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(72) Inventor(s):  
**MANSKI SYLWESTER**  
**GORIS KEN**

(73) Proprietor(s):  
**ATLAS COPCO AIRPOWER NV.**  
Boomsesteenweg 957  
2610 WILRIJK  
Belgium

(74) Agent and/or Address for Service:  
**Kate Syrtsova**  
Murgitroyd & Company, Unit 1, Block 8  
Cruiserath Road, Dublin 15  
Blanchardstown Corporate Park  
Ireland

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## **FILTER ELEMENT FOR SEPARATING OIL VAPOR FROM A GAS FLOW.**

The present utility model relates to a filter element and a filter device for separating oil vapor from a gas flow.

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In this context, "oil vapor" means a carbonaceous component or a group of carbonaceous components having a carbon number of 6 to 16.

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The present utility model relates more specifically to a filter element comprising

- a tubular outer screen that is permeable to the gas flow;
- a tubular inner screen that is permeable to the gas flow in an interior space delimited by an inner surface of the outer screen,

15

an intermediate space between the outer screen and the inner screen being filled with a packed bed of oil vapor-sorbing granules, nearly all of the oil vapor-sorbing granules having an effective granule diameter of between 0.001 mm and 1.5 mm.

20

In this context, "effective granule diameter" means a diameter of a spherical particle having a volume equivalent to a volume of an oil vapor-sorbing granule.

25

Cylindrical filter elements for separating an oil vapor from a gas flow are already known in the prior art that are completely filled with an oil vapor-sorbing bed, a characteristic diameter of such a cylindrical filter element being smaller than a characteristic length of said cylindrical filter element and the gas flow flowing through the oil vapor-sorbing bed in an axial direction of the cylindrical filter element.

30

The oil vapor-sorbing bed typically comprises granules of an oil vapor-sorbing material, such as activated carbon. These granules can be regular in shape,

for example spherical or rod-shaped, or irregular in shape. Characteristic dimensions of such granules typically vary between 0.5 mm and 5.0 mm.

5 The smaller the characteristic diameter of such a cylindrical filter element, the higher a flow rate of the gas flow through the oil vapor-sorbing bed.

This flow rate results in a high pressure drop across the oil vapor-sorbing bed, typically between 50 mbar and 1000 mbar, and a limitation in the sorbent capacity of the oil vapor-sorbing bed.

10

To avoid this high pressure drop and limitation in the sorbent capacity, the flow rate through the oil vapor-sorbing bed must therefore be limited to a value of typically 1.5 m/s.

15 Increasing the characteristic diameter of the filter element is usually not possible due to space limitations imposed by a filter housing around the filter element.

20 Reducing a flow rate of the gas flow that is applied to a filter device having the filter element is also not possible because said flow rate is often imposed due to devices through which the gas flow flows upstream of the filter device.

25 Distributing the flow rate of the gas flow over additional filter elements connected in parallel in the filter device would imply an additional cost for filter elements and pipes and thus an additional installation cost.

30 GB 1,096,989 describes a cylindrical adsorption unit for separating oil vapor from a gas flow consisting of an inner screen and outer screen placed concentrically with respect to one another and contained between two end caps, the space between the inner screen, the outer screen and the end caps being filled by a porous adsorbent material such as activated alumina or activated carbon.

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5 The gas flow flows through perforations in the outer screen, through the porous adsorbent material in a radial manner with respect to the adsorption unit, and finally through perforations in the inner screen away from the porous adsorbent material.

10 The radial flow of the gas flow through the porous adsorbent material reduces the flow rate of the gas flow through the porous adsorbent material in relation to an adsorption unit having the same dimensions, wherein the gas flow would have to flow axially through the porous adsorbent material.

15 As a result, a pressure drop across the porous adsorbent material will be significantly lower than in the case of a large absorption unit with axial flow of the gas flow.

Unfortunately, the relevant adsorption unit is characterized by a limited adsorption capacity, as stated on page 3, lines 49-51 in GB 1,096,989.

20 An adsorption unit as described in GB 1,096,989 is typically only capable of separating 90% to 95% of the oil vapor from the gas flow on a molar basis.

25 To avoid the high pressure drop across an oil vapor-sorbing bed through which the gas flow axially flows, woven or non-woven filter media have been developed that are impregnated with oil vapor-sorbing particles, as described for example in US 3,149,023 or GB 1,265,098.

Said woven or non-woven filter media are typically wrapped in a cylindrical shape to produce a filter medium through which the gas flow radially flows.

30 The disadvantage of such filter media is, however, that a total amount of oil vapor-sorbing material, which is directly proportional to an amount of oil vapor that can be removed from the gas flow, is much smaller than in an oil vapor-

sorbing bed having the same dimensions because only a small fraction of said filter media is taken up by oil vapor-sorbing material.

5 Furthermore, said wrapped filter media impregnated with oil vapor-sorbing bed particles are sensitive to damage, such as cracks, when overloaded. This damage can form a bypass for the gas flow around the still intact filter medium, along which the gas flow can leave the filter element without sufficient separation of oil vapor.

10 GB 2,109,268 describes a filter element having a filter medium through which a gas flow radially flows, the filter medium consisting of a combination of an inner tubular bed of packed activated carbon granules, around which a folded paper medium impregnated with activated carbon particles is wrapped.

15 However, the use of such a combination results in a complex layered structure and consequently complex installation of the filter medium in the filter element.

In this case, there is also the disadvantage that the folded paper medium impregnated with activated carbon particles is sensitive to damage when  
20 overloaded.

The present utility model aims at solving at least one of the said and/or other disadvantages.

25 For this purpose, the utility model relates to a filter element for separating an oil vapor from a gas flow,  
the filter element comprising:

- a tubular outer screen that is permeable to the gas flow; and
- 30 - a tubular inner screen that is permeable to the gas flow in an interior space delimited by an inner surface of the outer screen;

the outer screen and the inner screen being contained on both ends in, on the one hand, a first end cap and, on the other hand, a second end cap such that an intermediate space between the outer screen and the inner screen is sealed off to the gas flow on the first end cap and the second end cap,

5 the first end cap and/or the second end cap comprising an opening for placing an environment of the filter element in fluidic contact with an internal space that is contained by the inner screen, with the characteristic that the aforementioned intermediate space is filled with a packed bed of oil vapor-sorbing granules, nearly all of the oil vapor-sorbing granules individually having  
10 an effective granule diameter of between 0.001 mm and 1.5 mm.

In this context, "filled" means that the intermediate space is almost completely filled with the packed bed, such that for a gas flow through the intermediate space there is no bypass in the intermediate space around the packed bed.

15 In this context, "oil vapor-sorbing granules" can mean both oil vapor-absorbing granules and oil vapor-adsorbing granules.

In this context, the wording "nearly all of the oil vapor-sorbing granules  
20 individually" means that all of the oil vapor-sorbing granules are considered individually. In other words, nearly all of the oil vapor-sorbing granules individually have a possibly different effective granule diameter of between 0.001 mm and 1.5 mm.

25 Such a filter element according to the utility model has the advantage that a pressure drop across the filter element is lower and a sorbent capacity is higher than for filter elements already known of the same dimensions that are completely filled with oil vapor-sorbing granules and would be axially flowed through by the gas flow.

30 In this case, it is very surprising that the saturation time and consequently the lifetime of the filter element according to the present utility model can also be

higher than in a filter element already known that is completely filled with oil vapor-sorbing granules.

5 For the filter element according to the utility model, the sorbent capacity of the filter element is also higher than for filter elements already known of the same dimensions that would be radially flowed through by the gas flow and provided with a woven or non-woven wrapped filter medium impregnated with oil vapor-sorbing particles.

10 In this case, it is very surprising that the pressure drop across the filter element according to the present utility model can also be lower than in a filter element already known that is radially flowed through by the gas flow and provided with a woven or non-woven wrapped filter medium impregnated with oil vapor-sorbing particles.

15 In comparison with filter elements having a woven or non-woven wrapped filter medium impregnated with oil vapor-sorbing particles, the packed bed of oil vapor-sorbing granules is also not sensitive to cracks.

20 Preferably, nearly all of the oil vapor-sorbing granules individually have an effective granule diameter of at least 0.01 mm, preferably at least 0.1 mm.

Preferably, nearly all of the oil vapor-sorbing granules individually have an effective granule diameter of at most 1.0 mm, preferably at most 0.5 mm.

25 Preferably, more than 90% of the aforementioned granules individually have an effective granule diameter of between 0.1 mm and 0.5 mm.

30 Preferably, the aforementioned granules have a mean effective granule diameter of between 0.15 mm and 0.45 mm.

Preferably, the aforementioned granules have a surface-to-weight ratio of at least 800 m<sup>2</sup>/g, preferably at least 900 m<sup>2</sup>/g, more preferably 1000 m<sup>2</sup>/g.

5 The higher the surface-to-weight ratio of the oil vapor-sorbing granules, the higher the sorbent capacity of the filter element.

The aforementioned granules preferably have a bulk density of at least 400 kg/m<sup>3</sup>, preferably at least 500 kg/m<sup>3</sup>, more preferably at least 600 kg/m<sup>3</sup>, even more preferably at least 700 kg/m<sup>3</sup>.

10

The higher the bulk density of the oil vapor-sorbing granules, the higher the sorbent capacity of the filter element.

15 In a preferred embodiment of the filter element according to the utility model, the aforementioned granules comprise a carbonaceous porous material of a natural or synthetic origin.

A carbonaceous porous material provides good binding strength with the separated oil vapor.

20

The carbonaceous porous material preferably comprises activated carbon.

Activated carbon is available at a low cost in relation to other oil vapor-sorbing materials.

25

In another preferred embodiment of the filter element according to the utility model, the outer screen and/or the inner screen comprises:

30 - a sintered polymer, preferably polypropylene, having pores that are configured in such a way that the aforementioned granules cannot pass through the pores; and/or

- a perforated metal, preferably stainless steel, having perforations that are configured in such a way that the aforementioned granules cannot pass through the perforations.

5 In another preferred embodiment of the filter element according to the utility model, the outer screen and/or the inner screen comprises an expanded material that is laminated with a structured material, pores in the structured material being configured in such a way that the aforementioned granules cannot pass through the pores.

10

In this context, "expanded material" means a plate-shaped material that is cut and stretched in such a way that it forms a grid having a regular perforation pattern.

15 The advantage of either a sintered polymer and/or a perforated metal or an expanded material is that this makes the outer screen and/or the inner screen more rigid than only a non-woven material that is typically used for the outer screen and/or inner screen in existing filter elements.

20 Such a typically used non-woven material exhibits some expansion over time and significant deflection under a weight of the packed bed, as a result of which the intermediate space between the inner screen and the outer screen increases in volume. As a result, the intermediate space is no longer completely filled with the packed bed over time, and a bypass can form in the  
25 intermediate space around the packed bed between the inner screen and the outer screen. Oil vapor can be carried with the gas flow via such a bypass without being sorbed into the packed bed.

30 Furthermore, such a typically used non-woven material is more susceptible to damage, such as cracks, than either a sintered polymer and/or a perforated metal or an expanded material such as in the present utility model.

The structured material is preferably made of glass fibers.

Alternatively, the structured material is preferably a woven or non-woven polymer medium, preferably a polypropylene medium.

5

In another preferred embodiment of the filter element according to the utility model, the inner screen and the outer screen are axisymmetric and arranged concentrically with respect to each other.

10

In this case, a perpendicular distance between an inner surface of the outer screen and an outer surface of the inner screen is preferably at least 5.0 mm, preferably at least 10.0 mm, more preferably at least 20.0 mm, even more preferably at least 30.0 mm, still more preferably 40.0 mm and most preferably at least 50.0 mm.

15

The greater said perpendicular distance, the more oil vapor-sorbing material the filter element contains and consequently the higher a saturation time of the filter element will be.

20

The utility model also relates to a filter device for separating an oil vapor from a gas flow, with the characteristic that the filter device is provided with a filter element according to the utility model.

25

It goes without saying that such a filter device has the same advantages as the above-described embodiments of the filter element according to the utility model.

30

With a view to better demonstrating the characteristics of the utility model, as an example without any restrictive character, a preferred embodiment is described here of a filter element for separating an oil vapor from a gas flow according to the utility model and a filter device provided with such a filter element, with reference to the accompanying drawings, in which:

Fig. 1 is a cross section of a filter device provided with a filter element according to the utility model.

5 Fig. 1 shows a filter device 1 according to the utility model for separating oil vapor from a gas flow.

This gas flow may be a flow of compressed air, for example, but the utility model is not limited thereto.

10

The filter device 1 comprises a filter housing 2, which is composed of a lid 3 and a pot 4, which can be mounted on top of each other to form the filter housing 2.

15 In the example shown, the pot 4 is screwed into the lid 3, both the lid 3 and the pot 4 being provided with a cooperating screw thread 5.

It is not impossible that the pot 4 is, alternatively or additionally, attached in the lid 3 by means of a bayonet mount and/or some other way.

20

The lid 3 is equipped with an inlet 6 for gas to be purified and an outlet 7 for purified gas. Typically, the filter device 1 with its lid 3 is mounted in a machine pipe, such as a compressor installation. For this purpose, the lid 3 at the inlet 6 and the outlet 7 can be provided with flanges suitable thereto.

25

Furthermore, the lid 3 can be provided with a ventilation opening 8. Such a ventilation opening 8 provides an audible warning signal whenever the pot 4 is disassembled from the lid 3 while the filter housing 2 is internally still under pressure. Thus, the pot 4 can be unscrewed or disassembled completely from the lid 3 in a safe manner, namely only at the time when an internal pressure in the filter housing 2 has been completely vented and has reached the same value as that of a pressure in an external environment of the filter housing 2.

30

In the filter housing 2, more specifically in the pot 4, a filter element 9 is fitted.

The filter element 9 is composed of:

5

- a tubular outer screen 10 that is permeable to the gas flow, which outer screen 10 has a first outer screen end 11 and a second outer screen end 12 different from said first outer screen end 11;

10

- a tubular inner screen 13 that is permeable to the gas flow in an interior space delimited by an inner surface of the outer screen 10, the inner screen 13 having a first inner screen end 14 and a second inner screen end 15 different from said first inner screen end 14;

15

- a first end cap 16 in which the first outer screen end 11 and the first inner screen end 14 are contained in such a way that they are sealed with the first end cap 16, and a second end cap 17 in which the second outer screen end 12 and the second inner screen end 15 are contained in such a way that they are sealed with the second end cap 17, such that an intermediate space 18 between the outer screen 10 and the inner screen 13 is sealed off to the gas flow on the first end cap 16 and the second end cap 17, the second end cap 17 comprising an opening 19 that is configured in such a way that an internal space 20 that is contained by the inner screen 13 and the first end cap 16 is placed in fluidic contact with an environment of the filter element 9 along said opening 19.

20

Within the scope of the utility model, it is not ruled out that the first end cap 16 is also provided with the opening 19 or only the end cap 16 is provided therewith.

25

The intermediate space 18 is filled with a packed bed of oil vapor-sorbing granules, nearly all of the oil vapor-sorbing granules 21 individually having an effective granule diameter of between 0.001 mm and 1.5 mm.

30

Preferably, more than 90% of the granules 21 individually have an effective granule diameter of between 0.1 mm and 0.5 mm.

5 The granules 21 preferably have a mean effective granule diameter of between 0.15 mm and 0.45 mm.

Furthermore, the granules 21 preferably have a surface-to-weight ratio of at least 800 m<sup>2</sup>/g.

10 The granules 21 preferably have a bulk density of at least 400 kg/m<sup>3</sup>.

Preferably, but not necessary according to the utility model, the aforementioned granules 21 comprise a carbonaceous porous material of a natural or synthetic origin, preferably activated carbon.

15

The outer screen 10 and/or the inner screen 13 comprises:

- a sintered polymer, preferably polypropylene, having pores that are so small that the granules 21 cannot pass through the pores; and/or

20 - a perforated metal, preferably stainless steel, having perforations that are so small that the granules 21 cannot pass through the perforations.

Alternatively or additionally, the outer screen 10 and/or the inner screen 13 comprises an expanded material that is laminated with a structured material, pores in the structured material being so small that the granules 21 cannot pass through the pores.

25

The structured material is preferably made of glass fibers or of a woven or non-woven polymer medium, preferably a polypropylene medium.

30

In this case, the inner screen 13 and the outer screen 10 are axisymmetric and arranged concentrically with respect to each other.

In this case, a perpendicular distance between an inner surface and the outer screen 10 and an outer surface of the inner screen 13 is preferably at least 5.0 mm.

5

The filter device 1 having the filter element 9 is used to separate an oil vapor from a gas flow having an oil vapor concentration of at least 0.25 mg of oil vapor/m<sup>3</sup> of gas, preferably at least 0.30 mg of oil vapor/m<sup>3</sup> of gas, more preferably at least 0.35 mg of oil vapor/m<sup>3</sup> of gas, even more preferably at least 10 0.40 mg of oil vapor/m<sup>3</sup> of gas, still more preferably at least 0.45 mg of oil vapor/m<sup>3</sup> of gas.

Furthermore, the filter device 1 having the filter element 9 is used to separate an oil vapor from a gas flow to an oil vapor concentration of at most 0.010 mg of oil vapor/m<sup>3</sup> of gas, preferably at most 0.005 mg of oil vapor/m<sup>3</sup> of gas, more 15 preferably at most 0.003 mg of oil vapor/m<sup>3</sup> of gas.

Comparative examples:

20 A one-to-one test is carried out according to ISO standard no. 8573-5 for various filter devices already known with filter media for separating oil vapor in a typical compressor installation having, upstream of the filter device for separating the oil vapor,

- 25
- an oil-injected compressor for compressing a gas;
  - a cooling dryer for separating water vapor from the compressed gas; and
  - a coalescence filter for separating oil aerosols having a carbon number greater than 16.

30 In this case, the inlet concentration of oil vapor in the gas that enters the filter device for separating oil vapor is kept around a concentration of 0.5 mg of oil vapor/m<sup>3</sup> of gas.

The pressure and temperature of the gas entering the filter device are 7 bar and 0-35°C, respectively.

5 For the various filter media already known, the pressure drop across the filter device, the initial breakthrough concentration of oil vapor and the time period required to reach a breakthrough of 50% in the relevant filter medium are listed in table 1.

10 In this context, an "initial breakthrough concentration" means a concentration of oil vapor as initially occurs in the gas coming out of a still unsaturated filter medium.

15 The lower said initial breakthrough concentration, the higher the initial performance of the filter device.

In this context, a "breakthrough of 50%" means that a concentration of oil vapor that occurs in the gas coming out of the filter medium is 50% of the inlet concentration of oil vapor.

20

From the data in table 1, it is clear that, in wrapped filter media impregnated with oil vapor-sorbing particles, the pressure drop across the filter device is lower in relation to a filter medium that is designed as a fully packed bed.

25 Furthermore, the wrapped filter media are generally found to have a lower initial breakthrough concentration and in some cases a longer time period for reaching a breakthrough of 50% than a filter medium that is designed as a fully packed bed.

30 From this, it can be concluded that the filter devices having a wrapped filter medium generally have a higher level of performance with respect to pressure drops and initial breakthrough concentration and in some cases even a longer

saturation time and consequently lifetime than a filter device having a filter medium that is designed as a fully packed bed.

<b>Filter device</b>	<b>Type of filter medium</b>	<b>Pressure drop [mbar]</b>	<b>Initial breakthrough concentration [mg oil vapor/m<sup>3</sup>]</b>	<b>Time period for 50% breakthrough [h]</b>
Domnick Hunter ACS 020DBMX	wrapped	109	0.04	28
Donaldson Ultra filter DF 0120	wrapped	135	0.09	23
Hankison F06-CF-T	wrapped	23	0.10	4
FST – FST70AM	wrapped	56	0.14	<1
FST – FST70CAM	fully packed bed	587	0.15	<1
Atlas Copco QD35+	wrapped	140	0.14	<1

5 Table 1

Example:

10 A test is carried out for the filter device having the filter element according to the utility model under the same conditions as those for the comparative examples described above.

15 The filter element comprises two concentric cylindrical screens made of sintered polypropylene, the intermediate space between said screens being filled with a packed bed of activated carbon particles.

The activated carbon particles have an effective granule diameter of between 0.001 mm and 1.5 mm, more than 90% of the activated carbon particles having an effective granule diameter of between 0.1 and 0.315 mm and the activated carbon particles having a mean effective granule diameter of 0.21 mm.

5

The activated carbon particles have a bulk density of 735 kg/m<sup>3</sup> and a surface-to-weight ratio of 1050 m<sup>2</sup>/g.

A pressure drop across the filter device according to the utility model is only 75 mbar, while the initial breakthrough concentration is lower than 0.003 mg/m<sup>3</sup> and the time period required to achieve a breakthrough of 50% is higher than 100 h.

From this, it can be concluded that a filter device according to the present utility model generally

15

- has a higher level of performance with respect to the initial breakthrough concentration, namely a lower initial breakthrough concentration; and
- has a lower saturation time and consequently lifetime

20

than the filter devices described above as comparative examples.

In most cases, there is also a lower pressure drop across the filter device according to the present utility model than across the filter devices described above as comparative examples.

25

It should be noted in particular here that the filter device according to the present utility model has a higher level of performance with respect to pressure drops, initial breakthrough concentration, saturation time/lifetime than the comparative example of the filter device having the filter medium designed as a fully packed bed.

30

The present utility model is by no means limited to the embodiment described as examples and shown in the figure, but a filter device according to the utility model can be implemented in all shapes and sizes without going beyond the scope of the utility model defined in the claims.

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## Claims

1. A filter element for separating an oil vapor from a gas flow,  
the filter element (9) comprising:

- 5           - a tubular outer screen (10) that is permeable to the gas flow; and  
          - a tubular inner screen (13) that is permeable to the gas flow in an  
interior space delimited by an inner surface of the outer screen (10);

          the outer screen (10) and the inner screen (13) being contained on both  
ends in, on the one hand, a first end cap (16) and, on the other hand, a second  
10 end cap (17) such that an intermediate space (18) between the outer screen  
(10) and the inner screen (13) is sealed off to the gas flow on the first end cap  
(16) and the second end cap (17), the first end cap (16) and/or the second end  
cap (17) comprising an opening (19) for placing an environment of the filter  
element (9) in fluidic contact with an internal space (20) that is contained by  
15 the inner screen (13),

**characterized in that** the aforementioned intermediate space (18) is  
filled with a packed bed of oil vapor-sorbing granules (21), nearly all of the oil  
vapor-sorbing granules (21) individually having an effective granule diameter  
of between 0.001 mm and 1.5 mm.

20

2. The filter element according to claim 1 and one or more of the following:  
nearly all of the oil vapor-sorbing granules (21) individually have an  
effective granule diameter of at least 0.01 mm, preferably at least 0.1 mm;

25           nearly all of the oil vapor-sorbing granules (21) individually have an  
effective granule diameter of at most 1.0 mm, preferably at most 0.5 mm;

          more than 90% of the aforementioned granules (21) individually have  
an effective granule diameter of between 0.1 mm and 0.5 mm;

          the aforementioned granules (21) have an average effective granule  
diameter of between 0.15 mm and 0.45 mm;

30           the aforementioned granules (21) have a surface-to-weight ratio of at  
least 800 m<sup>2</sup>/g, preferably at least 900 m<sup>2</sup>/g, more preferably at least 1000  
m<sup>2</sup>/g;

the aforementioned granules (21) have a bulk density of at least 400 kg/m<sup>3</sup>, preferably at least 500 kg/m<sup>3</sup>, more preferably at least 600 kg/m<sup>3</sup>, even more preferably at least 700 kg/m<sup>3</sup>;

5 the aforementioned granules (21) comprise a carbonaceous porous material of a natural or synthetic origin; optionally, wherein the carbonaceous porous material comprises activated carbon.

3. The filter element according to claim 1 or claim 2, characterized in that the outer screen (10) and/or the inner screen (13) comprises one or more of  
10 the following:

- a sintered polymer, preferably polypropylene, having pores that are configured in such a way that the aforementioned granules (21) cannot pass through the pores; and/or- a perforated metal, preferably stainless steel, having perforations that are configured in such a way that the aforementioned  
15 granules (21) cannot pass through the perforations;

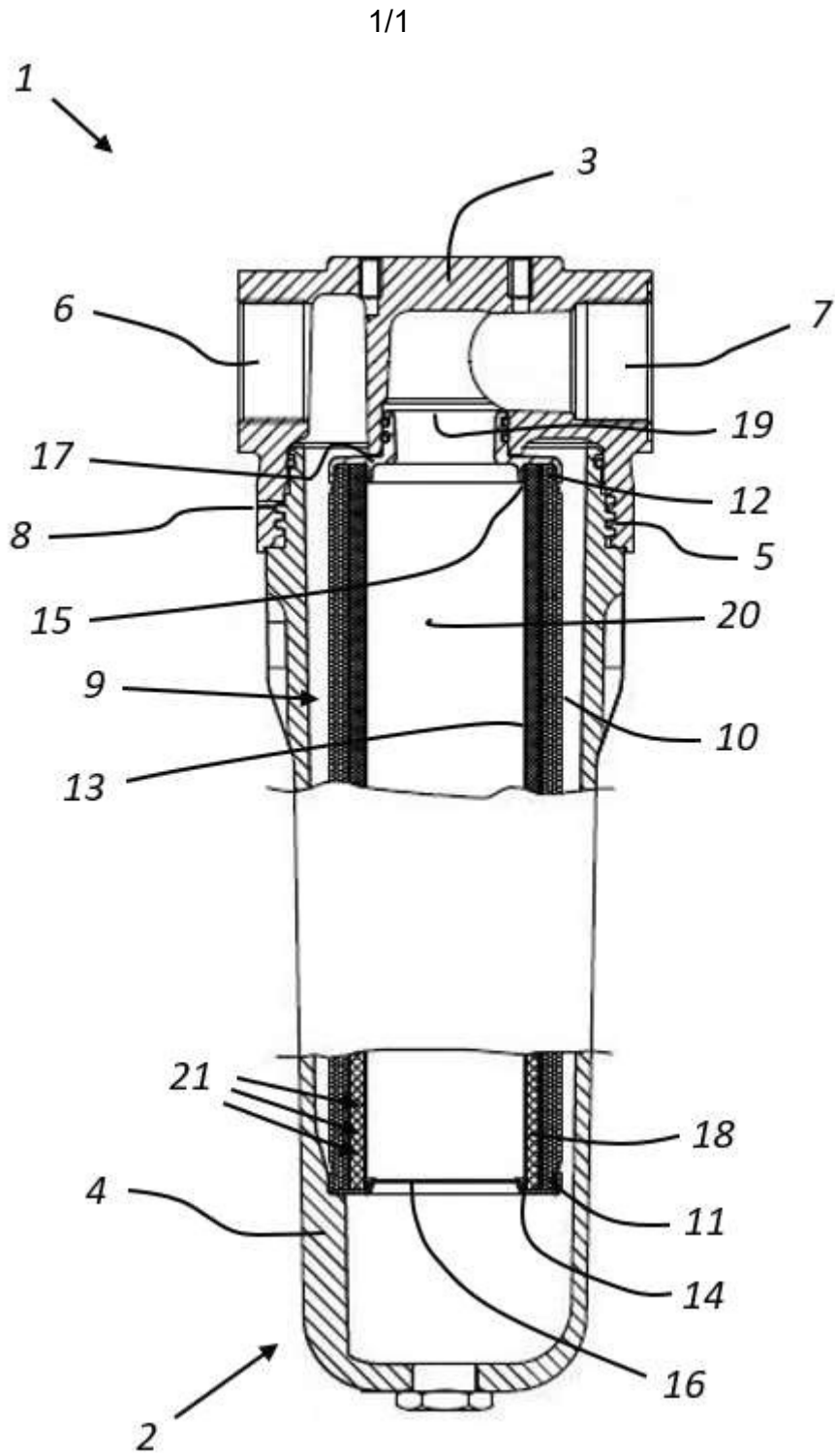
- an expanded material that is laminated with a structured material, pores in the structured material being configured in such a way that the aforementioned granules (21) cannot pass through the pores; optionally, wherein the structured  
20 material is made of glass fibers; optionally, wherein the structured material is a woven or non-woven polymer medium; and optionally, wherein, the polymer medium is a polypropylene medium;

4. The filter element according to any of preceding claims 1 to 3,  
25 characterized in that the inner screen (13) and the outer screen (10) are axisymmetric and arranged concentrically with respect to each other; optionally, wherein a perpendicular distance between an inner surface of the outer screen (10) and an outer surface of the inner screen (13) is at least 5.0 mm, preferably at least 10.0 mm, more preferably at least 20.0 mm, even more  
30 preferably at least 30.0 mm, still more preferably 40.0 mm and most preferably at least 50.0 mm.

5. A filter device for separating an oil vapor from a gas flow, characterized in that the filter device (1) is provided with a filter element (9) according to any of preceding claims 1 to 4.

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**Fig. 1**