FC-4000-1.

For example, a 12 in. high x 12 in. wide x $5\frac{7}{8}$ in. deep (305 mm high x 305 mm wide x 149 mm deep) filter listed in Table FC-4000-1 with a 14 gauge steel case, qualified to the requirements of Article FC-5000, would qualify a Type 2 axial flow circular filter with $10\frac{5}{8}$ in. (270 mm) 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.

New or revised Type 2 filter designs shall require qualification testing prior to acceptance and production. Filter designs shall be re-qualified at least every 5 years. 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-5000-2.

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 flange and end cap. The acceptance criterion for the piping, tubing, 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 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-5210 RESISTANCE TO AIRFLOW

The clean filter resistance to airflow shall meet the requirements of Table FK-4000-2 when tested in accordance with FK-5220.

FK-5220 TEST AEROSOL PENETRATION

The resistance to airflow and test aerosol penetration shall be determined in accordance with Table FK-5000-2. The total aerosol 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 micrometer 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 micrometer 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 minutes at $\frac{3}{4}$ 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, 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-5000-4.

Prior to being tested for resistance to pressure, the filter shall be conditioned at atmospheric pressure for 24 hours minimum in a chamber at $95^{\circ}\text{F} \pm 5^{\circ}\text{F}$ ($35^{\circ}\text{C} \pm 3^{\circ}\text{C}$) and a relative humidity of $95\% \pm 5\%$.

After being conditioned, the filters shall withstand the airflow and water spray environment listed in Table FK-5000-4 without rupture of the filter media.

Within 15 minutes 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 $700^{\circ}\text{F} \pm 50^{\circ}\text{F}$ ($370^{\circ}\text{C} \pm 28^{\circ}\text{C}$) for no less than 5 minutes. Ramping to this temperature shall be accomplished in no more than 15 minutes.

Following exposure to heated air and cooling of the filter in place, the filter shall be tested in accordance with FK-5220 at rated flow for test aerosol

penetrations through the filter media, case, and elastomer or gelatinous seal. The penetration shall not exceed 3% when tested in accordance with TA-4634.

A label showing the traceable UL control number shall be objective evidence of compliance with FK-5250.

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 ½ in. (64 mm) long with a tip temperature of 1750°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 minutes 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 minutes. 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 which through its traceable control number or UL-586 designation shall be acceptable objective evidence of compliance with FK-5260.

FK-5300 QUALIFICATION TESTING FOR TYPE 3 AXIAL FLOW RECTANGULAR OR CIRCULAR FILTERS WITH INLET AND/OR OUTLET CONNECTION(S)

Type 3 rectangular filters may be qualified based on the prior qualification of a filter size listed in Table FC-4000-1 containing the same materials of construction, the same pack configuration, using the same manufacturing methods and equipment, and rated at an identical useable face velocity as the filter being referenced for qualification. This is limited to Rectangular Type 3 Section FK filters with face dimensions that are smaller than the Section FC filters being referenced.

Type 3 circular filters may be qualified based on the prior qualification of a similar qualified Type 2 circular axial flow filter.

FK-5400 QUALIFICATION TESTING FOR TYPE 4 AXIAL FLOW RECTANGULAR FILTERS

Type 4 filters may be qualified based on the prior qualification of a filter size listed in Table FC-4000-1 containing the same materials of construction, the same pack configuration, using the same manufacturing methods and equipment, and rated at an identical useable face velocity as the filter being referenced for qualification. This is limited to Type 4 Section FK filters with face dimensions that are smaller than the Section FC filters being referenced.

FK-5410 RESISTANCE TO AIRFLOW

The clean filter resistance to airflow shall not exceed 1.3 inches WC (325 Pa) when tested in accordance with FK-5420.

FK-5420 TEST AEROSOL PENETRATION

The resistance to airflow and test aerosol penetration shall be determined in accordance with Table FK-5000-3. The total aerosol 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 micrometer 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 micrometer 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 minutes at $\frac{3}{4}$ 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, 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

The filter shall be tested for resistance to pressure on a machine capable of testing in accordance with Table FK-5000-4.

Prior to being tested for resistance to pressure, the filter shall be conditioned at atmospheric pressure for 24 hours minimum in a chamber at $95^{\circ}\text{F} \pm 5^{\circ}\text{F}$ ($35^{\circ}\text{C} \pm 3^{\circ}\text{C}$) and a relative humidity of $95\% \pm 5\%$.

After being conditioned, the filters shall withstand the airflow and water spray environment listed in Table FK-5000-4 without rupture of the filter media.

Within 15 minutes 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

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 $700^{\circ}\text{F} \pm 50^{\circ}\text{F}$ ($370^{\circ}\text{C} \pm 28^{\circ}\text{C}$) for no less than 5 minutes. Ramping to this temperature shall be accomplished in no more than 15 minutes.

Following exposure to heated air and cooling of the filter in place, the filter shall be tested in accordance with FK-5420 at rated flow for test aerosol penetrations through the filter media, case, and elastomer or gelatinous seal. The penetration shall not exceed 3% when tested in accordance with TA-4634.

A label showing the traceable UL control number shall be objective evidence of compliance with FK-5450.

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 $1750^{\circ}\text{F} \pm 50^{\circ}\text{F}$ ($955^{\circ}\text{C} \pm 25^{\circ}\text{C}$), 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 minutes 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 minutes. 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 which through its traceable control number or 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 Tables FK-4000-1 through Table FK-4000-3 for Type 1, 2 or 3 filters. 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

FK-5610 Production Testing of Type 1, Type 2, and Type 4 HEPA Filters

Each Type 1, 2, and 4 filter manufactured for delivery shall be tested for resistance to airflow and test aerosol penetration in accordance with:

FK-5110 and FK-5120 for Type 1 filters

FK-5210 and FK-5220 for Type 2 filters

FK-5410 and FK-5420 for Type 4 filters

Results shall be marked on the label of each filter.

FK-5620 Production Testing of Type 3 HEPA Filters

Each Type 3 filter manufactured for delivery shall be tested in accordance with FK-5621 and FK-5622.

FK-5621 Partial Assembly Test

- (a) Each Type 3 circular filter without end plates and nipple connection shall be tested for resistance to airflow and test aerosol penetration in accordance with FK-5210 and FK-5220.
- (b) Each Type 3 rectangular filter without end plates and nipple connection shall be tested for resistance to airflow and test aerosol penetration in accordance with FK-5410 and FK-5420.

Test results shall be marked on the label of each Type 3 filter.

FK-5622 Complete Assembly Test

- (a) Each Type 3 circular filter with end plates and nipple connection shall be tested for resistance to airflow and test aerosol penetration in accordance with FK-5210 and FK-5220.
- (b) Each Type 3 rectangular filter with end plates and nipple connection shall be tested for resistance to airflow and test aerosol penetration in accordance with FK-5410 and FK-5420.
- (c) The complete assembly shall be leak tested if required by the Owner. The leakage acceptance criteria shall meet the requirements of the Design Specification.

Test results shall be marked on the label of each Type 3 filter.

TABLE FK-5000-1
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 penetration at rated airflow	FK-5120
		Resistance to pressure	FK-5140
		Test aerosol penetration at 20% of rated airflow only	FK-5120
II	4	Resistance to rated airflow	FK-5110
		Test aerosol penetration at rated airflow	FK-5120
		Resistance to rough handling	FK-5130
		Test aerosol 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 penetration at 40% or greater of rated airflow (See Note 1)	FK-5120

Notes:

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 8 filters total.

TABLE FK-5000-2
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 penetration at rated airflow	FK-5220
		Resistance to pressure	FK-5240
		Test aerosol penetration at 20% of rated airflow only	FK-5220
II	4	Resistance to rated airflow	FK-5210
		Test aerosol penetration at rated airflow	FK-5220
		Resistance to rough handling	FK-5230
		Test aerosol 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 penetration at 40% or greater of rated airflow (See Note 1)	FK-5220

Notes:

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 8 filters total.

TABLE FK-5000-3
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 penetration at rated airflow	FK-5420
		Resistance to pressure	FK-5440
		Test aerosol penetration at 20% of rated airflow only	FK-5420
II	4	Resistance to rated airflow	FK-5410
		Test aerosol penetration at rated airflow	FK-5420
		Resistance to rough handling	FK-5430
		Test aerosol 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 penetration at 40% or greater of rated airflow (See Note 1)	FK-5420

Notes:

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 8 filters total.

TABLE FK-5000-4
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 ± 0.25 lb/minute per 1000 cfm 0.454 ± 0.11 kg/minute per 1700 m ³ /hr
Pressure differential across filter	10.0 ± 0.2 inches of water (2.5 kPa)
Time to reach pressure	0.5 minutes, maximum
Time duration at sustained differential pressure	1 hour, minimum
Airflow	That required for producing the above pressure differential

Notes:

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 one inch before the face of the 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) over the total filter length, flat within $\frac{1}{16}$ in. (1.6 mm).
- (c) Type 3 (Rectangular) and 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.
- (d) Type 3 (Circular) filter 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).

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 3 (Rectangular) filters 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). The above dimensions exclude gaskets. Depth tolerances apply to both the completed unit and the filter case.
- (d) Type 3 (Axial Flow Circular) filters shall have diameters within +0 in./- $\frac{1}{8}$ in. (+0 mm/-3 mm), and depths within $+\frac{1}{16}$ in./-0 in., (+1.6 mm/-0 mm). The above dimensions exclude gaskets.
- (e) 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 faceguards, 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 workmanship possible.

ARTICLE FK-7000

PACKAGING, SHIPPING, AND STORAGE

Packaging and storage shall be in accordance with Article AA-7000 and ANSI/ASME NQA-1 Level B.

HEPA filters shall be shipped under controlled conditions while maintaining protection of the goods in shipment to prevent damage, loss, or deterioration.

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, Type 3, 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 feet (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 assure 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 ASME AG-1 Section FK.

ARTICLE FK-9000

NAMEPLATES

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 $\frac{1}{8}$ 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 (inches WC or Pascals) at 100% rated flow
- (g) Overall penetration at rated flow
- (h) Overall penetration and pressure drop (inches WC or Pascals) of complete assembly for Type 3 filters only
- (i) UL label indicating successful testing per UL-586 if applicable
- (j) 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 $\frac{3}{8}$ in. (10 mm) high
- (c) Filter model number
- (d) Purchase order number or other identifying mark requested by Purchaser

Non-Mandatory 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 the tensile strength fails at 13 years. Tests indicated that folded media does not have the required 2.5 pounds per inch tensile strength even when new and is extremely low at 7 years. Research showed 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 to 8 years. Thus, under dry conditions, the filter media fail the required tensile strength or have very low burst strengths after 7 to 13 years, or an average of 10 years.

Based on this data, it is recommended that HEPA filter life under dry conditions be set at 10 years.

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 years to 3 years. Exposure to water will reduce the HEPA tensile strength to less than the initial acceptance tests. Thus, a filter that could fail at 7 to 13 years when dry could fail at about 3 to 7 years, or an average of 5 years, 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 years.

A 5-year 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 to 10 years using a specific filter media roll. Until such long term studies are conducted, establishing a 5 year and 10 year 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 Non-Mandatory Appendix have been adapted from Bergman, W., "Maximum HEPA Filter Life," UCRL-AR-134141, Lawrence Livermore National Laboratory, 1999.