An Overview and Status Report on the Draft Section FI Metal Media Filters

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Abstract

Development of a Section FI has been under way for almost ten years. This paper will provide a brief history of the development process of this section and a detailed overview of its current content/status. There have been at least two points when dramatic changes have been made in the scope of the document due to feedback from the full CONAGT committee. Development of the proposed section has required resolving several difficult issues associated with scope; namely, filtering efficiency, operating conditions (media velocity, pressure drop, etc.), qualification testing, and quality control/acceptance testing.

A proposed version of Section FI is currently undergoing final revisions prior to being submitted for balloting. The section covers metal media filters of filtering efficiencies ranging from medium (less than 99.97%) to high (99.97% and greater). Two different types of high efficiency filters are addressed; those units intended to be a direct replacement of Section FC fibrous glass HEPA filters and those that will be placed into newly designed systems capable of supporting greater static pressures and differential pressures across the filter elements. Direct replacements of FC HEPA filters in existing systems will be required to meet equivalent qualification and testing requirements to those contained in Section FC. A series of qualification and quality assurance test methods have been identified for the range of filtering efficiencies covered by this proposed standard.

Performance characteristics of sintered metal powder vs. sintered metal fiber media are dramatically different with respect to parameters like differential pressures and rigidity of the media. Wide latitude will be allowed for owner specification of performance criteria for filtration units that will be placed into newly designed systems. Such allowances will permit use of the most appropriate metal media for a system as specified by the owner with respect to material of manufacture, media velocity, system maximum static pressure, maximum differential pressure across the filter, and similar parameters.

This paper covers the general structure of the current draft version of Section FI. Highlighting the current version offers conference attendees an opportunity for input prior to submission of the document for balloting. A projected time line of submission for balloting will also be provided as part of the conference presentation.

Introduction

Metal media filters have existed for decades; predominantly in the form of sintered metal powder or metal wire mesh units. They have been employed in all sorts of operations and processes, however, there has not been an AG-1 section that addressed use on these types of filters in nuclear applications. A decade ago a working group was assembled by the CONAGT FC Subcommittee to begin the process of developing a section of the standard for metal media filters. The initial intent was to have a single section that would cover all levels of filtering efficiency.

The working group labored for approximately three years to develop a standard that would facilitate use of metal media filters as a direct replacement of fibrous glass filters of HEPA efficiency. However, when the draft FI section was balloted, there were quite a number of negatives that seemed to require starting over from first principles in redeveloping the section.

Rather than having the initiative lapse into inactivity, new members of the working group were engaged to assist in the process of development. One of the issues that had to be resolved involved the potential for metal media HEPA filters to serve as a direct replacement of Section FC HEPA filters. Numerous issues associated with this line of thought precipitated consideration of separating the initial draft into two sections addressing HEPA efficiency units and those of lower efficiency in a manner similar to fibrous glass filters (Section FC and FB).

The working group recognized the priority of developing a section of the standard for HEPA efficiency units, but also recognized the larger market potential for using metal media units upstream of conventional FC filters as protective prefilters. Such application would not require that the metal media filters possess the 99.97% efficiency rating and may be significantly lower by design. So a decision was made to limit applicability of Section FI to HEPA equivalent filters and then to turn attention to development of another section addressing lower efficiency units.

The 2006 Air Cleaning Conference resolved many of the issues associated with negatives from the balloting of the initial FI draft. A status report on progress of the working group was presented at the conference detailing the approach being taken. A great deal of input was received from conference attendees emphasizing the need for a broader standard, one including efficiencies less than HEPA quality. The range of comments convinced working group members that a solution had to be found to bring harmony to the wide variance of performance attributes of low and high efficiency metal media made from either sintered metal powder or fiber.

The approach that has yielded the current draft of an FI section has included the requirement that the standard address high and low efficiency filters, units that can be utilized as direct replacements of Section FC HEPA filters, and can accommodate media manufactured from powered metal or metal fiber. Additionally, the standard must

provide for qualification testing and for performance testing of filter elements and for units that are provided as ensembles of elements and housings. Each of these problematic issues seems to have been resolved in the current draft version of the standard.

The approach taken has been to initially categorize units addressed under the section with respect to filtering efficiency. Two general categories exist, one for HEPA quality units and the other for lower efficiency units. The term unit is used here to represent either filter elements or functional units comprised of elements and housing.

The HEPA filter category is further subdivided with respect to design factors associated with how they will be deployed. This segregation divides HEPA filtering efficiency units into those that would be considered for direct replacement of Section FC filters in existing systems and those that would be used in newly designed systems. The obvious difference in these units has to do with differential pressures, physical dimensions of the units, and media velocities. Clearly, metal media units can be packaged in different configurations from FC filters and are capable of withstanding much greater dPs. Subdividing the category with respect to deployment makes allowance for taking advantage of the strengths and flexibility of metal media units in the design of new filtration systems. It also provides equal opportunity for use of either sintered metal powder or fiber media.

The second major category of metal media filters addressed by this draft standard includes units with filtering efficiencies lower than the 99.97% level of HEPAs. This covers a wide range of potential applications for metal media filters.

The range of conditions that metal media filters can withstand and the applications for which they may be used are diverse. Configurations and dimensional requirements can also be customized for a given application. Therefore, the standard has been drafted to allow for owner/designer specification of metal durability, dimensional specifications, media velocity, maximum and minimum differential pressure allowances, and filtering efficiency. It is to be understood that this flexibility of specification is limited to filtration units that will be used in newly designed systems or restricted to operating ranges of existing systems.

Language calling for design input on metal media filters includes the following:

> **A set of design/performance criteria shall be prepared by the Owner in sufficient operating detail to provide a complete basis for equipment design** in accordance with this Code, including at minimum the temperature, pressure, and flow ranges of equipment operation. The chemical nature of solids, gases and liquids to which equipment internals and externals are to be exposed shall also be identified. **Table FI-4110-1 gives an example of the parameters that can be specified in the design criteria for metal media and metal media HEPA filters**. The list is illustrative only and can be reduced or increased as required by the Owner.

Examples of the parameters that can be specified by the owner are provided in Table 4110-1 as displayed here:

Dimensions	Length, Width, Depth
Operating Conditions	Temperature and pressure range Initial and max dP Relative humidity range Media velocity (max, min) Volumetric flow (min, max)
Materials of Construction	Gasket material Filter media material Adhesive material Filter housing material
Mounting frame/housing	Allowable materials (corrosion resistance, durability) Structural requirements -deflection limits -impact loading -stress limits -equipment design verification
Access	Filter housing, filter element Location of filter
Filter media	Filtering efficiency Unique challenge conditions (NO_x, HCl, etc.)

As stated earlier, these user-defined criteria do not apply to metal media HEPA filters that will be used as a direct replacement for section FC fibrous glass filters.

The standard also addresses requirements of filter design by:

> FI-4120 METAL MEDIA FILTERS
>
> Metal media filters are intended to be used in various nuclear air cleaning processes including applications for protecting workers, the public and the environment from hazardous and radioactive particles. **Metal media filters shall be constructed to specific designs prepared by the Owner in sufficient operating detail to provide a complete basis for equipment designed in accordance with referenced standards in FI-2000 of this Code**. The design of metal media filters can have a cylindrical or flat panel configuration.

The tensile strength and rigidity of metal media allow for the design of filters that are capable of withstanding much greater differential pressures than fibrous glass media. Flexibility is provided in the standard for the design of units to accommodate a wide range of air flows and media velocities. Section FI-4221 includes the opportunity to specify the range of differential pressures and media velocities and also specifies protocols for qualification and testing.

> The resistance to airflow at the rated airflow of the clean filter **shall be specified by Owner** and shall be tested in accordance with FI-5111.

This break from tradition of having the standard restrict resistance to airflow by imposing a ceiling value for clean filters provides opportunity for numerous questions regarding filtering efficiency, effects on most penetrating particle size, and even the test methods for evaluating these parameters. The current draft of the standard takes into account that the conditions encountered by metal media filters may not be equivalent to those commonly used in testing fibrous glass filters.

Sufficient specificity of testing methods for ranges of filtering efficiencies is provided to establish a minimum set of test protocols, yet flexibility is provided to offer the owner/designer the ability to include test conditions necessary to ensure performance within the operational environment. The listing of test procedures for metal media filters in general are contained in subpart FI-5121:

> FI-5121 Metal Media Filters
>
> The resistance to air flow and test **aerosol penetration shall be determined using a test method approved by the Owner**. The following test standards can be used for the metal media filters:
>
> (a) ISO/TS 11155-1 **for efficiencies between 10%-95%** for KCl or equivalent particles with size of 0.3-10 microns. This testing standard is not designed for the extended media velocities possible with metal media filters. Filter efficiency

testing of metal media filters at exaggerated differential pressures using KCl particles of the 0.3-10 micron size range can be accomplished in a manner equivalent to ISO/TS 11155-1 subject to approval by the Owner.

(b) MIL-STD-282 **for efficiencies between 95%- 99.99%** for DOP or DOS particles with size of 0.3 microns.

(c) IEST-RP-CC007.1 **for efficiencies between 99.99%- 99.999%** for various particles with sizes of 0.1-0.2 microns.

(d) SEMI F038-0699 **for efficiencies between 99.999%- 99.999999%** for particle sizes of 0.05, 0.07, and 0.1 microns.

(e) **Other test methods based on the most penetrating particle size are also acceptable if approved by the Owner**.

Modifications to the listed test methods may be required for metal media filters having high pressure drops, for example any unit operated and tested at media velocities sufficient to produce pressure drops in excess of 10 inches of w.c. The increase, if any, in filter pressure drop during the test shall be less than 5% of the initial pressure drop for the test to be accepted. Note that the ISO/TS 11155-1 test yields a filter efficiency curve as a function of particle size from 0.3 to 10 microns. The other tests yield filter efficiency at a single particle size.

The applicable testing standards for user defined performance criteria as defined above are not applicable for metal media HEPA filters. Testing standards for HEPA filters are given in a separate section that has some commonality with those listed in subpart FI 5121. Specification of pressure drop for units of HEPA filtering efficiency is provided in one of two subparts, and testing of units intended as direct replacements of FC filters are tested by the same protocols as FC units.

FI-4222 Metal Media HEPA Filters

The resistance to airflow at the rated airflow of the clean filter to be **used in applications originally designed for Section FC HEPA filters shall not exceed 3" water gauge (750 Pa)**, when tested in accordance with FI-5112. Rated airflow shall be as specified by Owner, and shall conform to Tables FI-4131 and FI-4132 when filters within design category FI-4130 are specified.

or

FI-5122 Metal Media HEPA Filters

The **resistance to air flow and test aerosol penetration shall be determined using a test method approved by the Owner**. The following test standards are approved for the metal media HEPA filters:

(a) **MIL-STD-282 for efficiencies between 99.97%- 99.99%** at particle size of 0.3 microns.

(b) **IEST-RP-CC007.1 for efficiencies between 99.99%- 99.9999%** for particle sizes of 0.1-0.2 microns.

Modifications to the listed test methods may be required for metal media filters having high pressure drops, for example any unit operated and tested at media velocities sufficient to produce pressure drops in excess of 10 inches of w.c. The increase, if any, in filter pressure drop during the test shall be less than 5% of the initial pressure drop for the test to be accepted.

The total test aerosol penetration through the filter shall be no greater than 0.03% of upstream concentration at rated airflow and at 20% of rated airflow.

Thus far the categories of filters covered under the draft FI standard have been covered along with the introduction of owner defined performance criteria. Test methods for filter elements or complete units have been identified for the range of filtering efficiencies and operating conditions (differential pressures, etc.) covered by the standard. Before providing tables of configurations, nominal sizes, and performance parameters for units covered under the standard, it is important to specify what the standard does not cover.

Numerous applications of metal media filters in nuclear environments are currently covered by existing standards. Most notably, bung vents for drums and vents for TRUPACs have standards that cover their fabrication and performance requirements. To include these units under this standard would require a mechanism to ensure harmony between standards or run the risk of conflicts as the individual standards are updated. For that reason, a list of "point of use" filters has been excluded from the standard with identification of the current standards covering them.

It must be currently conceded that metal media filters for applications larger than "point of use" units such as drum or container bungs and instrument filters are specialty units. This makes the process of providing general descriptive information about dimensions, flow rates, pressure drops, etc., in the standard because of the range and types of media used and the uniqueness of current applications difficult at best and in all likelihood, misleading. Standardized sizes/configurations for larger flow rate units do not exist and metal media filters covered by this standard do not have "off the shelf" availability. The working group has expressed concern that including tables of representative descriptive data implying that standard sizes are available may jeopardize future use of the standard. Yet the group has also recognized that tables of nominal dimensions and performance information need to be included.

After extensive discussion and consideration, it is believed that an appropriate balance has been struck for presenting tables of descriptive information in sufficient detail with precautionary explanations. Note the points at which reference is made to metal media

filters being specialty filters and the inclusion of footnotes to emphasize that tabular data do not represent the full range of sizes and configurations that are available.

The following tables and additional descriptive language are provided for cylindrical filters and panel filters. Section FI-4121 provides tables of sizes and nominal performance data for various sizes of cylindrical metal media filter elements. It is important to emphasize the draft status of these tables. The reader should anticipate that additional input from manufacturers will be used to finalize the structure and content of these tables. Data for Section FI-4122 panel filters will be provided next followed by similar data for HEPA quality metal media filters that are covered in Sections FI-4131 and FI-4132.

Table 4121-1 NOMINAL RATINGS FOR 66 mm (2.65 inch) DIAMETER CYLINDRICAL METAL MEDIA FILTERS (flows given in cfm)

Length cms	Q @ 1000 Pa (4”)	Q @ 1500 Pa (6”)	Q @ 2000 Pa (8”)	Q @ 2500 Pa (10”)	Q @ 3000 Pa (12”)	Q @ 5000 Pa (20”)	Q @ 10000 Pa (40”)	Q @ 20000 Pa (80”)	

									Q @ 30000 Pa(120”)

250	20	30	40	55	70	110	215		

Manufacturers can supply pleated 316L Stainless Steel sintered metal fiber filter elements in diameters and lengths as desired by the user. Data in this table is provided as being representative of volumetric flow rates for a given length of filter element and differential pressure.

Table 4121-2 NOMINAL RATINGS FOR 86 mm (3.375 inch) DIAMETER CYLINDRICAL METAL MEDIA FILTERS (flows given in cfm)

	Volumetric Flow rate (Q_{cfm})								
Length cms	Q @ 1000 Pa (4”)	Q @ 1500 Pa (6”)	Q @ 2000 Pa (8”)	Q @ 2500 Pa (10”)	Q @ 3000 Pa (12”)	Q @ 5000 Pa (20”)	Q @ 10000 Pa (40”)	Q @ 20000 Pa (80”)	Q @ 30000 Pa (120”)

250	40	60	80	95	110	180	335		

1000	110	150	190	225	265	420	710	1120	1420

Manufacturers can supply pleated 316L Stainless Steel sintered metal fiber filter elements in diameters and lengths as desired by the user. Data in this table is provided as being representative of volumetric flow rates for a given length of filter element and differential pressure.

METAL MEDIA FILTERS (flows given in cfm)

	Volumetric Flow rate (Q_{cfm})								
Length cms	Q @ 1000 Pa (4”)	Q @ 1500 Pa (6”)	Q @ 2000 Pa (8”)	Q @ 2500 Pa (10”)	Q @ 3000 Pa (12”)	Q @ 5000 Pa (20”)	Q @ 10000 Pa (40”)	Q @ 20000 Pa (80”)	Q @ 30000 Pa (120”)

250	50	75	100	125	150	240	450		

1000	120	165	210	270	330	550	1000	1550	1940

Manufacturers can supply pleated 316L Stainless Steel sintered metal fiber filter elements in diameters and lengths as desired by the user. Data in this table is provided as being representative of flow rates for a given length of filter element and differential pressure.

Fig. 4122 Panel Metal Media Filter

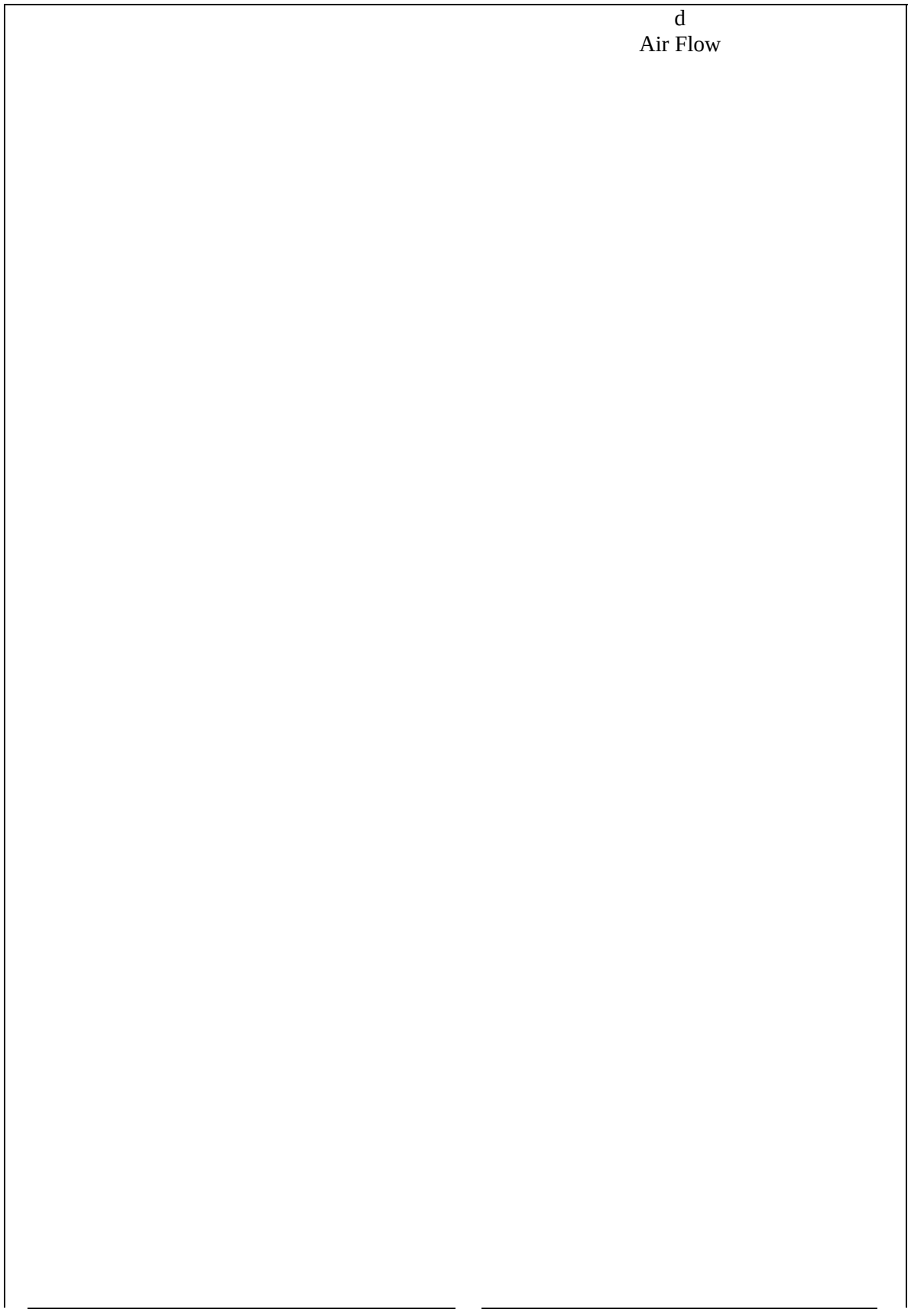
An example of a basic design of a panel metal media filter is shown in Fig. FI-4100-6. **Dimensions, flow rating, and pressure drops for panel metal media HEPA filters have not been standardized. While designs for panel filters capable of being directly substituted for Section FC fibrous glass media HEPA filters exist, metal media HEPA filters should still be considered specialty filters**. As such, panel metal media HEPA filters are subject to design specifications of the Owner. **Data included in Table 4122 are provided as representative of units for which designs exist or that have been used in an application. Other designs are also acceptable**.

(a) Where a panel geometry is employed, the gasket shall be fixed to the metal filter housing with an adhesive in conformance with FI-3120 and FI-3130.

Table 4122 TYPICAL SIZES AND RATINGS FOR PANEL METAL MEDIA FILTERS

Table 4122 Typical Sizes and Ratings for Panel Metal Media Filters[1]

Size[2]	Minimum Rated


d
Air Flow

Inches	mm	acfm	M^3/hr

24 x 24 x 11 $^{1}/_{2}$	610 x 610 x 292	1250	2125
24 x 24 x 11 $^{1}/_{2}$	610 x 610 x 292	2000	3400

	10 x 610 x 292	
2 x 11 $^{1}/_{2}$	305 x 305 x 292	424

[1] Penetration and flow resistance are to be specified by owner.

er.
[2] Other sizes are available.

FI-4130 METAL MEDIA HEPA FILTERS

L MEDIA HEPA FILTERS

Metal media HEPA filters have strength and endurance capabilities different from Section FC fibrous glass HEPA filters. As such, Section FI filters may be utilized in broader applications than Section FC filters. **Section FI of this standard addresses two categories of metal media HEPA filters: (1) units intended for direct replacement of Section FC filters in existing systems and (2) units placed into new systems designed and fabricated to meet owner defined acceptance criteria in addition to HEPA filtering efficiency**. In this latter case, metal media HEPA filters shall be constructed to specific designs prepared by the Owner in sufficient operating detail to provide a complete basis for equipment designed in accordance with referenced standards in FI-2000 of this Code. The design of metal media HEPA filters can have a cylindrical or flat panel configuration.

(a) The maximum housing pressure, maximum filter pressure drop, and maximum external housing leakage rate shall be as specified by the Owner.

(b) If welding is employed in metal media HEPA filter element construction, the finished filter element shall be solution annealed in a reducing atmosphere.

(c) Metal media HEPA filters shall be designed to meet qualification testing per FI-5100 and performance testing per FI-4200.

(d) Metal media HEPA filters having cylindrical or other configurations with single or multiple filter elements are acceptable.

(e) Construction shall conform to Section FI-6000 of this Code.

(f) Total mass of the metal media filters shall conform with load bearing capabilities of existing systems or new system design criteria.

FI-4131 Cylindrical Metal Media HEPA Filters

Cylindrical metal media HEPA filters can vary greatly in size and flow rating ranging from drum vent filters with a minimum flow of 35 ml/min to large facility ventilation filters with flows in excess of 2,000 cfm. Figures FI-4100-4, FI-4100-5 and FI-4100-7 illustrate examples of a cylindrical metal media HEPA filter designs.

Table 4131-1 NOMINAL RATINGS FOR 66 mm (2.625 inch) DIAMETER CYLINDRICAL METAL MEDIA FILTERS (flows given in cfm)

Length mm	250	500	750	1000

(inches)	(10)		(20)		(30)		(40)	
	Flow cfm	DP Pa	Flow cfm	DP Pa	Flow cfm	DP Pa	Flow cfm	DP Pa
	10	730	20	790	30	850	40	910

Filter Material in tables: 316L Stainless Steel

in tables: 316L Stainless Steel

Manufacturers can supply pleated sintered metal fiber filter elements in diameters and lengths as desired by the user. Data in this table is provided as being representative of volumetric flow rates for a given length of filter element and differential pressure.

Table 4131-2 NOMINAL RATINGS FOR 86 mm (3.375 inch) DIAMETER CYLINDRICAL METAL MEDIA FILTERS (flows given in cfm)

Length. mm (inches	250 (10)		500 (20)		750 (30)		1000 (40)	
	Flow cfm	DP Pa	Flow cfm	DP Pa	Flow cfm	DP Pa	Flow cfm	DP Pa

	16	760	32	810	48	880	64	980

Filter Material in tables: 316L Stainless Steel

Manufacturers can supply pleated sintered metal fiber filter elements in diameters and lengths as desired by the user. Data in this table is provided as being representative of volumetric flow rates for a given length of filter element and differential pressure.

Table 4131-3 NOMINAL RATINGS FOR 100 mm (4 inch) DIAMETER CYLINDRICAL METAL MEDIA FILTERS (flows given in cfm)

Length. mm (inches)	250 (10)		500 (20)		750 (30)		1000 (40)	
	Flow cfm	DP Pa	Flow cfm	DP Pa	Flow cfm	DP Pa	Flow cfm	DP Pa

	23	728	45	774	66	841	88	944

Filter Material in tables: 316L Stainless Steel

Manufacturers can supply pleated sintered metal fiber filter elements in diameters and lengths as desired by the user. Data in this table is provided as being representative of volumetric flow rates for a given length of filter element and differential pressure.

Table 4132 TYPICAL SIZES (NOMINAL) AND RATINGS FOR PANEL METAL MEDIA HEPA FILTERS

Table 4132 Typical Sizes (Nominal) and Ratings for Panel Metal Media HEPA Filters

Size[1]	Minimum Rated Air Flow	Clean Maximum Resistance

Inches	mm	acfm	M^3/hr	g.	Pa

$5\ ^{7}/_{8}$	305 x 305 149	125	212	3	50	

24 x 24 x 5 $^{7}/_{8}$	610 x 610 x 149	500	850	3	750

24 x 24 x 11 $^{1}/_{2}$	610 x 610 x 292	00	3400	3	750
12 x 12 x 11 $^{1}/_{2}$	305 x 305 x 292	250	424	3	750

5 x 292

[1] Other sizes are available

There are numerous other subparts of the current draft structure of Section FI that are not covered in detail in this paper. Unique issues of metal media filters involve attachment of candle-type filter elements to a supporting plate, seams of cylindrical filter elements, sealing surfaces of filter elements and housings, and tests for air flow resistance and filter efficiency. While these issues are not trivial, there are reasonable solutions based on similar standards that have been drawn on by the FI Working Group. The current draft

also includes non-mandatory appendices such as one that provides guidance in the design of filter assemblies/housings to assist process design engineers in development of new systems.

While this paper does not provide coverage of all aspects of the current draft of Section FI, it is intended to give the reader a sense of the areas of the standard that have been the most difficult to develop. There has also been an attempt to include those aspects of the current draft that have received the most comment and concern in past interactions between the FI Working Group, the Filtration Subcommittee, and the full CONAGT committee. It is hoped that presenting the issues covered in this paper will facilitate incorporation of input from conference attendees into a final draft that can be presented to the full CONAGT committee for balloting in the very near future.