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(71) Applicant: **BDR Thermea Group B.V.**
7332 BD Apeldoorn (NL)

(72) Inventors:
- **GENTIL, Pierre**
  7332 BD Apeldoorn (NL)
- **IKEN, Mohamed**
  7332 BD Apeldoorn (NL)
- **ZERGOUNE, Zakaria**
  7332 BD Apeldoorn (NL)
- **ANTOINE, Florian**
  7332 BD Apeldoorn (NL)

(74) Representative: **Grabovac, Dalibor**
AAP Patentanwaltskanzlei Grabovac
Pfeivestlstr. 12
81243 München (DE)

(54) **HEAT PUMP COMPRISING AN ACOUSTIC NOISE REDUCTION WALL**

(57) The present invention is directed to a heat pump (251, 252) having an acoustic noise reduction wall (161, 162, 163, 164, 165, 166), the acoustic noise reduction wall (161, 162, 163, 164, 165, 166) comprising :
- a base material (18) being a foam material and
- one or more tubes (221, 222, 223) for diffusing sound waves (λ), the tubes (221, 222, 223) being made of a tube material (23) that is different from the base material.

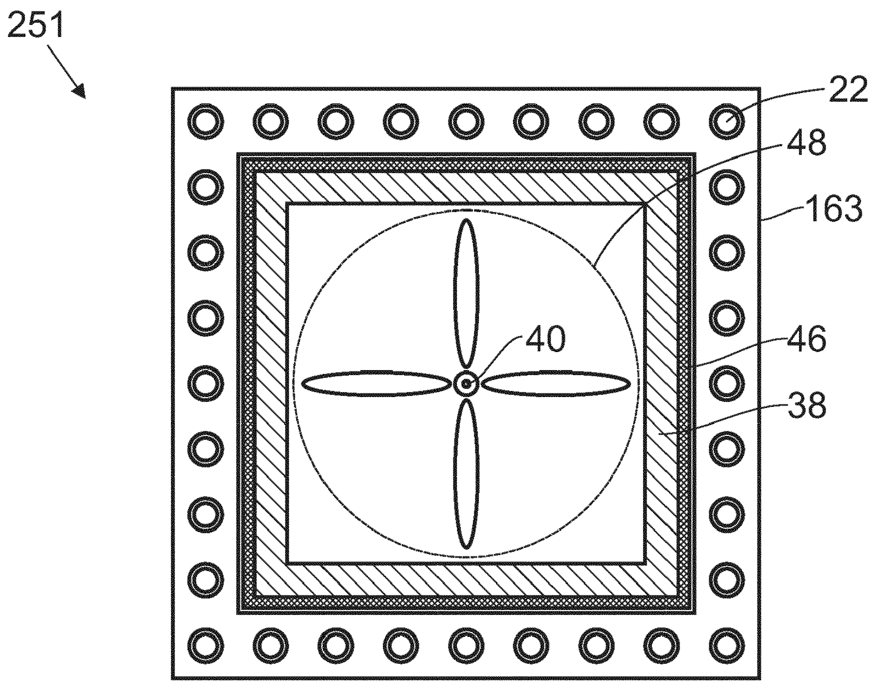

Fig.9

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Description

[0001] The present invention relates to a heat pump comprising an acoustic noise reduction wall.

[0002] A heat pump is a device that uses work to transfer heat from a first medium to a second medium by transferring thermal energy using a refrigeration cycle, thereby cooling the first medium and warming the second medium. As a heat pump transfers, rather than produces, heat, it is more energy-efficient than other ways of heating. The energy needed in particular for operating the compressor can be provided in form of electrical energy without the need to combust fossil fuels. Heat pumps may help reducing the CO2-emission and can also be used for cooling in an efficient way which are some reasons why heat pumps are becoming more and more popular. It also stands out from other technologies thanks to its reversibility, which makes it possible to cool or heat the second or final medium.

[0003] A heat pump comprises noise sources such as compressors and fans. The operation of a heat pump may therefore be considered as disturbing not only for the residents of a house equipped with a heat pump but also for the residents of houses located in the vicinity. For reducing the noise transmission from the heat pump it is known to employ sound or noise absorbing walls, in the following referred to as acoustic noise reduction walls. Such acoustic noise reduction walls are sometimes also referred to as acoustic noise reduction panels. However, to sufficiently reduce the noise transmission, the acoustic noise reduction walls need to be provided with a fairly large thickness and need to be made of dense material which leads to an increase of the weight and installation space. In this respect, reference is made to IT202100005240U1

[0004] It is one task of one embodiment of the present invention to provide a heat pump comprising an acoustic noise reduction wall by which the disadvantages previously described can be reduced and in particular by which the wall thickness and the installation space of the heat pump comprising such an acoustic noise reduction wall can be kept low or small, respectively, but still maintaining a high acoustic dampening performance.

[0005] The object is solved by the features specified in claim 1. Advantageous embodiments are the subject of the dependent claims.

[0006] According to an embodiment of a heat pump having an acoustic noise reduction wall, the acoustic noise reduction wall comprises:

- a base material being a foam material and
- one or more tubes for diffusing sound waves, the tubes being made of a tube material that is different from the base material.

[0007] The sound waves, sometimes also referred to as acoustic waves, that are emitted by components of a heat pump, in particular by fans, pump and compressors, and impinging on an acoustic noise reduction wall and penetrate the same. As a result of passing through the base material, the sound waves are dampened, and the noise transmission is then reduced.

[0008] The sound waves hitting the tubes can be subdivided into several groups. A first group of sound waves cross the acoustic noise reduction wall along a longer path compared to the sound waves crossing the acoustic noise reduction wall without hitting the tubes. The longer path is due to a deformation of the path to be crossed when the wave bounces off a tube. As a consequence, the first group of sound waves lose more energy compared to the sound waves not hitting the tubes.

[0009] A second group of sound waves hit the tubes such that they travel back into the heat pump. The sound waves of the second group do not propagate to the outside environment of the heat source, so these sound waves are not noted by persons in the vicinity of the heat pump.

[0010] A third group of sound waves crosses the foam without being in contact with a tube so that they pass between tubes. Thus, the sound waves are not modified and reduces compared to current design without tubes. This is particulary the case if there are direct paths between inside and outside the foam, especially when the tubes are far away from each other and with only one or few rows of tubes.

[0011] The sound waves that hit the acoustic foam will primarily undergo an absorption phenomenon. Simultaneously, part of the sound waves will interact with the walls of the heat pump, leading to two phenomena: reflection and transmission. As a result, the transmitted waves have already been attenuated by the absorption within the foam, and the reflected waves return to the heat pump, people in close proximity to the heat pump do not perceive these waves.

[0012] From a manufacturing point of view, it is fairly straightforward to provide walls with such tubes. Thus, the acoustic noise reduction wall is inexpensive to produce. The noise transmission can further be reduced by the choice of the base material and the tube material. At the same time the weight of the wall can be kept low without the need to increase the wall thickness.

[0013] The heat pump can be a monobloc unit or a split unit. The first medium and the second medium mentioned above may both be liquid, in particular water. In said case the heat pump is a ground source heat pump. Alternatively, the first medium is air and the second medium is liquid, in particular water. In said case the heat pump is an air/water heat pump.

[0014] In another embodiment the heat pump comprises a housing, wherein the acoustic noise reduction wall is fastened to the housing, is part of the housing or is forming the housing and/or is arranged inside a compartment delimited by the housing.. The housing can be formed by one or more panels. In many cases, such acoustic noise reduction walls are usually not load bearing. Thus, they need to be fastened to other components of the heat pump such as the housing. When fastened to the housing, no additional fastening sections or support members are needed for the acoustic noise reduction wall. However, mainly depending on the base material and the tube material, the acoustic noise reduction wall may be equipped with a stability that is big enough to form a part of the housing or the entire housing. In this case, the tubes do not only have an acoustic function but also a stabilizing mechanical function. The manufacturing process of the heat pump can be facilitated, and constructional space can be saved.

[0015] According to another embodiment the heat pump comprises one or more heat pump components. The heat pump components can be fastened to the acoustic noise reduction wall. Respective heat pump components may be components that are noise-generating such as pumps, compressors or fans. However, other heat pump components may be chosen to fasten the acoustic noise reduction wall to, e.g., the tank. The heat pump components may serve for a support for the acoustic noise reduction wall, thereby avoiding additional support members. The heat pump components to which the acoustic noise reduction walls may be fastened to can be chosen according to the dampening effect so obtained.

[0016] A further embodiment is characterized in that the heat pump comprises at least one heat pump compartment delimited by at least one heat pump compartment wall, the heat pump components being located inside the heat pump compartment, wherein the acoustic noise reduction wall is fastened to the heat pump compartment wall or forms the heat pump compartment wall. In many cases, a heat pump does not only comprise an exterior housing, in particular panel, that delimits the heat pump to the surroundings but also comprises heat pump compartment walls that may serve for the support of one or more heat pump components. The acoustic noise reduction walls may also be fastened to such heat pump compartment walls. Also in this case, no additional fastening sections or support members are needed. In case the acoustic noise reduction wall is sufficiently stable, in particular due to a respective choice of the base material and the tube material, it may also form the heat pump compartment wall.

[0017] In another embodiment, fastening means are employed for fastening the acoustic noise reduction wall to the housing, the heat pump components and/or the heat pump compartment wall, wherein the fastening means form a material bond and/or a form closure.

[0018] A material bond may be established by gluing and/or by mechanical assembling. A form closure may be provided by an assembly system comprising protrusions and complementary recesses. The recesses may extend into the tubes. Other ways for establishing a material bond or a form closure may be conceivable as long as they do not form additional noise sources, e.g., due to vibrations that are transferred to surfaces of the heat pump. Specifically, the assembly system can be like a male-female assembly between the tubes of the wall and protrusions in the housing panel from the heat pump. Said protrusions are able to get inside the tubes. Alternatively, the assembly system can be like a male-female assembly between the tubes of the wall and holes inside the panel enabling to let the tubes to pass through.

[0019] In a further embodiment the base material is a plastic foam, preferably an expanded plastic foam. The plastic foam may comprise closed cells, thereby providing a high attenuation of the sound waves and is thus particularly suited for reducing the noise transmission. At the same time the wall can be made lightweight but still be provided with a sufficient stability. However, according to the specific application and the frequencies of the noise to be reduced, also a foam with open cells may be used.

[0020] According to a further embodiment the acoustic noise reduction wall has a wall thickness in the range between 10 mm and 150 mm, in particular between 15 and 30 mm. Moreover, the acoustic noise reduction wall has an acoustic absorption rate of at least 0.6, preferably 0.8, for at least one frequency in the range of 400 and 2000 Hz.

[0021] The acoustic noise reduction wall is designed to reduce the noise at specific frequency range, in particular frequency. Each material has its own absorption rate depending on the frequency range, in particular frequency. The absorption rate corresponds to a capacity to reduce the power of the noise transmitted through a defined acoustic noise reduction wall. An absorption rate of zero correspond to no absorption and no noise-reduction, while an absorption rate of one correspond to 100% absorption of the noise at the specific frequency.

[0022] However, the transmitted noise comprises various frequencies and not only one frequency. It is the aim to obtain an absorption rate of at least 0.6 and preferably 0.8 of absorption rate for the identified frequency. The advantage of the invention is that the sound wave has an average longer path to pass through the foam compared to a solution without tube. So the thickness of the foam can be reduced to obtain the same global performance compared to solution without tubes. Or the thickness can be kept and then, the adding of tubes will improve the performance of the solution. It will improve the absorption rate and/or the frequency range on which the solution is efficient.

[0023] In another embodiment the tube material has a first rigidity higher than a second rigidity of the base material. In other words, the tube material is more rigid than the base material. The rigidity may be expressed by the Young's modulus. The first rigidity may have a Young's modulus 100 times higher, more preferably 1000 times higher, than the Young's modulus of second rigidity of the base material. The bigger the differences between the first rigidity and the second rigidity, the better the diffusion. To obtain a high first rigidity, the tubes may be made of hard plastic or of metal like steel or aluminum.

[0024] In a further embodiment one surface of the tubes is provided with corrugations. Corrugations can be embodied as elevations and depressions in particular on the outer surface of the tubes. The sound waves that enter the wall impinge on the outer surface of the tubes. The corrugations may be of microscopic scale and thus be provided by an increased roughness of the outer surface of the tubes. Alternatively, the outer surface of the tubes may be provided with flutings or the like. The corrugations increase the diffusion of the sound waves and reduce the perceived noise.

[0025] According to a further embodiment the tubes include one or more through holes that run perpendicular to the longitudinal axis of the tubes. One through hole may run along the entire length of the tube such that the tube is not completely closed but has a C-shaped cross-section. Such tube may be easy to manufacture. Alternatively, a plurality of through holes may be either uniformly or randomly distributed within the tube. Some of the sound waves can enter the tube and get locked inside the tube. The perceived noise can thus be reduced. Thus, further deflective surfaces are created that may increase the absorption rate.

[0026] According to another embodiment the tubes of one acoustic noise reduction wall have different dimensions. The more different the dimensions of the tubes the higher the degree of diffusion and the lower the noise transmission.

[0027] In a further embodiment the dimensions comprise the length and/or the width. The length and the width are the dimensions that are easy to change, in particular, from a manufacturing point of view. Moreover, in particular the width of the tubes determines the degree of diffusion at sound waves of a certain frequency. When having a circular diameter, the width may equal the diameter of the tubes. If the noise transmission is to be reduced for sound waves of a narrow frequency range, the width of the tubes may be chosen to be optimized to the frequency range and thus be relatively uniform. However, if the noise transmission of sound waves of a broad frequency range is to be reduced, tubes of significantly differing width may be used.

[0028] In accordance with another embodiment the tubes have a ring section and/or at least partly a circular section and/or an elliptical section and/or a polygonal section. The shape of the tubes is, however, not limited to the mentioned shapes. Oval or drop-like shapes may also be employed, to name a few. These shapes add to the degree of diffusion and thus further lower the noise transmission.

[0029] In another embodiment the tubes have a circular section with a circular section diameter, the circular section diameter ranging from 5 mm up to 100 mm, especially from 7 to 20 mm. It has been found that a good absorption rate can be obtained with these circular section diameters. Moreover, such dimension is compact enough to be easily implemented in a heat pump system.

[0030] In another embodiment the tubes have a straight or curved progression. Tubes of a straight progression facilitates the production of tubes by extrusion, their integration into the base material and their organization, and therefore their number and associated effect in the base material.. However, tubes of a curved progression increase the degree of diffusion due to a longer length of the tube for a same height

[0031] In a further embodiment the tubes form at least one open end or at least one closed end. The tubes may communicate with the environment of the wall via the open end. Sound waves may thus leave the tubes via the open end and thus along a different direction compared to the remaining sound waves that pass through the wall. The degree of diffusion is increased. However, the sound waves that leave the wall via the open end are not dampened by the first material. It is therefore also possible to provide the tubes with a closed end.

[0032] In a further embodiment the acoustic noise reduction wall comprises at least one plug by which the tubes can be closed at the open end. In some cases, it may not be desirable to deflect the sound waves via the open ends without any dampening. For this purpose, the open ends may be closed with a plug which may provide a certain degree of dampening. The plugs may be inserted into the tubes and withdrawn from them in a fairly easy and quick way. In case a certain area should particularly be protected from sound waves, the plugs may be inserted into the respective plugs. The sound propagation may thus be easily modified according to the constraints in a particular mounting condition.

[0033] In another embodiment the tubes are arranged in a matrix comprising at least two rows and at least two columns. The number of tubes inside a given wall can be increased and a cumulation of the diffusion achieved. However, the tubes may be arranged in at least one row and/or at least one column.

[0034] In a further embodiment the tubes are running parallel and at a distance to each other, wherein the distance is varying within one acoustic noise reduction wall. Since the tubes are running parallel to each other, a homogenous diffusion along the wall can be achieved. However, the distance between the tubes is varying. The smaller the distance between two adjacent tubes, the better the diffusion of sound waves of higher frequencies and vice versa. Thus, a varying distance increases the frequency range a given wall is effective.

[0035] In another embodiment the tubes extend over the entire acoustic noise reduction wall. The entire wall can be used for the diffusion of the sound waves. The available space can be efficiently used for reducing the intensity of sound waves.

[0036] In another example, at least some of the tubes protrude from the base material on at least one their ends. The protruding part of the tubes can be used to attach the acoustic noise reduction wall to the housing or to other heat pump components or to the heat pump compartment wall, thereby facilitating their fixation.

[0037] In a particular embodiment, the protruding parts of the tubes are inserted into components of the heat pump made of a foam material or any other protuberance.

In particular, the tubes are inserted in parts made of injected expanded foam such as expanded polyethylene or polystyrene or are inserted inside plug-shape parts such as screws, pins or shapes integrated in a structural part.

[0038] Another aspect of the invention is directed towards a heat pump comprising an acoustic dampening wall according to one of the embodiments previously presented. The technical effects and advantages as discussed with regard to the present acoustic dampening wall to a large extent also apply to the heat pump. Briefly, the dampening degree can be increased by diffusing the sound waves that are passing through the wall without the need to increase the wall thickness. The weight and the installation space of the heat pumps equipped with such a wall is kept low.

[0039] In another embodiment the acoustic noise reduction wall is part of the outer wall of the heat pump or is forming a part of the outer wall of the heat pump. The noise reduction wall can thus form the casing of the heat pump or at least form parts therefrom. As a casing is needed anyway, it may not be necessary to equip the heat pump with additional parts to reduce the noise transmission. The walls fulfil the function of noise. The walls can also fulfill other functions such that support of internal heat pump components, internal walls to create technical heat pump compartment and/or sealed spaces in the unit, protection against external intrusion, frame for other parts of the unit, casing function and the like.

[0040] The present invention is described in detail with reference to the drawings attached wherein

Figure 1	is a principle cross section through an acoustic noise reduction wall known from the prior art,
Figure 2	is a principle cross section through an acoustic noise reduction wall according to a first embodiment of the present invention,
Figure 3A	is a perspective view of an acoustic noise reduction wall according to a second embodiment of the present invention,
Figure 3B	is a perspective cross section through the acoustic noise reduction wall of Figure 3A,
Figure 4	is a perspective view of an acoustic noise reduction wall according to a third embodiment of the present invention,
Figures 5A to 5D	are principle cross sections of differently shaped tubes for diffusing sound waves,
Figure 6	is a principle cross section through an acoustic noise reduction wall according to a fourth embodiment,
Figure 7	is a principle cross section through an acoustic noise reduction wall according to a fifth embodiment,
Figure 8	is a principle top view on an acoustic noise reduction wall according to a sixth embodiment, and
Figure 9	is a principle cross section through a heat pump comprising an acoustic noise reduction wall according to one of the embodiments shown in Figures 1 to 8.
Figure 10 A	shows a second embodiment of the heat pump 252 according to the present invention.
Figure 10B	a sectional view along the plane A-A defined in Figure 10A.

[0041] Figure 1 shows a principle cross section through an acoustic noise reduction wall 10 known from the prior art. Such acoustic noise reduction walls 10 are sometimes also referred to as dampening panels. In Figure 1 a group of sound waves λ is illustrated by means of an arrow. The sound waves λ generated by a noise generating component of a heat pump 251 (see fig. 9) like a compressor, motor, pump or fan impinge the acoustic noise reduction wall 10 on a first surface 12, pass through and exist the same on a second surface 14. Depending in particular on the wall thickness, the frequency of the wave and the wall material, the sound waves λ are attenuated when passing through the acoustic noise reduction wall 10. In Figure 1, the attenuation is visualized by the width of the arrow. Although the sound waves λ are significantly attenuated, their wave front is still the same which means that the direction of the noise propagation remains unchanged.

[0042] As mentioned, the wall thickness is one of the decisive factors on the attenuation of the sound waves λ. However, in particular due to limitations regarding the costs, the weight of the acoustic noise reduction wall 10 and in particular the installation space of the heat pump, it is usually not possible to increase the wall thickness until the desired attenuation is obtained.

[0043] Figure 2 is a principle cross section through an acoustic noise reduction wall 161 according to a first embodiment of the present invention. The acoustic noise reduction wall 161 comprises a base material 18 which is in the first embodiment an open cell foam 20 which provides a high attenuation of the sound waves λ passing through the acoustic noise reduction wall 161. Moreover, it is a light material such that the acoustic noise reduction wall 161 can be provided in a lightweight way and with a sufficiently high stability.

[0044] The acoustic noise reduction wall 161 has a thickness T which ranges between 10 and 150 mm and in particular between 15 mm and 30 mm.

[0045] The acoustic noise reduction wall 161 is provided with a plurality of tubes 22 by which the sound waves λ passing through the acoustic noise reduction wall 161 are diffused. The tubes 22 are separate members and are made of a tube material 23 that is different from the base material 18. The tube material 23 has a first rigidity R1 and the base material 18 a second rigidity R2, wherein the first rigidity R1 is higher than the second rigidity R2. Accordingly, the tube material 23 may be made of steel, wood, hard plastic or the like. It is also noted that the tubes 22 enclose a hollow space, which is, however, not necessary, however preferred.

[0046] The tubes 22 act like an obstacle for the sound waves λ passing through the acoustic noise reduction wall 161. When a given group of sound waves λ impinges on a tube, some of the sound waves λ are deflected and travel through the acoustic noise reduction wall 161 via another path than the remaining sound waves λ. As shown in Figure 2, the group of sound waves λ is subdivided into multiple smaller first groups λ1 travelling through the acoustic noise reduction wall 161 via different paths and exit the acoustic noise reduction wall on the second surface 14. Sound waves of a second group λ2 are reflected back and enter the acoustic noise reduction wall 161 via the first surface 12. The second group λ2 of the sound waves is thus redirected back to the noise generating component and are not perceivable by a person. At the same time, the energy of λ2 is reduced during this travel. The energy of λ2 is lower when it goes back out than when it enters the foam due to the absorption of the foam. So, the wave λ2 will go back inside the compartment and will probably try to escape the compartment in another direction. But its energy and so the associated noise will be reduced compared to a known embodiment. The energy of sound waves λ, λ1 is reduced when passing through the foam.. Said energy is reduced compared to a sound wave not being deviated by the tube. Indeed, the sound wave have a longer path through the foam than without the solution. So it is reduced as if it has crossed a foam larger than T.

[0047] Figures 3A and 3B show a second embodiment of the acoustic noise reduction wall 162 according to the present invention, wherein Figure 3A is a perspective view and Figure 3B is a sectional view through the acoustic noise reduction wall 161 shown in Figure 3A. The principle design of the acoustic noise reduction wall 162 of the second embodiment is to a large extent similar to the one of the acoustic noise reduction wall 161 of the first embodiment. However, Figures 3A and 3B show that the tubes 22 have a straight progression and are vertically oriented. A horizontal or inclined orientation is also possible (not shown). Further, the tubes 22 extend over the entire acoustic noise reduction wall 162.

[0048] Figure 4 shows a perspective view of a third embodiment of the acoustic noise reduction wall 163 of the present invention. It consists mainly of four acoustic noise reduction walls 162 of the second embodiment which are, integrally connected to each other such that an integral unit is formed. Such a unit may be obtained by expansion molding, cutting and gluing assemblance.. However, four individual acoustic noise reduction walls 162 as shown in Figure 3A may be connected to each other by suitable connection means like screwing, latching or gluing.

[0049] The acoustic noise reduction wall 163 of the third embodiment encloses a hollow space 27 in which at least one heat pump component 40, e.g., a compressor and/or a fan and/or a motor and/or a pump, can be arranged. In this case, they are to the full extent surrounded by the acoustic noise reduction walls 163 which may form a casing of heat pump or a part of the casing thereof.

[0050] Figures 5A to 5D show principle cross sections of differently shaped tubes 22 separated from e.g., the acoustic noise reduction wall 161 of the first embodiment. In Figure 5A the tube 22 has a circular cross section, the tube 22 shown in Figure 5B has an elliptical cross section and the tube 22 of Figure 5C has a polygonal cross section. Other shapes like oval, drop-like or cloverleaf-shaped cross sections are also possible.

[0051] The tube 22 shown in Figure 5A comprises one or more through holes 29 such that a passage is created from outside to the inside of the tube 22. The through holes 29 run approximately perpendicular to a longitudinal axis AL of the tube 22. One through hole 29 may be provided that runs along the entire length L of the tube 22 such that the tube 22 has a C-shaped cross section. The tubes 22 have a width W which may be defined as the maximal extension perpendicular to the longitudinal axis AL. As noted, the tube 22 shown in Figure 5A has a circular shape. In this case the width W equals the outer diameter D of the tube 22.

[0052] The tube 22 shown in Figure 5D has, like the tube 22 shown in Figure 5A, a circular shape, however, is provided with corrugations 24 on its outer surface. The corrugations 24 may be provided by extrusion, machining or the like. Alternatively, they may be of microscopic scale and thus be provided by an increased roughness of the outer surface. Combinations of both variants are also possible.

[0053] Figure 6 is a principle cross section through an acoustic noise reduction wall 164 of a fourth embodiment of the present invention. The acoustic noise reduction wall 164 of the fourth embodiment is largely similar to the acoustic noise reduction wall 162 of the second embodiment and comprises a plurality of straight tubes 22 of a length L and extend over the entire acoustic noise reduction wall 164, thereby forming two open ends 26. One open end 26 is closed by a plug 28. All of the tubes 22 have the same length L and the same width W with the exception of the tube 22 arranged in the center of the acoustic noise reduction wall 164. This tube 22 protrudes over the second surface 14 of the acoustic noise reduction wall 164. The protruding part of the tube 22 may be used as a fastening means 46 for fixing the tube 22 to adjacently arranged components (see Figure 10B).

[0054] Figure 7 is a principle cross section through an acoustic noise reduction wall 165 of a fifth embodiment of the present invention. A first group 221 of tubes 22 has a straight progression and extends over the entire acoustic noise reduction wall 165. A second group 222 of tubes 22 also has a straight progression but does not extend over the entire acoustic noise reduction wall 165. As a result, it forms one open end 26 and one closed end 30. The length L of the tubes 22 of the second group 222 is smaller than the length L of the tubes 22 of the first group 221, while the width W of the tubes 22 of the second group 222 is bigger than the width W of the tubes 22 of the first group 221. The tubes 22 of a third group 223 have a curved progression.

[0055] Figure 8 is a principle top view on an acoustic noise reduction wall 166 of a sixth embodiment of the present invention. The tubes 22 of the second group 222 are arranged in a matrix 32 and form two rows 34 and three columns 36. The distance DC between the tubes 22 of the second group 222 within the columns 36 is the same. The distance DR between the tubes 22 of the second group 222 within the rows 34 is also the same, however, different from the distance DC. Not shown is an embodiment in which the distance DC within the column 36 and the distance DR within the row 34 are not the same but randomly chosen. A kind of organic arrangement can thereby be provided.

[0056] A first group 221 of tubes 22 is arranged along a row 34 between two adjacent rows 34 of the second group 222 of tubes 22. As mentioned with respect to the fifth embodiment, the width W of the tubes 22 of the first group 221 is smaller than the width W of the tubes 22 of the second group 222. Moreover, the distance DR between two adjacent tubes 22 of the first group 221 within a row 34 is smaller than the distance DR between two adjacent tubes 22 of the second group 222 within a row 34.

[0057] Figure 9 is a principle cross section through a heat pump 251 comprising an acoustic noise reduction wall 163 according to one of the embodiments shown in Figures 1 to 8, in this case an acoustic noise reduction wall 163 according to the third embodiment which encloses a hollow space 27 in which components of the heat pump 251 like ducts, compressors and/or fans (not shown) are arranged. In particular compressors and fans are one of the biggest noise sources of a heat pump 251. The acoustic noise reduction wall 163 can be designed such that it surrounds the entire heat pump 251 like a casing except for openings that are needed for the heat exchange with the environment.

[0058] Figures 10A shows a second embodiment of the heat pump 252 according to the present invention by means of a principle drawing. The heat pump comprises a heat pump compartment wall 44 that subdivides the housing 38 into two heat pump compartments 42. In each heat pump compartments 42 a heat pump component 40 such as a compressor or a motor are located. An acoustic noise reduction wall 167 is mounted to the heat pump compartment wall 44.

[0059] Figure 10B is a sectional view along the plane A-A defined in Figure 10A. The tubes 22 protrude on one side over the acoustic noise reduction wall 167 and are inserted into the heat pump compartment wall 44. In this case the protruding part of the tubes 22 serve as fastening means. This kind of fastening may be particularly convenient in case the heat pump component wall is made of a foam material or another comparatively soft material.

[0060] The heat pump component 40 arranged on the right heat pump compartment 42 of Figure 10A is provided with an acoustic noise reduction wall 167 that is directly applied to the outer surface of its casing.

Reference list

[0061]

10	acoustic noise reduction wall of the prior art
12	first surface
14	second surface
161 - 166	acoustic noise reduction wall
18	base material
20	cell foam
22	tubes
221	first group of tubes 22
222	second group of tubes 22
223	third group of tubes 22
23	tube material
24	corrugations
251, 252	heat pump
26	open end
27	hollow space
28	plug
30	closed end
32	matrix
34	row
36	column
38	housing

40	heat pump component
42	heat pump compartment
44	heat pump compartment wall
46	fastening means
48	air duct

AL	longitudinal axis
DR, DC	distance
L	length
R1	first rigidity
R2	second rigidity
W	width

T thickness

A sound wave
λ1 first group of sound waves
λ2 second group of sound waves

Claims

1. Heat pump (251, 252) having an acoustic noise reduction wall (161, 162, 163, 164, 165, 166), the acoustic noise reduction wall (161, 162, 163, 164, 165, 166, 167) comprising :

   - a base material (18) being a foam material and
   - one or more tubes (221, 222, 223) for diffusing sound waves (λ), the tubes (221, 222, 223) being made of a tube material (23) that is different from the base material.

2. Heat pump (251, 252) according to claim 1, **characterized in that** the heat pump (251, 252) comprises a housing (38), wherein the acoustic noise reduction wall (161, 162, 163, 164, 165, 166) is fastened to the housing (38) and/or is part of the housing (38) and/or is forming the housing (38) and/or is arranged inside a compartment delimited by the housing (38).

3. Heat pump (251, 252) according to one of the claims 1 or 2, **characterized in that** the heat pump (251, 252) comprises at least one heat pump component (40), in particular a pump and/or a fan and/or a compressor.

4. Heat pump (251, 252) according to claim 3, **characterized in that** the heat pump (251, 252) comprises at least one heat pump compartment (42) delimited by at least one heat pump compartment wall (44), said heat pump component (40) being located inside the heat pump compartment (42), wherein the acoustic noise reduction wall (161, 162, 163, 164, 165, 166) is fastened to the heat pump compartment wall (44) or forms the heat pump compartment wall (44).

5. Heat pump (251, 252) according to one of the claims 2 to 4, **characterized in that** fastening means (46) are employed for fastening the acoustic noise reduction wall (161, 162, 163, 164, 165, 166) to the housing (38) and/or to the heat pump components (40) and/or to the heat pump compartment wall (44), wherein the fastening means (46) form a material bond and/or a form closure.

6. Heat pump (251, 252) according to one of the preceding claims, **characterized in that** the base material (18) is a plastic foam, preferably an expanded plastic foam.

7. Heat pump (251, 252) according to one of the preceding claims, **characterized in that** the acoustic noise reduction wall (161, 162, 163, 164, 165, 166) has a wall thickness (T) in the range between 10 mm and 150 mm, in particular between 15 and 30 mm.

8. Heat pump (251, 252) according to previous claim, **characterized in that** the acoustic noise reduction wall (161, 162, 163, 164, 165, 166, 167) has an acoustic absorption rate of at least 0.6, preferably 0.8, for at least one frequency in the range between 400 to 2000 Hz

9. Heat pump (251, 252) according to one of the claims 1 or 2, **characterized in that** the tube material (23) has a first rigidity (R1) higher than a second rigidity (R2) of the base material (18), preferably the tube material (23) has a Young's modulus 100 times higher, more preferably 1000 times higher, than the Young modulus of the base material.

10. Heat pump (251, 252) according to one of the preceding claims, **characterized in that** at least one surface of the tubes (221, 222, 223) is provided with corrugations (22).and/or includes openings between outer surface and inner surface of the tube.

11. Heat pump (251, 252) according to one of the preceding claims, **characterized in that** the tubes (221, 222, 223) of one acoustic noise reduction wall (161, 162, 163, 164, 165, 166) have different dimensions, in particular a different length (L) and/or width (W).

12. Heat pump (251, 252) according to one of the preceding claims, **characterized in that** the tubes (221, 222, 223) have at least partly a circular section and/or elliptical section and/or polygonal section and/or ring section.

13. Heat pump (251, 252) according to claim 9, **characterized in** when the tubes (221, 222, 223) have a circular section their diameters are comprised from 5 mm up to 100 mm, especially from 7 to 20 mm.

14. Heat pump (251, 252) according to one of the preceding claims, **characterized in that**

    a. the tubes (221, 222, 223) are arranged in a matrix (32) comprising at least two rows (34) and at least two columns (36) And/or **in that**
    b. the tubes (221, 222, 223) are running parallel and at a distance (DC, DR) to each other, wherein the distance (DC, DR) is varying within one acoustic noise reduction wall (161, 162, 163, 164, 165, 166) and/or **in that** the tubes (221, 222, 223) extend over the entire acoustic noise reduction wall (161, 162, 163, 164, 165, 166).

15. Heat pump according to one of the precedent claims, **characterized in that** at least an acoustic dampening wall is fixed to a panel of the heat pump,

a. using a glue assembly between the dampening wall and the panel and/or
b. by holding the tubes of the dampening wall to the panel with countershape.

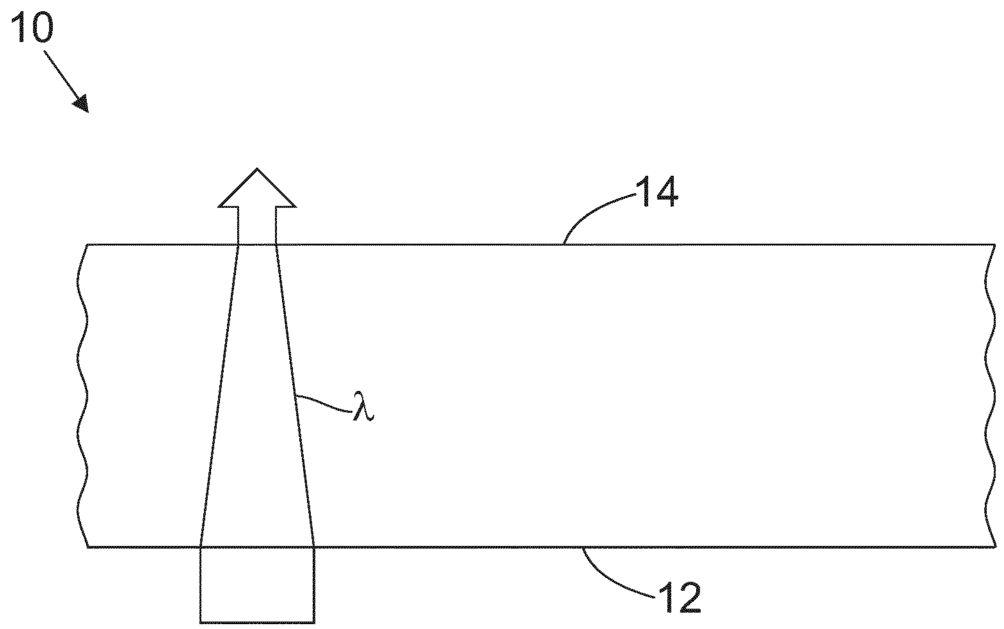

Fig.1

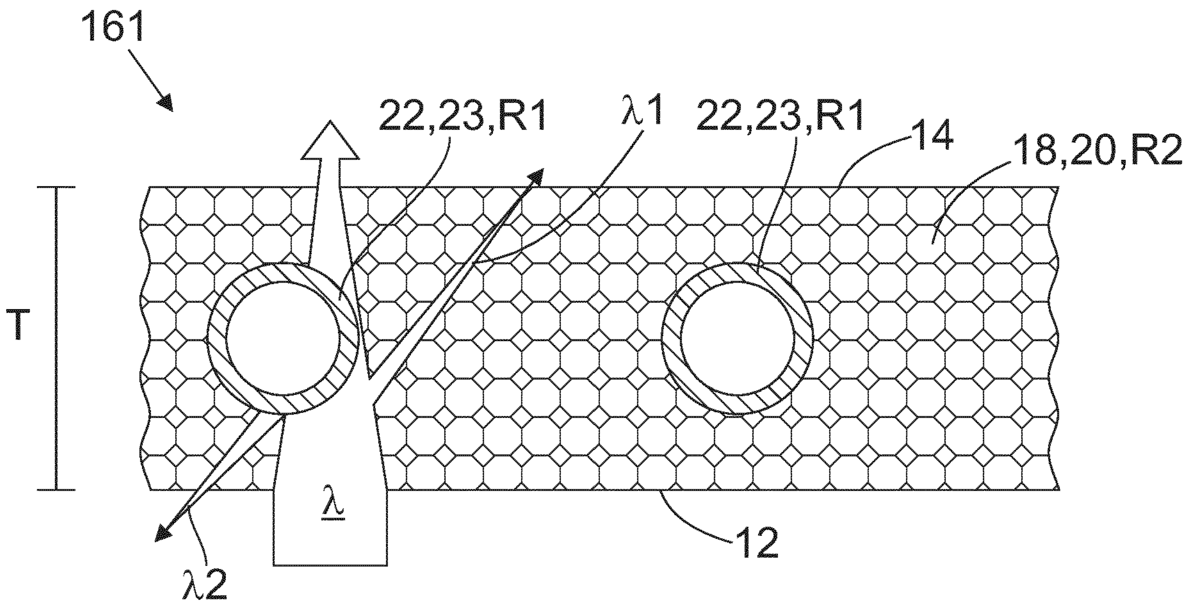

Fig.2

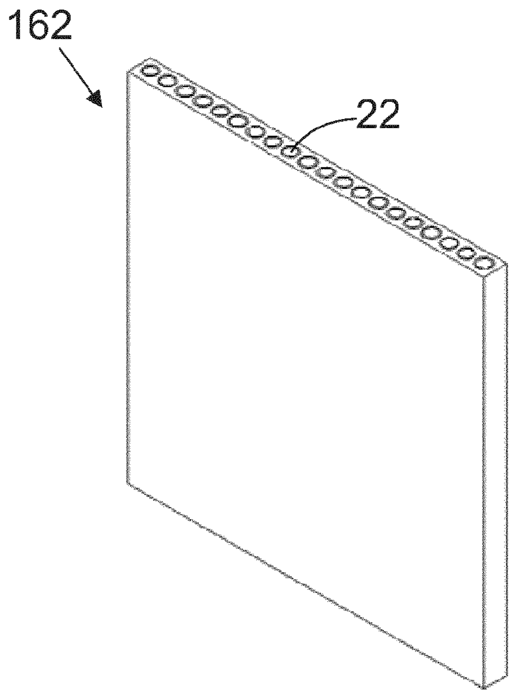

Fig.3A

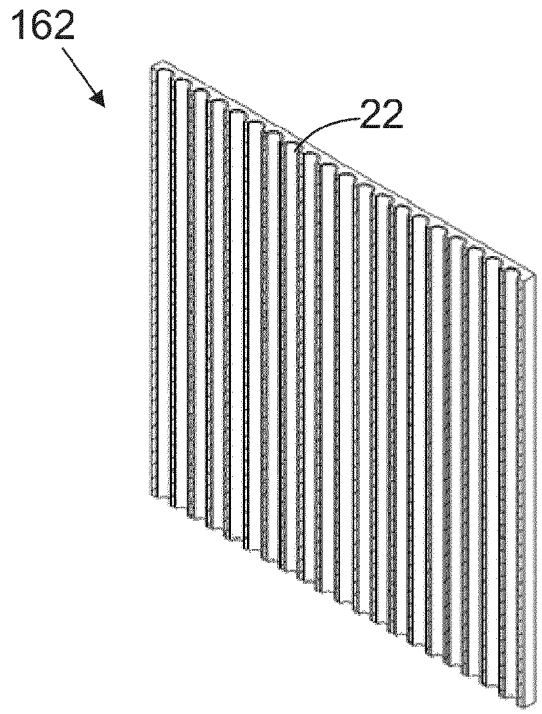

Fig.3B

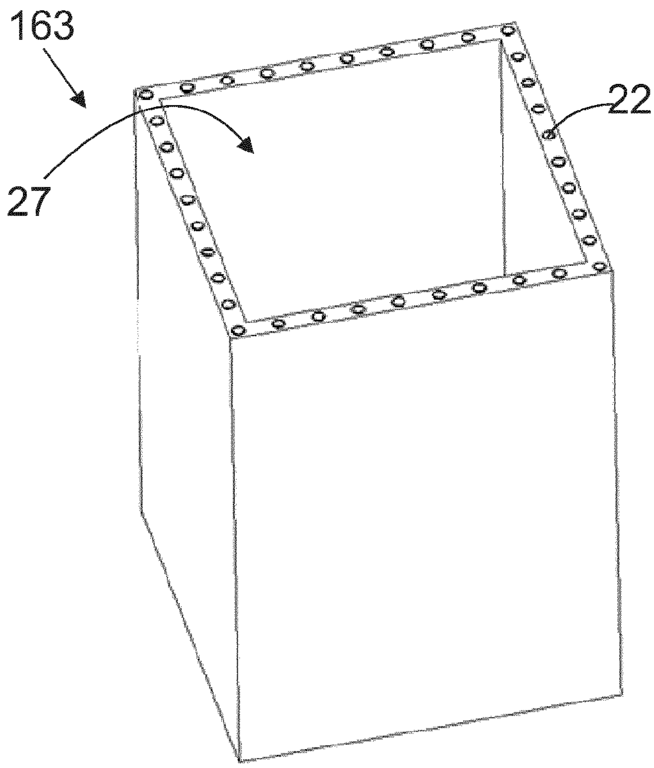

Fig.4

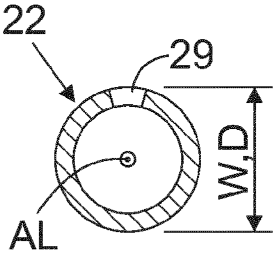

Fig.5A

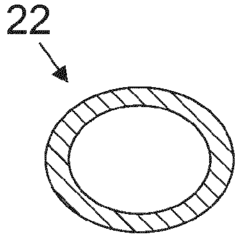

Fig.5B

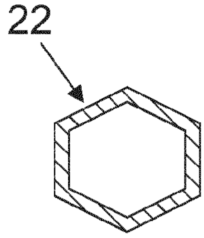

Fig.5C

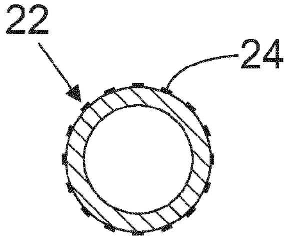

Fig.5D

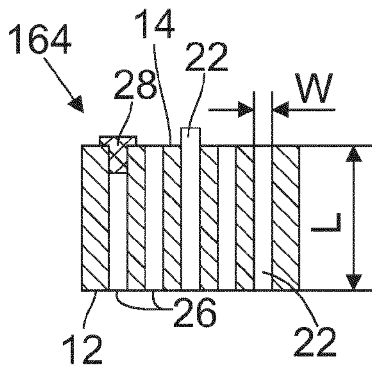

Fig.6

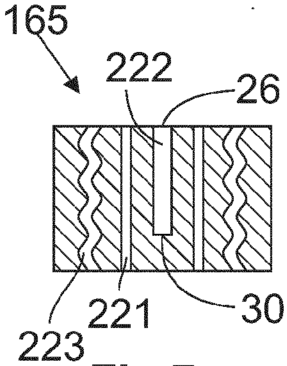

Fig.7

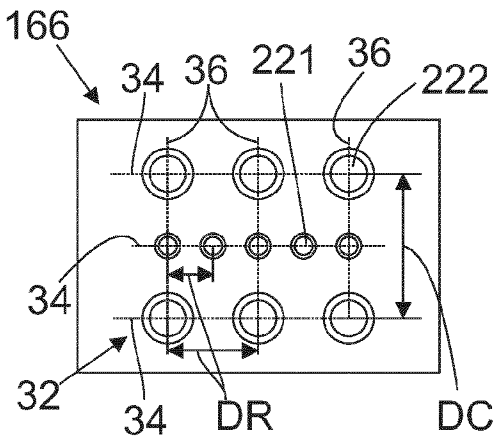

Fig.8

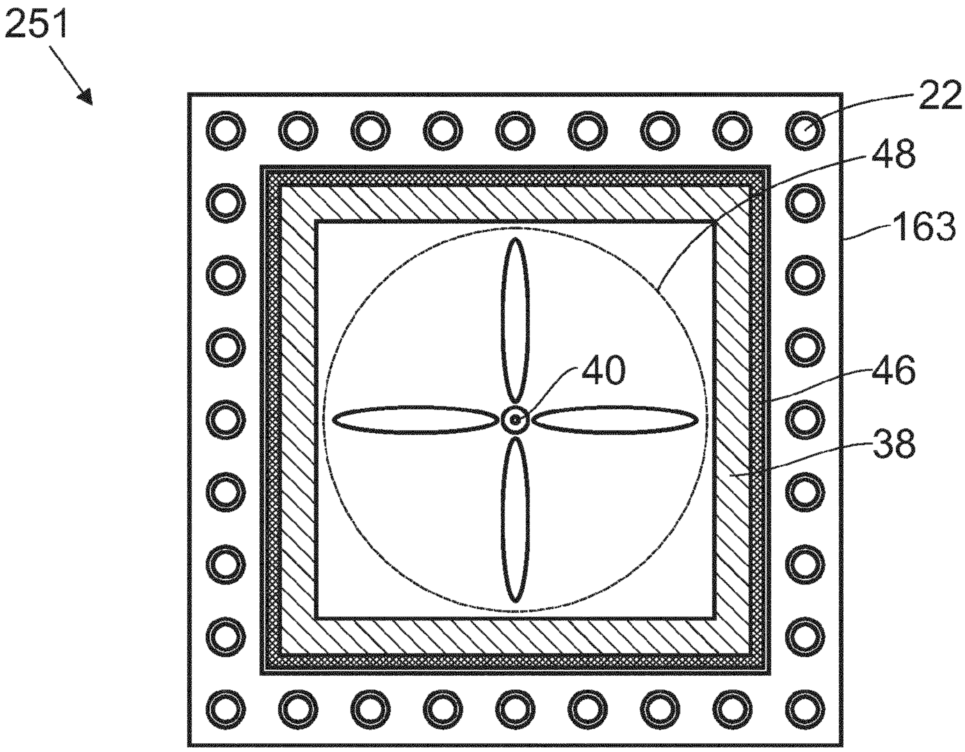

Fig.9

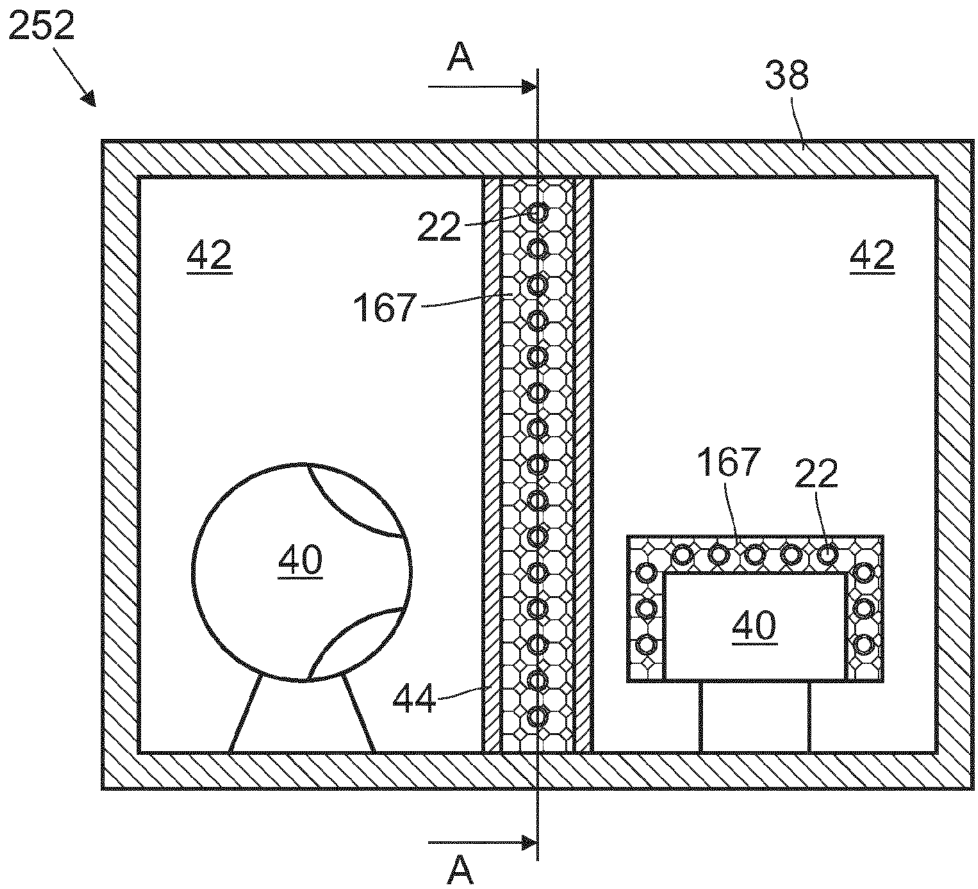

Fig.10A

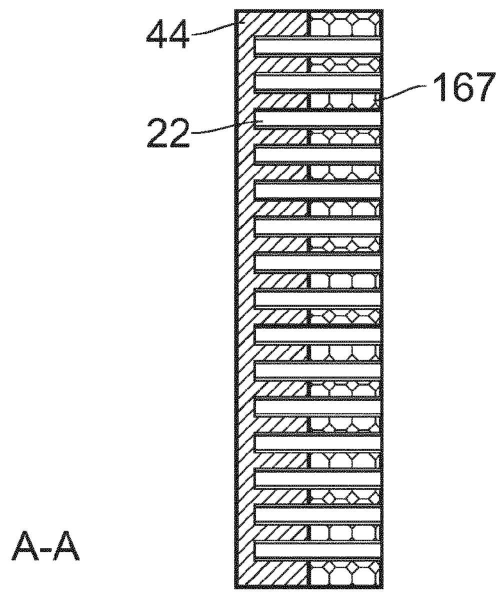

Fig.10B

EUROPEAN SEARCH REPORT

Application Number
EP 23 20 5711

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	CN 110 748 981 A (GUANGDONG MIDEA REFRIGERATION EQUIPMENT CO LTD; MIDEA GROUP CO LTD) 4 February 2020 (2020-02-04) * abstract; figures 1-3 * -----	1-15	INV. F24F1/12 F24F13/24
A	US 10 928 096 B2 (ROBERT BOSCH LLC [US]; BOSCH GMBH ROBERT [DE]) 23 February 2021 (2021-02-23) * column 4, line 1 - line 26; figures 1, 18, 19 * -----	1-15	
A	WO 2022/162731 A1 (MITSUBISHI ELECTRIC CORP [JP]) 4 August 2022 (2022-08-04) * paragraphs [0030] - [0032]; figure 7 * -----	1-15	
A	EP 2 894 414 B1 (ATLANTIC CLIMATISATION ET VENTILATION [FR]) 21 July 2021 (2021-07-21) * paragraph [0050]; figure 8 * -----	1-15	
A	KR 101 870 414 B1 (AN YOON SEOK [KR]) 22 June 2018 (2018-06-22) * abstract; figures 3-5 * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC) F24F F25B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	9 April 2024	Valenza, Davide

CATEGORY OF CITED DOCUMENTS

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L : document cited for other reasons

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EP 23 20 5711

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09-04-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 110748981 A	04-02-2020	NONE	
US 10928096 B2	23-02-2021	NONE	
WO 2022162731 A1	04-08-2022	EP 4286762 A1	06-12-2023
		JP WO2022162731 A1	04-08-2022
		WO 2022162731 A1	04-08-2022
EP 2894414 B1	21-07-2021	EP 2894414 A1	15-07-2015
		FR 3013426 A1	22-05-2015
KR 101870414 B1	22-06-2018	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- IT 202100005240 U1 **[0003]**