ASME AG-1 HEPA Filters; A Comparison of Configurations - 11604

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ABSTRACT

HEPA filters utilized in United States nuclear industry are those that meet and are qualified in accordance with the requirements of the American Society of Mechanical Engineers (ASME) AG-1 Code on Nuclear Air and Gas Treatment section FC. Although filters that meet these requirements are largely considered equivalent, there are substantial difference in construction allowed within this code section. The most notable differences are the configuration of the filter pack, the frame material and the gasket material utilized in the construction of a qualified filter. Additionally, a new ASME AG-1 code section is under development that defines HEPA filters that exceed the strength capabilities of current HEPA filters.

INTRODUCTION

HEPA filters serve as an important safety device in the event of containment failure or process containment. They serve to protect control room personnel as well as the public and environment. The environmental conditions a filter can be exposed to during normal operation or a containment failure, can range from a nominal change to significant changes is humidity, temperatures and pressures relative to normal operating conditions. In some applications, normal operation exposes filter to highly corrosive gasses. The concern is the ability of the HEPA filter to perform this function over its entire life and specifically during an event that could occur later in its life. It is possible that the construction of the filter including the configuration of the filter pack, frame material or gasket material could have an impact on the ability of the filter to continue to perform in extreme conditions later in life. The different filter pack configurations, frame materials and gasket materials specified in section FC of the ASME AG-1 code along with their strengths, weaknesses and considerations for specific applications will be reviewed in this paper. A new ASME AG-1 code section, under development, that is focused on higher strength filters capable of withstanding pressures that are orders of magnitude higher than conventional ASME AG-1 section FC HEPA filters will also be briefly discussed.

ALLOWABLE PACK TYPES

The current code for nuclear grade HEPA filters defines 4 specific pack types acceptable in the construction of qualified HEPA filters [1]. The difference between these 4 pack types is the method utilized to separate the pleats and in one case includes the actual configuration of the filter. The 4 pack types are defined below and are direct excerpts from the ASME AG-1 code section FC [1];

(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 in the adhesive/sealant. The separators shall not extend beyond the ends of the case when the media pack is bonded to the case. The filter pack shall be rigid with the case, and the separators shall be perpendicular to two opposite parallel sides of the case. Separators and media shall not vary more than ¼ in. (6 mm) from a straight line connecting the fixed ends. Abrupt deviations are not acceptable. (See figure 1 below for a photograph of a Type A filter pack).

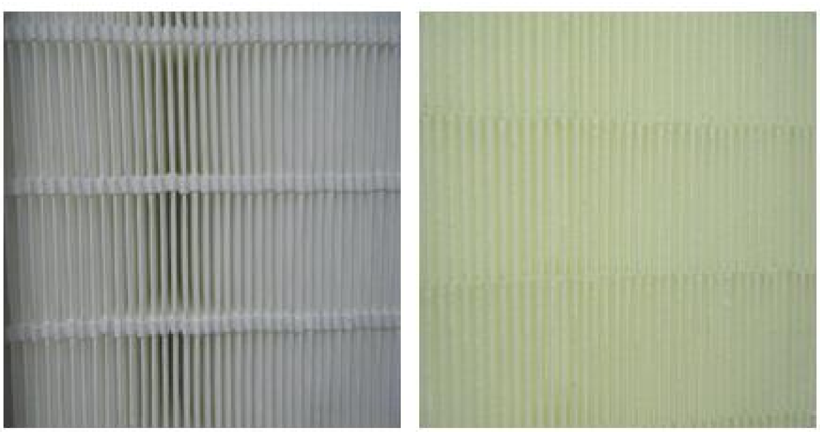
(b) Type B filter packs shall be made from a series of flat panels of pleated filter media, which are assembled in a V form. Pleats shall be separated and supported by ribbons of glass fiber media or noncombustible threads bonded to the filter media. When the panels are installed in the filter case, the top and bottom panels shall be sealed. The mating panels shall have a common bonded metal joint. Panel flatness, including separator, shall vary no more than ¼ in. (6 mm). Side panels shall be securely bonded to the side of the filter case with adhesive. (See figure 1 below for a photograph of a Type B filter pack).

(c) Type C filters packs shall be made by corrugating or embossing a continuous sheet of filter media and folding media to the required depth to make the filter pack. When the panels are installed in the filter case, the top and bottom of the panels shall be sealed. When in the case, the self-supporting media convolute or embossed centers shall not vary by more than $^{3}/_{8}$ in. (10mm) top to bottom from a straight line drawn perpendicular to the top and bottom case. Crest-to-crest contacts on adjacent folds shall not vary by more than $^{1}/_{16}$ in. (1.5mm). Abrupt deviations in media folds are not acceptable. Filter media or filter media supports, if used, shall not extend beyond the filter case. The filter pack shall be rigid within the case and there shall be no kinked media. (See figure 1 below for photograph of a Type C filter pack).

Type A Type B Type C

Fig. 1. Photographs of pack types A, B and C as defined in ASME AG-1 section FC.

(d) Type D filter packs shall be made by folding the media to the required depth. The folded filter media shall be separated and supported by ribbons of glass fiber media or noncombustible threads, glued to the filter media. The filter pack shall be rigid within the case, and the media pleats shall be perpendicular to two opposite parallel sides of the case. Abrupt deviations in media are not acceptable. When the panels are installed in the case, the top and bottom of the panels shall be sealed in a reservoir of potting adhesive at least $^{1}/_{16}$ in. (1.5 mm) deep.



Type D (media ribbons) Type D (threads)

Fig. 2. Photographs of pack type D as defined in ASME AG-1 section FC.

Filter pack types A, C and D are typically applied in a configuration where the face of the pack is perpendicular to the flow through the filter and the pack depth is nominally the depth of the filter. Pack type B is a specific configuration that pack type D packs are applied. These packs are applied in a V configuration as depicted in Fig. 1 above and are nominally 25 mm (1 inch) in depth.

PLEAT PACK CONSTRUCTION PHILOSOPHIES

There are two very different philosophies present in the methods utilized to separate pleats in the different pleat pack types. One philosophy avoids media to media contact while the other allows it.

(a) In pack type A (aluminum separators) and pack type D (with thread separator) there is no media to media contact. In the case of type A, the aluminum separators serve to separate the pleats allowing air to flow into the pleat and through the media. The tightness and stability of the pack relies on both the compression of the aluminum separators and media during filter assembly. For type D (with thread separator), the thread serves to separate the pleats allowing air to flow into the pleat and through the media. The thread is also bonded to the media and itself resulting is a very tight and stable pack that does not rely on compression.

(b) In pack type C and pack type D (with ribbons of glass fiber media separator) there is direct media to media contact. In the case of type C, the raised areas of the media caused by the corrugating or embossing process serve to separate the pleats and allow air to flow into the pleat and through the media. The tightness and stability of the pack relies on the compression of the media corrugations or embosses during filter assembly. For type D (with ribbons of glass fiber media separator), the ribbons of media serve to separate the pleats and allow air to flow into the pleat and through the media. The tightness and stability of the pack relies on the compression of the media ribbon and filter media itself. It should be noted, as required in the AG-1 code, the media ribbon should be bonded to the filter media but is not bonded to itself.

STRENGTHS/WEAKNESSES OF PLEAT SEPARATION METHODS

Each allowable pleat pack separation method has potential strengths and weaknesses. One of the key factors in the service life and potential failure of a qualified ASME AG-1 HEPA filter is related to the ageing characteristics of the HEPA filter media. There have been several ageing studies performed [2-5] along with a summary of these studies [6] showing that the filter media strength and water repellency degrade with filter age. It should also be noted that a substantial decrease in media strength characteristics was identified when exposed to high humidity or direct water exposure. A key factor to also consider in conjunction with these studies is the composition of the glass fiber and binder utilized in the media. These attributes can have profound effects on the medias ageing characteristics and response to moisture. The determination of acceptable strength characteristics of a newly qualified HEPA filter is based on both the filter media dry and wet tensile strength and subsequent overpressure test on new filters. The pleat separator methods can be separated in one of the following four categories;

i. Non-media rigidly bonded material.

ii. Non-media material.

iii. Filter media

a. Independent of the media used for filtration.

b. The media relied on for filtration.

It is clear that the non-media rigidly bonded material category may provide the longest term robust pack since it does rely on media itself. The non-media material may also be a good choice since it also does not rely on media itself. The filter media category may be of concern due to the loss of physical characteristics of the media with age or moisture exposure. Each pleat separator method along with its category and perceived strengths and weaknesses are shown in Table I.

Table I. A Summary of Allowable Pack Types Identifying Perceived Strengths and Weaknesses

Pack Type	**Separator Category**	**Separator Details**	**Strengths**	**Weaknesses**
Type A	ii (non-media material)	Corrugated aluminum separators	Rigid Pack, No media to media contact, configuration flexibility	Weight, Manufacturing process
Type B/D	i. (non-media rigidly bonded mat'l)	Bonded threads	Very Rigid Pack, No media to media contact, Light weight, Manufacturing process, configuration somewhat flexible	Manufacturing process
Type B/D	iii-a (Filter media that is independent from the media used for filtration)	Ribbons of glass fiber media	Rigid Pack, Light weight, Manufacturing process,	Media to media contact, configuration flexibility
Type C	iii-b (Filter media relied on for filtration)	Corrugated or embossed filter media	Light weight, Manufacturing process, configuration flexibility	Media to media contact, Less rigid pack

ALLOWABLE CASE MATERIALS

The current code for nuclear grade HEPA filters defines 2 categories of case materials allowed in the construction of qualified HEPA filters [1]. They are stainless steel and plywood. These two categories are separated into 3 specific defined materials that are included below as direct excerpts from the ASME AG-1 code section FC [1] ;

a) Stainless steel Type 409, 304, 304L, 316 or 316I per ASTM A 240. Steel sheet, having minimum thickness equal to 0.072 in. (14 gage USS) (1.83mm).
b) Marine plywood, minimum grade A (interior side) and minimum grade B (exterior side), APA PS-1. The minimum thickness shall be ¾ in. (19 mm). The grade shall be fire retardant treated. The plywood shall have a flame spread classification of 25 or less when tested as specified in ASTM E 84.
c) Exterior plywood, minimum grade A (interior side) and minimum grade C (exterior side, APA PS-1). The minimum thickness shall be ¾ 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.

These frame materials each have distinct strengths and weakness. A summary of perceived strengths and weaknesses are included in table II below.

Table II. A Summary of Case Materials Identifying Perceived Strengths and Weaknesses

Case Material	**Strengths**	**Weaknesses**
Stainless Steel	Robust, Durable,	Heavy, incineration, compaction, cost
Marine Plywood	Light weight, incineration, compaction (disposal), cost	Less robust
Exterior Plywood	Light weight, incineration, compaction (disposal), cost	Less robust

ALLOWABLE GASKET MATERIALS

There are two gasket options allowed in the current code for nuclear grade HEPA filters. The two options are elastomer (gasket) and gelatinous (gel). These two options differ greatly in physical characteristics. These options are defined below as direct excerpts from the ASME AG-1 code section FC [1];

a) Elastomer: Elastomer shall be of an oil-resistant, closed cell expanded cellular elastomer in accordance with grade 2C3 or 2C4 of ASTM D 1056, with the physical requirements specified for ASTM D 1056 Cellular rubbers classified as Type 2, Class C, Grade 3 (2C3), or Grade 4 (2C4).
b) Gelatinous Seal: Gelatinous seals shall be self-adhesive and self-healing cured gel seals made of polydimethylsiloxane.

These gasket materials each have perceived strengths and weaknesses. A summary of perceived strengths and weaknesses are included in table III below.

Table III. A Summary of Gasket Materials Identifying Perceived Strengths and Weaknesses

Gasket Material	**Strengths**	**Weaknesses**
Elastomer	Durable, high pressure differentials,	memory, corner joints leak risk,
Gelatinous	Low clamping force; easy seal,	More fragile, lower pressure differentials

APPLICATION CONSIDERATIONS:

The specific application that the filter is utilized can affect its service life and possibly it's actual selection for the application. The pack type, frame material and gasket material can all an impact on these decisions/determinations. Table IV below is a matrix that relates some common nuclear filter applications including the associated environmental conditions to the previously discussed construction options identifying if there is Major Concern (MC), Potential Concern (PC) or No Concerns (NC) with applying the option to the application.

	Glove Box (Zone 1 & 2)	Waste Tank Breather Systems	Control Room Isolation	Waste Container and Drum Venting	Fuel Enrichment Ventilation	Waste Processing
	Radioactive particulate	High Humidity, elevated temperatures, radioactive particulate	Radioactive Particulate	High Radiation, explosive gas	Potential for corrosive fumes, high humidity	High humidity, elevated temperatures, radioactive particulate
Pack Type A	NC	PC	NC	PC	MC	PC
Pack Type B	NC	PC	NC	PC	MC	PC
Pack Type C	NC	MC	NC	PC	MC	MC

Pack Type D	NC	PC	NC	PC	MC	PC
Stainless Steel Frame	NC	NC	NC	PC	MC	NC
Marine Plywood Frame	NC	PC	NC	PC	MC	PC
Exterior Plywood Frame	NC	PC	NC	PC	MC	PC
Elastomer Gasket Seal	NC	NC	NC	PC	MC	NC
Gelatinous Seal	NC	NC	NC	PC	MC	NC

As you can see, there are many areas of potential concern and/or major concern depending on the exact conditions the filter may be exposed. High humidity, corrosive fumes or explosive gases (high impulse pressure situations) are of primary concern. It should also be noted that filters constructed with Pack Type C are potentially the worst choice when filters are (possibly) subjected to applications containing high humidity/moisture. In all cases, standard nuclear grade filters are a major concern when utilized in applications with highly corrosive fumes. In these cases, the owner must determine appropriate replacement intervals or justify the use of specially designed and potentially unqualified filters.

NEW HIGH STRENGTH FILTERS

There is a new ASME AG-1 code section under development that defines filters constructed to exceed the strength, by orders of magnitude, of current filters. These filters primarily rely on media that has a reinforcement layer laminated to the downstream side. This reinforcement layer substantially increases the tensile strength of the composite. The design also requires the use of aluminum separators to provide the pleat separation. If properly compressed, this separation method provides a very stable and robust pack. Initial testing using an intermediate scale pressure impulse test system showed very promising results [7]. The filters tested continued to perform with particle penetration values less than 0.03% when subjected to an impulse pressure as high as 18.5 PSI. A full scale test system is currently in development to formalize the capabilities of these filters and finalize the new code section. The use of this type of filter in the above matrix would be no concern in all applications except those containing corrosive gases.

CONCLUSIONS

It is clear that all nuclear grade filters are not equivalent and that the current code does not fully address the construction of filters to meet all applications. It is also clear that a Type C pack may be the least desirable since it relies on media to media contact to separate the pleats and likely has the least rigid pack of all types. This pack type has lower pack tightness since the pack can only be compressed into the frame without deforming or crushing the embossing or corrugations. The initial tightness of the pack is critical to pass the qualification test requirements. Although this is very important, the ability of the filter to continue to perform for years after initial installation is critical. As the filter media ages with time and environmental conditions, it is likely that the pack tightness may decrease making the pack more susceptible to failure under adverse conditions. With this in mind, a future study that compares the strength of filters relative to age, moisture exposure and pack type is highly recommended.

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