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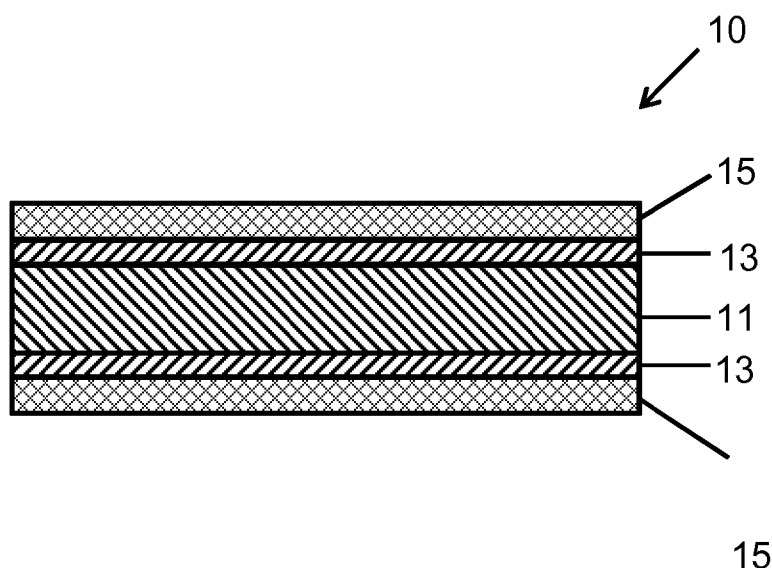
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(54) Title: HEPA FILTRATION MEDIA



(57) Abstract: A HEPA filtration media comprises a central layer and at each side of the central layer one or more further layers. The media comprises with respect to the central layer a symmetrical layer built-up over the thickness dimension of the filtration media. The central layer of the media comprises a nonwoven web comprising stainless steel fibers of average equivalent diameter less than 2 μm. The central layer has a specific weight between 750 and 1200 g/m². The media comprises at both sides of the central layer a first further layer in direct contact with the central layer. Each of the two first further layers comprises a nonwoven web comprising stainless steel fibers of average equivalent diameter between 3 μm and 8 μm.

Fig. 1

HEPA filtration media

Description

Technical Field

[0001] The invention relates to the field of HEPA (High-efficiency particulate air) filtration media for use in high temperature filtration of gasses, e.g. up to 450 °C, e.g. for use in nuclear power plants.

Background Art

[0002] HEPA is a type of air or gas filter. HEPA filters composed of a mat of randomly arranged glass fibers are known and have many applications. However, HEPA filters out of glass fibers have a number of drawbacks. Typical high efficiency gas filters including glass fiber filters are mechanically weak and fragile so that they may be structurally damaged when subjected to high air flow, high temperature, high humidity, heavy dust loads or combinations of these factors. An important drawback is that they do not withstand cleaning by means of back pulsing; and that they do not withstand high pressure drops.

[0003] High efficiency particulate air (HEPA) filters are utilized in a number of different industries including the nuclear industry to prevent chemical contamination. For various applications the filter should operate at high temperatures and have high strength. The filter should have high efficiency at high flow rates. The filter design should also be as compact as possible to minimize the impact on the overall system design.

[0004] Particulate air filtration media out of stainless steel fibers have the benefit of high corrosion resistance, high temperature resistance and mechanical resistance, beneficial in many applications, such as for use in nuclear industry.

[0005] A specific application of particulate air filtration where high efficiency of filtration is required is in nuclear power plants, more specifically for the safety containment of a nuclear reactor. Such filtration systems are e.g. described in US5267283A and US4865803A. US4865803A discloses a

pressurized gas discharge system for the safety containment of a nuclear reactor. The system includes a conduit structure connected to the containment and consisting of a plurality of modular conduit units which are flanged together end-to-end, each having flanged side openings with filter frame members including stainless steel fiber filter packs flanged thereto in end-to-end relationship. The document does not contain specifics on the filtration media, nor performance results.

- [0006] US5353949A discloses a vent filter assembly that may be disposed in a wall of a sealed waste container containing radioactive waste or the like and utilized for venting gases. The vent filter includes a housing coupled to the container. A filter is coupled to the housing and disposed across the gas flow path such that gas flowing between the openings flows through the filter. The filter includes a porous metal hydrophobic filter media. The document mentions that a stainless steel metal fiber filter can be used, but does not provide any specifics on the filtration media nor on its performance.
- [0007] US5358552A discloses a method for cleaning via backwashing a gas filtration system. The filtration system has a holding vessel containing a gas filter for clarifying an influent gas stream passing through the gas filter in one direction. The preferred filter element is a high efficiency metal fiber media, comprising sinter bonded metal fibers. The media is relatively thin and pleated so that high flows can be handled at low pressure differentials in compact assemblies.
- [0008] US5814118A describes a HEPA filter used in a vent for venting a chamber containing a radioactive material such as plutonium slurry. The filter element includes a stainless steel wire mesh tube which supports a sintered stainless steel filter media thereon. The filter element comprises a filter media of sintered stainless steel fibers arranged as a fiber mat. The diameters of the fibers are in a range of 2 - 40 μm and are generally equally distributed throughout the mat so that the mat is of substantial uniform density. The mat has a thickness in the range of about 0.010 inch to about 0.050 inch and is preferably about 0.014 inch thick.
- [0009] US4687579A mentions that one approach to HEPA filtration is to fabricate HEPA filters from a fibrous, stainless steel media. However, although

stainless steel filters can withstand high temperature, pressure and humidity, they do not have efficiencies comparable to conventional HEPA filters. The problem is that the smallest stainless steel fiber diameter that can be produced is about 2 microns and in order to achieve efficiencies comparable to current HEPA filters, it is necessary to have fiber diameters of about 0.5 microns. Thus, sintered metal filters have only a 65% efficiency or less at its minimum. The primary reason for the use of glass micro-filters in HEPA filters is the availability of bulk fibers having diameters as small as 0.3 microns which are responsible for the high efficiency of HEPA filters. Unfortunately, these micro-fibers cannot be formed into a high strength filter media using conventional adhesives. US4687579A discloses a particulate filter media for HEPA filtration formed of a sintered composite of 0.5 micron diameter quartz fibers and 2 micron diameter stainless steel fibers. A preferred composition is about 40 volume percent quartz and about 60 volume percent stainless steel fibers. The media is sintered at about 1100 °C in order to bond the stainless steel fibers into a cage network which holds the quartz fibers. Since the sintered media will crack if it is bent, the continuous media must be formed into the final filter configuration prior to sintering. High filter efficiency and low flow resistance are provided by the smaller quartz fibers. High strength is provided by the stainless steel fibers. The resulting media has a high efficiency and low pressure drop, with tensile strength at least four times greater, and a maximum operating temperature of about 550 °C. The filter media can be used to filter particles in both liquids and gases. The filter media is especially suited for HEPA filtration, with a pleated filtration media.

[0010] US2014/007550A discloses a filter device for filtering a gas flow that is loaded with at least one of aerosols and gaseous radioactive iodine, the filter device comprising: a housing that is closed fluid tight, including at least one raw gas inlet, a clean gas outlet, at least one filter element including a filter media, the filter element arranged in the housing so that a gas flow to be filtered moves from the at least one gas inlet to the clean gas outlet exclusively through the filter element, at least one tubular element penetrating the housing from a first pass through cross-section to

a second pass through cross-section which is arranged in vertical direction above the first pass through cross-section, so that an entire inner cavity of the at least one tubular element is exclusively in contact with an ambient fluid surrounding the filter device. The filter media can be formed from a metal fleece. No detail is provided on the composition of the metal fleece, nor of its performance levels.

- [0011] The standard for HEPA of the American Society of Mechanical Engineers ASME-AG-1 of 2012 ("Code on nuclear air and gas treatment") specifies a face velocity of 2.5 cm/s for testing filtration efficiency.
- [0012] It is a problem that no pleatable, temperature resistant, low pressure drop filtration media is available for HEPA filtration at high face velocity of more than 5 cm/s for nuclear power plants. The standard face velocity in such application is normally about 2.5 to 3 cm/s. It is a further problem that no such HEPA filter is available that can be cleaned via back pulsing.

Disclosure of Invention

- [0013] It is an object of the invention to provide a pleatable, temperature resistant, low pressure drop and cleanable via back pulsing filtration media for HEPA filtration at high face velocity of more than 5 cm/s in nuclear power plants.
- [0014] It is a specific objective to provide a pleatable, temperature resistant (preferably up to 450°C) and cleanable via back pulsing HEPA filtration media for nuclear power plants, wherein the HEPA filtration media shows an air permeability of at least 4.8 liter/(dm².min) when measured at 200 mbar pressure drop and a filtration efficiency (local retention ratio) of more than 99.97% for particles of 0.3 µm size when measured according to EN1822:2009 and at a face velocity of 6 cm/s.
- [0015] The first aspect of the invention is a HEPA filtration media, preferably for use in nuclear industry. The media comprises a central layer and at each side of the central layer one or more further layers. The HEPA filtration media comprises with respect to the central layer a symmetrical layer built-up over the thickness dimension of the filtration media. The central layer of

the HEPA filtration media comprises - and preferably consists out of - a nonwoven web comprising - and preferably consisting out of - stainless steel fibers of average equivalent diameter less than $2\text{ }\mu\text{m}$, preferably of less than $1.8\text{ }\mu\text{m}$; and more preferably of more than $1\text{ }\mu\text{m}$; and more preferably of more than $1.2\text{ }\mu\text{m}$ (e.g. $1.5\text{ }\mu\text{m}$). The central layer has a specific weight between 750 g/m^2 and 1200 g/m^2 , preferably between 800 and 1000 g/m^2 . The HEPA filtration media comprises at both sides of the central layer a first further layer in direct contact with the central layer. Each of the two first further layers comprise – and preferably consist out of - a nonwoven web comprising – and preferably consisting out of - stainless steel fibers of average equivalent diameter between $3\text{ }\mu\text{m}$ and $8\text{ }\mu\text{m}$; and preferably between $3\text{ }\mu\text{m}$ and $7\text{ }\mu\text{m}$; and more preferably between $4\text{ }\mu\text{m}$ and $7\text{ }\mu\text{m}$ (e.g. $6.5\text{ }\mu\text{m}$).

- [0016] With “equivalent diameter” of a fiber is meant the diameter of a circle having the same surface area as the cross section of a fiber which does not necessarily has a circular cross section.
- [0017] Surprisingly, it was found that the inventive media did not drop as much in filtration efficiency at high face velocity of more than 5 cm/s compared to lower face velocity of $2.5 - 3\text{ cm/s}$ as other high efficient filtration media do. This way, the inventive media is pleatable, temperature resistant, has a low pressure drop, is cleanable via back pulsing filtration; and surprisingly achieves the HEPA filtration requirement (filtration efficiency of more than 99.97% for particles of $0.3\text{ }\mu\text{m}$ size when measured according to EN1822:2009) at high face velocity of 6 cm/s .
- [0018] HEPA filtration media according to the invention could be pleated without the occurrence of cracks that are detrimental for the functionality of the HEPA filter.
- [0019] In a preferred embodiment, the HEPA filtration media comprises second further layers at each side of the central layer and more distant from the central layer than the first further layers. Each of the second further layers comprise - or preferably consist out of - a nonwoven web of stainless steel fibers of average equivalent diameter higher than $10\text{ }\mu\text{m}$, preferably higher than $12\text{ }\mu\text{m}$, preferably higher than $15\text{ }\mu\text{m}$, preferably higher than $20\text{ }\mu\text{m}$

and preferably less than 30 μm .

In a further preferred embodiment, the second further layers each contact one of the first further layers.

In a further preferred embodiment, the second further layers are the outer layers of the HEPA filtration media.

- [0020] In a preferred embodiment, the porosity of the HEPA filtration media is between 70 and 80%.
- [0021] In a preferred embodiment, the porosity of the central layer is between 70 and 80%.
- [0022] In a preferred embodiment, at least part of the stainless steel fibers are bonded to each other at their contacting points by means of metal bonds, e.g. by means of sinter bonds or by means of welded bonds, e.g. by means of bonds created by means of Capacitive Discharge Welding (CDW).
- [0023] In a preferred embodiment, bonding of the stainless steel fibers layers to each other in the HEPA filtration media is provided by means of metal bonds, e.g. by means of sinter bonds or by means of welded bonds, e.g. by means of bonds created by means of Capacitive Discharge Welding (CDW).
- [0024] In a preferred embodiment, the filtration media has a thickness of less than 2 mm, preferably of less than 1 mm, even more preferably of less than 0.7 mm.
- [0025] Preferably, the filtration media has a specific weight less than 1400 g/m^2 , preferably less than 1375 g/m^2 and preferably of more than 1300 g/m^2 .
- [0026] Preferably, the HEPA filtration media is pleated.
- [0027] It is a second aspect of the invention to provide a HEPA filter, comprising a HEPA filtration media as in any embodiment of the first aspect of the invention.
- [0028] A third aspect of the invention is a method to manufacture a pleated HEPA filtration media. The method comprises the steps of
- making a HEPA filtration media as in the first aspect of the invention;
 - bonding the stainless steel fiber layers of the HEPA filtration media by

means of metallic bonding, e.g. by means of sintering or by means of welding, e.g. by means of Capacitive Discharge Welding (CDW);
- pleating the bonded HEPA filtration media.

Brief Description of Figures in the Drawings

[0029] Figure 1 shows an example of a HEPA filtration media according to the invention.

Mode(s) for Carrying Out the Invention

[0030] Figure 1 shows an example 10 of a HEPA filtration media according to the invention. The HEPA filtration media 10 comprises a central layer 11. The central layer 11 consists out of 900 g/m² nonwoven layer of bundle drawn stainless steel fibers of average equivalent diameter 1.5 µm. The porosity of this central layer 11 is 73%. The HEPA filtration media 11 comprises at both sides of the central layer 11 a first further layer 13 in direct contact with the central layer 11. Each of the two first further layers 13 is a nonwoven web of 75 g/m² of bundle drawn stainless steel fibers of average equivalent diameter 6.5 µm. The HEPA filtration media 11 comprises second further layers 15 at each side of the central layer and more distant from the central layer 11 than the first further layers 13. Each of the second further layers 15 is a nonwoven web of 150 g/m² of bundle drawn stainless steel fibers of average equivalent diameter 12 µm. With respect to the central layer, the HEPA filtration media 10 has symmetrical layer built-up over its thickness dimension. The layers of the filtration media 10 have been bonded to each other by means of sintering, thereby creating sinter bonds between stainless steel fibers at their contacting points.

The filtration media of the example has a total specific weight of 1350g/m², a total thickness of 0.64 mm, a porosity of 73%. The air permeability at 200 mbar pressure drop was 5.6 liter/(dm²*minute) (tested according to ISO 4022:1987), indicating the low pressure drop of the filtration media.

[0031] The exemplary filtration media was tested according to standard EN 1822:2009 at a face velocity of 6 cm/s. The result showed that the

exemplary filtration media fulfilled the requirement of class H14 of EN 1822:2009 at the face velocity of 6 cm/s, as the measured local retention rate for 0.3 μm sized particles was 99.990%, which is higher than 99.97% as required by the standard.

[0032] The exemplary filtration media could be pleated.

[0033] Filters comprising the exemplary filtration media, even if pleated, can be cleaned by means of back pulsing.

Claims

1. HEPA filtration media (10),
comprising a central layer (11) and at each side of the central layer (11) one or more further layers (13; 15);
wherein the HEPA filtration media (10) comprises with respect to the central layer (11) a symmetrical layer built-up over the thickness dimension of the filtration media (10);
wherein the central layer (11) of the HEPA filtration media comprises a nonwoven web comprising stainless steel fibers of average equivalent diameter less than 2 μm ;
wherein the central layer (11) has a specific weight between 750 and 1200 g/m^2 ;
wherein the HEPA filtration media (10) comprises at both sides of the central layer (11) a first further layer (13) in direct contact with the central layer (11),
wherein each of the two first further layers (13) comprise a nonwoven web comprising stainless steel fibers of average equivalent diameter between 3 μm and 8 μm .
2. HEPA filtration media (10) as in claim 1, wherein the HEPA filtration media (10) comprises second further layers (15) at each side of the central layer (11) and more distant from the central layer (11) than the first further layers (13);
wherein each of the second further layers (15) comprises a nonwoven web of stainless steel fibers of average equivalent diameter higher than 10 μm .
3. HEPA filtration media (10) as in any of the preceding claims, wherein the porosity of the HEPA filtration media (10) is between 70 and 80%.
4. HEPA filtration media (10) as in any of the preceding claims, wherein the porosity of the central layer (11) is between 70 and 80%;
5. HEPA filtration media (10) as in any of the preceding claims, wherein the filtration media (10) has a thickness less than 2 mm.

6. HEPA filtration media (10) as in any of the preceding claims, wherein the filtration media (10) has a specific weight of less than 1400 g/m^2 , and preferably of more than 1300 g/m^2 .
7. HEPA filtration media (10) as in any of the preceding claims, wherein at least part of the stainless steel fibers are bonded to each other at their contacting points by means of metal bonds.
8. HEPA filtration media (10) as in any of the preceding claims, wherein bonding of the stainless steel fibers layers (11, 13, 15) to each other in the HEPA filtration media (10) is provided by means of metal bonds.
9. HEPA filtration media (10) as in any of the preceding claims, wherein the HEPA filtration media is pleated.
10. HEPA filter, comprising a HEPA filtration media (10) as in any of the preceding claims.
11. Method to manufacture a pleated HEPA filtration media, comprising the steps of
 - making a HEPA filtration media as in any of the claims 1 to 6;
 - bonding the stainless steel fiber layers of the HEPA filtration media by means of metallic bonding; and
 - pleating the bonded HEPA filtration media.

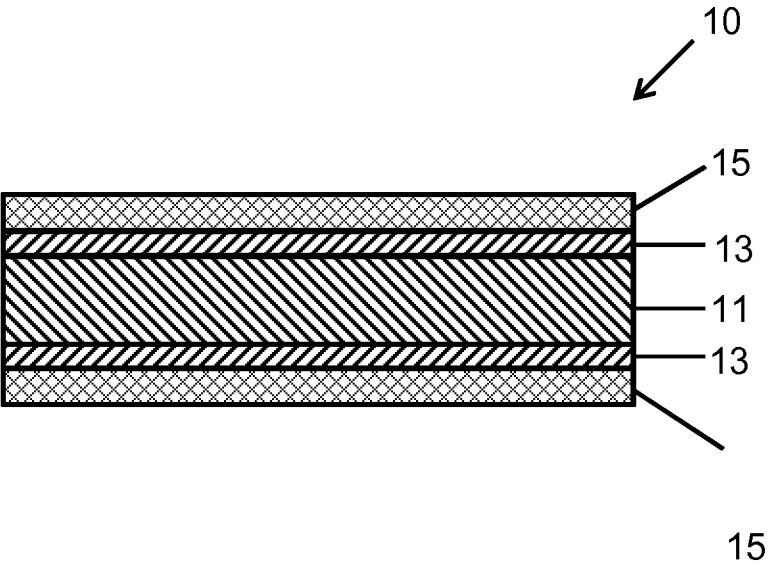


Fig. 1

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2015/070207

A. CLASSIFICATION OF SUBJECT MATTER
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2001/037972 A1 (QUICK NATHANIEL R [US] ET AL) 8 November 2001 (2001-11-08) paragraph [0123] - paragraph [0127]; claims	1-11
A	----- US 5 665 479 A (VANDAMME JOHAN [BE] ET AL) 9 September 1997 (1997-09-09) the whole document	1-11
A	----- EP 1 018 357 A1 (BEKAERT SA NV [BE]) 12 July 2000 (2000-07-12) claims; figures	1-11



Further documents are listed in the continuation of Box C.



See patent family annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2015/070207

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2001037972	A1	08-11-2001	NONE

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