(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 907 407 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
10.11.2021 Bulletin 2021/45

(21) Application number: **20173180.9**

(22) Date of filing: **06.05.2020**

(51) Int Cl.:
F04D 25/08 *(2006.01)*
F04D 29/42 *(2006.01)*
F04D 29/66 *(2006.01)*
F24F 13/20 *(2006.01)*
F24F 13/24 *(2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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(54) **FAN COIL UNIT WITH SILENCER**

(57) A fan coil unit (300; 700; 800) for a heating, ventilation, and air conditioning (HVAC) system, the fan coil unit (300; 700; 800) comprising: a cabinet (202) having an inlet (208) and an outlet (210), the cabinet housing: a heat exchanger assembly (206), a fan assembly (204), a separator (220) extending across the fan assembly such that the cabinet is divided into an inlet portion (222) and an outlet portion (224), with the fan assembly being for generating a pressure difference between the inlet portion and the outlet portion, and a silencer (350; 750; 850a, 850b) configured to reduce noise generated in the fan coil unit (300; 700; 800) during use of the fan assembly (206) to move air between the inlet (208) and the outlet (210) of the cabinet (202), the silencer comprising: one or more cells (360a, 360b, 360c; 400a; 400b; 400c; 400d; 760a, 760b), wherein each cell comprises an end wall (354; 754), and a perforated wall (352; 752) spaced apart from the end wall.

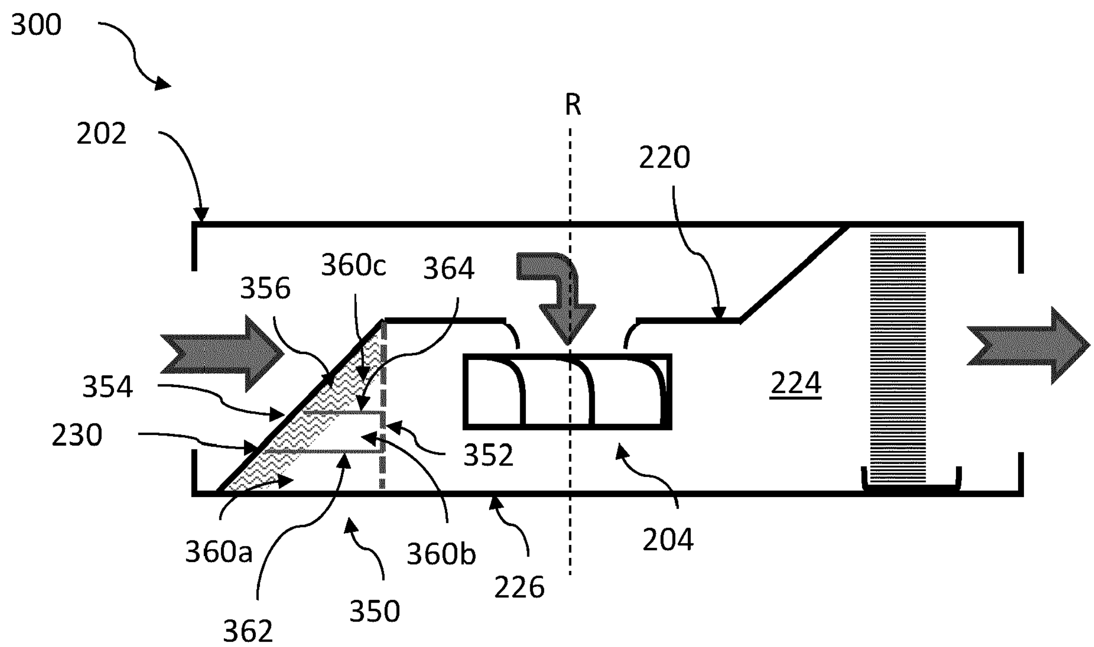

Figure 3

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Description

[0001] The present invention relates to a fan coil unit of a heating, ventilation, and air conditioning (HVAC) system, particularly to a system and method for reducing noise in such a system.

[0002] A fan coil unit of a HVAC system typically includes a fan positioned in a housing or cabinet to direct airflow across a heat exchanger in the cabinet. The airflow then exits the fan coil unit as supply airflow for the system to cool, heat or otherwise condition a space, depending on the operational mode or configuration of the HVAC system.

[0003] Typical fan configurations and orientations in the cabinet have led to units which are too large to be used in confined spaces such as narrow false ceilings or false floors.

[0004] In the prior art, proposals have been made for fan coil units that may be more space efficient. An example configuration of a so-called "slim" fan coil unit is disclosed in WO 2019/171096 and is described in further detail below.

[0005] Figure 1 shows a cross-sectional view of a fan coil unit 10 of a HVAC system. The fan coil unit 10 includes a cabinet or housing duct 12 which houses various components of the fan coil unit 10. For example, the cabinet 12 houses a heat exchanger assembly 14 configured to cool or heat air in its vicinity and a fan assembly 16 configured to circulate air through the heat exchanger assembly 14. Depending on the desired specification of the fan coil unit 10, the fan assembly 16 may be positioned either upstream of the heat exchanger assembly 14 (i.e. a "blow through" configuration), as is shown in Figure 1, or downstream of the heat exchanger assembly 14 (i.e. a "draw through" configuration).

[0006] The heat exchanger assembly 14 shown in Figure 1 comprises a single heat exchanger coil 18 arranged perpendicular to the primary flow direction of air through the cabinet 12, wherein the primary flow direction is shown to generally be from left to right of the fan coil unit 10 shown in Figure 1. In a heating mode, the heat exchanger assembly 14 is configured to heat the air in the primary flow as it passes through the heat exchanger assembly 14. In a cooling mode, the heat exchanger assembly 14 is configured to absorb heat from the air passing though the heat exchanger assembly 14. In either mode, the air is provided to one or more spaces to be conditioned.

[0007] The cabinet 12 comprises at least one inlet 20 through which air flows into the cabinet 12 and at least one outlet 22. The inlet 20 is located at a first cabinet end 24 and the outlet 22 is located at a second cabinet end 26, wherein the second cabinet end 26 is opposite the first cabinet end 24. The airflow flows in a general flow direction 28 from the inlet 20 to the outlet 22.

[0008] The fan assembly 16 includes a fan housing 30 and an impeller 32 located in the fan housing 30 and being configured to be driven about an axis of rotation 34. The axis of rotation 34 is perpendicular to the general flow direction 28 through the cabinet 12. That is, in Figure 1, the general flow direction 28 is from left to right, whereas the axis of rotation 34 is oriented vertically.

[0009] The cabinet 12 also houses a separator 36 which extends across the fan assembly 16 such that the fan assembly 16 is located at a separator opening 38. The separator 36 divides the cabinet 12 into an inlet portion 40 upstream of the fan assembly 16, and an outlet portion 42 downstream of the fan assembly 16. The fan assembly 16 comprises a fan inlet 44 and a fan outlet 46, where the fan inlet 44 is located in the inlet portion 40 and the fan outlet 46 is located in the outlet portion 42. In this way, the air must pass through the fan assembly 16 to move from the inlet portion 40 to the outlet portion 42.

[0010] The separator 36 includes an upstream section 48 extending away from a lower cabinet wall 50 towards the fan assembly 16. The upstream section 48 extends such that a cross-sectional flow area of the inlet portion 40 decreases along the general flow direction 28 as the upstream section 48 approaches the fan assembly 16. Similarly, the separator includes a downstream section 52 extending away from the fan assembly 16 towards an upper cabinet wall 54. The lower cabinet wall 50 and the upper cabinet wall 54 are opposite one another and the distance between these walls is known as the cabinet thickness 56. The lower cabinet wall 50 and the upper cabinet wall 54 each extend between the inlet 20 and the outlet 22.

[0011] The upstream section 48 and the downstream section 52 are positioned on opposite sides of the fan assembly 16 from one another and are such that the upstream section 48 extends towards a side of the fan assembly 16 that faces the inlet 20 and the downstream section 52 extends from a side of the fan assembly 16 that faces the outlet 22. The downstream portion 52 extends such that a cross-sectional area of the outlet portion 42 increases along the general flow direction 28 as the downstream section 52 approaches the cabinet upper wall 54.

[0012] The example fan coil unit above may have a smaller cabinet thickness compared to that of other fan coil unit configurations. A fan coil unit having a reduced cabinet thickness compared to typical fan coil units may be referred to as a "slim" fan coil unit. This small thickness may have three consequences:

- A reduced cabinet thickness may lead to an increased internal pressure in the cabinet.
- This reduced cabinet thickness may lead to the use of a smaller diameter impeller compared to those used in common configurations. The reduced diameter of the impeller and the increased internal pressure may require that the impeller rotation speed is higher compared to typical fan coil unit configurations.
- Typical types of fans used in typical fan coil units

have a large number of small forward curved blades. Such fans are not suitable for use in fan coil units having a reduced cabinet thickness. Instead, the impeller described above may have a few backward curved blades. This type of fan may be known as a "plug fan".

[0013] As a result, such slim fan coil units may generate high levels of audible noise. Such noise is not desirable, and so there is a need for noise reduction in fan coil units of HVAC systems.

[0014] Viewed from a first aspect, the present invention provides a fan coil unit for a heating, ventilation, and air conditioning (HVAC) system, the fan coil unit comprising: a cabinet having an inlet and an outlet, the cabinet housing: a heat exchanger assembly, a fan assembly, a separator extending across the fan assembly such that the cabinet is divided into an inlet portion and an outlet portion, with the fan assembly being for generating a pressure difference between the inlet portion and the outlet portion, and a silencer configured to reduce noise generated in the fan coil unit during use of the fan assembly to move air between the inlet and the outlet of the cabinet, the silencer comprising: one or more cells, wherein each cell comprises an end wall, and a perforated wall spaced apart from the end wall.

[0015] An advantage of first aspect is that noise generated in the fan coil unit may be reduced by the silencer while maintaining the space efficiency of fan coil units similar to the example described in WO 2019/171096. That is, the invention may make use of space in the fan coil unit to provide a discreet silencer for noise reduction without changing the dimensions of the cabinet. The inventor has realised that the space reducing measures in prior art such as WO 2017/171096 can undesirably increase noise/vibration and the proposed silencer addresses this without any disadvantage regarding dimensions.

[0016] The following describes optional features that may be combined with the fan coil unit of the first aspect.

[0017] The silencer may further comprise a sound absorbing material occupying at least some of the space between the perforated wall and the end wall of at least one of the cells. As discussed further below, the use of a sound absorbing material may be with varying arrangements of spacing within the cell(s). The inventors have found that a cellular construction with a perforated wall combines well with the addition of sound absorbing material to provide increased performance for the silencer.

[0018] The cabinet may have a horizontal direction and a vertical direction. The horizontal direction may be defined as the direction extending between the inlet and the outlet and/or between an inlet end and an outlet end of the cabinet. The inlet end may be a region within the cabinet that is proximate to the inlet. The inlet end may be entirely within the inlet portion. The outlet end may be a region within the cabinet that is proximate to the outlet. The outlet end may be entirely within the outlet portion. The vertical direction may be orthogonal to the horizontal direction. The cabinet may have a cabinet thickness, wherein the cabinet thickness may be parallel to the vertical direction.

[0019] The fan assembly may comprise a fan housing and an impeller, wherein the impeller may be located in the fan housing. The impeller may be configured to rotate about an axis of rotation. The fan assembly may have a fan assembly inlet and a fan assembly outlet. The fan assembly may be a plug fan.

[0020] The impeller may be configured to rotate at speeds in the range 1500 rpm to 3500 rpm, or optionally 2500 rpm to 3500 rpm, when in use. The impeller may have a number of blades equal to or fewer than 12. The impeller may be a backwards curved impeller, meaning that the blades may be curved backwards. The difference in flow direction between a forward and backward curved impeller is the direction that the air exits the impeller circumference. With a backward curved impeller, the air exits in a radial direction whereas with a forward curved the air exits tangentially from the circumference of the impeller.

[0021] Due to the rotation speed and the number of blades, the impeller may generate high levels of audible noise. This noise may have a significant component in the frequency range 200-500 Hz, which may be significantly lower to the frequency range of maximum noise emitted by typical configurations of fan coil units. That is, the impeller may have a blade passing frequency between 200 Hz and 500 Hz when in operation. In this frequency range, the impeller may induce relatively large amounts of aerodynamic noise when in operation that result in generation of noise from the fan coil unit.

[0022] The inlet may be adjacent to the inlet portion and the outlet may be adjacent to the outlet portion. The inlet may be at a cabinet first end and the outlet may be at a cabinet second end. The inlet may be opposite the outlet. The cabinet first end may be opposite the cabinet second end. The inlet portion may be fluidly connected to the outlet portion via the fan assembly such that the air must pass through the fan assembly to move from the inlet portion to the outlet portion.

[0023] The air flow from the inlet to the outlet may turn within the cabinet as it passes through the fan assembly. Thus, the cabinet may have a horizontal direction defined with reference to the inlet end and outlet end as discussed above, which may be a direction between the cabinet first end and the cabinet second end, and the air may turn away from the horizontal direction as it passes through the fan assembly.

[0024] A general flow direction may be defined as the overall flow direction of air within the fan coil unit when the fan coil unit is in operation. The general flow direction may be from the inlet end to the outlet end. The general flow direction may be parallel to the horizontal direction. The axis of rotation may be perpendicular to the general flow direction. The axis of rotation may be perpendicular to the horizontal direction and may be parallel to the vertical direction.

[0025] The separator may comprise a separator opening, wherein the separator opening may surround the fan assembly inlet. The fan assembly may be mounted to the separator such that the fan housing is substantially within the outlet portion or substantially within the inlet portion. The distribution of the fan assembly may vary between configurations and the proportion of the fan assembly that is present in the inlet and outlet portions may therefore change.

[0026] The separator may include an upstream section, a downstream section, and a central section. The cabinet may further comprise a lower cabinet wall and an upper cabinet wall. The lower cabinet wall may be opposite the upper cabinet wall. The lower cabinet wall and the upper cabinet wall may extend between the inlet and the outlet. The distance between the upper cabinet wall and the lower cabinet wall may define the cabinet thickness.

[0027] The upstream section may extend away from the lower cabinet wall towards the fan assembly and may connect to the central section. The upstream section may extend such that a cross-sectional flow area of the inlet portion decreases along the general flow direction as the upstream section approaches the fan assembly. That is, the upstream section may extend upwards and at an angle from the lower cabinet wall towards the fan assembly and may connect to the central assembly.

[0028] The central assembly may extend in the horizontal direction only. That is, the central section may have no component that extends in the vertical direction. The central section may comprise the separator opening. The central assembly may partially or fully extend over a horizontal extent of the fan assembly.

[0029] The upstream section and the downstream section may be positioned on opposite sides of the fan assembly from one another. The upstream section may extend towards an inlet side of the fan assembly. The downstream section may extend from an outlet side of the fan assembly. That is, the inlet side of the fan assembly may face a direction towards the inlet and the outlet side of the fan assembly may face a direction towards the outlet. The horizontal extent of the fan assembly may be the horizontal distance between the inlet side of the fan assembly and the outlet side of the fan assembly.

[0030] The downstream section may extend from the central section and away from the fan assembly towards the upper cabinet wall. The downstream portion may extend such that a cross-sectional area of the outlet portion increases along the general flow direction as the downstream section approaches the cabinet upper wall.

[0031] The silencer end wall may be opposite to the perforated wall. The silencer end wall may abut the separator. Alternatively, the silencer end wall may be spaced apart from the separator. A further alternative is that the silencer end wall may be integral with the separator.

[0032] The silencer end wall may abut, be spaced apart from or be integral with the upstream portion of the separator. Alternatively, the silencer end wall may abut, be spaced apart from or be integral with the downstream portion of the separator. The silencer end wall may be provided by a surface of the separator.

[0033] The silencer may have a silencer lower wall. The silencer lower wall may abut or be spaced apart from or be integral with the cabinet lower wall. Alternatively, the silencer may have an upper wall. The silencer upper wall may abut or be spaced apart from or be integral with the cabinet upper wall.

[0034] The silencer may be positioned in the inlet portion of the cabinet or in the outlet portion of the cabinet.

[0035] The fan coil unit may comprise more than one silencer.

[0036] The silencer may be a self-contained unit that may be installed in existing fan coil units.

[0037] The perforated wall may face the fan assembly, and thus the perforated wall may have a surface facing into the inlet portion or the outlet portion. Advantageously, the perforated wall has a surface facing into the outlet portion and hence facing into a space occupied by higher pressure air that has passed through the fan. As noted above, the end wall is spaced apart from the perforated wall and may be opposite the perforated wall. The end wall may effective be behind the perforated wall relative to the fan assembly, with the perforated wall hence being in between the fan assembly and the end wall.

[0038] The perforated wall may have a plurality of holes. For example, the perforated wall may have a perforation rate equivalent to having 1 to 3200 holes in a circular plate with a diameter of 100mm. The plurality of holes may each have the same diameter between 0.25 mm and 3 mm or they may each have a diameter between 0.25 mm and 3 mm. The perforated wall may have a thickness between 0.25 mm and 2.5 mm, or optionally between 0.5 mm and 1.5 mm. The perforated wall may have a perforation rate of between 0.1% and 2.5%, or optionally between 0.5% and 1%. The perforated wall may be constructed from metal, plastic, composite, or other appropriate material.

[0039] The sound absorbing material may be a porous material, for example it may be a foam material, a woven material or a felted material, mineral fibre or cotton felts. The sound absorbing material may have a density of between 10 kg/m^3 and 150 kg/m^3 or optionally between 20 kg/m^3 and 100 kg/m^3. The sound absorbing material may have a thickness between 1 cm and 15 cm or optionally between 2 cm and 5 cm. The sound absorbing material may abut the silencer end wall. The sound absorbing material may extend partially or fully along a height of the silencer.

[0040] The sound absorbing material may be spaced apart from the perforated wall. That is, there may be a gap between the sound absorbing material and the perforated wall, for example a gap of 1 cm to 15 cm or optionally a gap of 2 cm to 5 cm. Alternatively, the sound absorbing material may abut the perforated wall. The sound absorbing material may abut the perforated wall along the full length of the perforated wall or partially along the length of the perforated wall.

[0041] Each of the one or more cells may have a cell length extending in the horizontal direction. The cell length may be the distance along the cell between the perforated wall and the end wall, including space occupied by the sound absorbing material. Each of the one or more cells may have a cell height extending in the vertical direction. Each of the one or more cells may have different cell lengths from one another. Each of the one or more cells may have different cell heights from one another. The cell length is measured from the midpoint of the cell height from the perforated wall to the end wall.

[0042] An advantage of a silencer having two or more cells of differing lengths is that each of the cells may be tuned to reduce different noise frequencies and their harmonics, and so may attenuate noise over a greater frequency range compared to one or more cells all having the same length. The cells may include multiple cells each with a cell length in the range 1 cm to 15 cm, advantageously with multiple cells having differing cell lengths.

[0043] Cells attenuate noise at frequencies attributed to its cell length. A sound absorbing material may be located within one or more of the cell(s), and optionally within all of the cells.

[0044] An advantage of having sound absorbing material in a cell may be to improve the attenuation at the resonance frequency of the cell and to widen the peak of maximum attenuation.

[0045] In the case of the silencer having two or more cells, the cells may be stacked on one another in the vertical direction, with vertical defined relative to the cabinet/housing as set out above. That is, the silencer may have at least a bottom cell and a top cell. In this way, the overall cross-sectional shape of the silencer may be triangular or trapezoidal in a plane defined by the horizontal direction and the vertical direction.

[0046] In the case that the silencer has two cells, there may be a bottom cell and a top cell, wherein the upper boundary of the bottom cell may be the lower boundary of the top cell. In the case of the silencer having more than two cells, the silencer may have a bottom cell, a top cell, and one or more middle cells.

[0047] Each of the one or more cells may have a triangular cross-section or a trapezoidal cross-section along their lengths. That is, the cross-section of each of the one or more cells may be triangular or trapezoidal in a plane defined by the horizontal direction and the vertical direction. Alternatively or additionally, at least one of the cells may have a rectangular cross-section along the cell length.

[0048] Each of the one or more cells may be bounded on a first end by the perforated wall and on a second end by the silencer end wall. At least one of the one or more cells comprises the sound absorbing material. That is, each of the one or more cells may have a cell cavity defined by boundaries of the cell and the sound absorbing material may be disposed in the cell cavity of at least one of the one or more cells.

[0049] In the case of a cell having a triangular cross-section, the cross-section may correspond to a right-angled triangle or it may be an oblique triangle, where oblique triangles comprise acute triangles and obtuse triangles.

[0050] In the case of a cell having a trapezoidal cross-section, the cross-section may correspond to a right-angled trapezoid, an acute trapezoid or an obtuse trapezoid.

[0051] The silencer may comprise one or more additional perforated walls, for example further walls spaced apart from one another. Each of the one or more additional perforated walls may divide at least of the one or more cells into smaller sub-cells. That is, one or more of the one or more cells may comprise two or more sub-cells, wherein one or more of the sub-cells may comprise a sound absorbing material.

[0052] The heat exchanger assembly may comprise one or more heat exchanger coils. The one or more heat exchanger coils may be arranged in a generally V-shaped configuration, a generally A-shaped configuration, a generally N-shaped configuration, or any other appropriate configuration. The heat exchanger assembly may have fluid connections for receiving a fluid for use in heating or cooling the air that passes through the fan coil unit. These connections may be for allowing the heat exchanger assembly to operate within a cooling or heating circuit such as through being a so-called water terminal or air terminal, for example a water terminal for a hydronic cooling system. Alternatively the connections may be for joining the heat exchanger assembly to a refrigeration circuit

[0053] The fan assembly may be configured to drive air through the heat exchanger assembly to heat or cool the air passing through the heat exchanger assembly, depending on the mode of the HVAC system. That is, in a heating mode, the heat exchanger assembly may be configured to heat the air as it passes through the heat exchanger assembly by absorbing heat that is rejected from the heat exchanger, for example from a fluid within the heat exchanger. In a cooling mode, the heat exchanger assembly may be configured to absorb heat from the air passing though the heat exchanger assembly and hence to cool the air, which may be done by heating a fluid within the heat exchanger. In either mode, the air that has passed through the heat exchanger may be provided to one or more spaces to be conditioned.

[0054] The heat exchanger assembly may be upstream from the fan assembly or it may be downstream from the fan assembly.

[0055] The fan coil unit may be connected to spaces to be conditioned or to other components by ductwork. For example, the outlet may be connected directly to a space to be conditioned or may be connected to one or more spaces to be conditioned by ductwork.

[0056] The air being heated or cooled in the fan coil unit may be provided from a return air duct connected to a space to be conditioned and/or may be fresh air drawn in from an outside source.

[0057] Viewed from a second aspect, the invention provides a method for noise reduction in a fan coil unit for a heating, ventilation, and air conditioning (HVAC) system, the fan coil unit comprising: a cabinet having an inlet and an outlet, the cabinet housing: a heat exchanger assembly, a fan assembly, and a separator extending across the fan assembly such that the cabinet is divided into an inlet portion and an outlet portion, with the fan assembly being for generating a pressure difference between the inlet portion and the outlet portion, the method comprising providing a silencer configured to reduce noise generated in the fan coil unit during use of the fan assembly to move air between the inlet and the outlet of the cabinet, the silencer comprising: one or more cells, wherein each cell comprises an end wall, and a perforated wall spaced apart from the end wall.

[0058] The method may relate to a fan coil unit having features as discussed above in connection with the first aspect and optional features thereof. The method may include determining the expected frequencies of noise from the fan assembly and providing the silencer with suitable dimensions, such as dimensions selected from those above, in order to reduce noise emissions from the fan coil unit.

[0059] The method may involve operating the fan coil unit, wherein the fan assembly may comprise a fan housing and an impeller located in the fan housing, wherein the method may further comprise driving the impeller at speeds in the range of 1500 rpm to 3500 rpm or optionally 2500 rpm to 3500 rpm.

[0060] The method may further comprise using the fan assembly to draw in air through the inlet, through the heat exchanger assembly, and out of the cabinet via the outlet. The path taken by the airflow may be restricted by the separator such that the airflow must pass through the fan assembly when moving from the inlet portion to the outlet portion.

[0061] Certain example embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings in which:

Figure 1 shows an example fan coil unit having fan coil features that are known from the prior art.

Figure 2 shows a schematic view of a fan coil unit.

Figure 3 shows a schematic view of a fan coil unit comprising a silencer in an outlet portion.

Figures 4A, 4B, 4C, and 4D show detailed schematic views of variations of a cell that may form part of the silencer.

Figures 5A and 5B show schematic views of variations on the shape of cell cross-sections.

Figures 6A and 6B show schematic views of variations of a silencer having three cells.

Figure 7 shows a schematic view of a fan coil unit having a silencer in an inlet portion.

Figure 8 shows a schematic view of a fan coil unit having a silencer in each of the inlet portion and the outlet portion.

[0062] Figure 2 shows a schematic view of a fan coil unit 200 as a cross-section of the fan coil unit 200. The fan coil unit 200 comprises a cabinet 202 for housing a fan assembly 204 and a heat exchanger assembly 206. The cabinet 202 has an inlet 208 and an outlet 210.

[0063] The fan assembly 204 comprises a fan assembly housing 212 and an impeller 214 housed in the fan assembly housing 212. The fan assembly 204 also has a fan inlet 215. In this case, the fan assembly 204 is a centrifugal fan assembly and the impeller 214 is a backwards curved impeller. The fan assembly 204 may be positioned either upstream of the heat exchanger assembly 206 (i.e. a "blow through" configuration), as is shown in Figure 1, or downstream of the heat exchanger assembly 206 (i.e. a "draw through" configuration).

[0064] The heat exchanger assembly 206 shown in Figure 2 comprises a single heat exchanger coil 216 and a condensate pan 218. The heat exchanger coil 216 is arranged perpendicular to the primary flow direction of air through the cabinet 202, wherein the primary flow direction is shown to be from the left of the cabinet 202 to right of the cabinet 202 shown in Figure 2. In a heating mode, the heat exchanger assembly 206 is configured to heat the air in the primary flow as it passes through the heat exchanger assembly 206. In a cooling mode, the heat exchanger assembly 206 is configured to absorb heat from the air passing though the heat exchanger assembly 206. In either mode, the air is provided to one or more spaces to be conditioned.

[0065] The cabinet 202 also comprises a separator 220 positioned in the cabinet 202 in order to divide the cabinet into an inlet portion 222 and an outlet portion 224. The fan assembly 204 is mounted to the separator 220 such that, when the fan coil unit 200 is in operation, air must travel through the fan assembly 204 in order to flow from the inlet portion 222 to the outlet portion 224. To achieve this, the separator 220 comprises a separator opening 221 which allows fluid communication between the inlet portion 222 and the fan inlet 215. The fan assembly 204 is mounted on the outlet side of the separator 220 so that the fan assembly is substantially within the outlet portion 224. In this way, in operation, the fan assembly 204 draws air from the inlet portion 222 through the separator opening 221 and the fan inlet 215 into the fan assembly 204 and expels air from the fan assembly 204 into the outlet portion 224.

[0066] The impeller 214 is configured to rotate about a rotation axis R. The impeller 214, therefore, lies in a plane perpendicular to the rotation axis R. As shown in Figure 2, the impeller plane is disposed horizontally within the cabinet 202 and is parallel to the primary flow direction.

[0067] The cabinet 202 comprises a lower cabinet wall 226 and an upper cabinet wall 228. The lower cabinet wall 226 and the upper cabinet wall 228 are shown in Figure 2 to be opposite and parallel to one another and to be parallel to the impeller plane, thereby perpendicular to the rotation axis R. The distance between the lower cabinet wall 226 and the upper cabinet wall is known as the cabinet thickness.

[0068] The separator 220 includes an upstream section 230 extending away from the lower cabinet wall 226 towards the fan assembly 204. The upstream section 230 extends such that a cross-sectional flow area of the inlet portion 222 decreases along the general flow direction as the upstream section 230 approaches the fan assembly 204.

[0069] The separator also includes a downstream section 232 extending away from the fan assembly 204 towards the upper cabinet wall 228. As shown in Figure 2, the lower cabinet wall 226 and the upper cabinet wall 228 each extend between the inlet 208 and the outlet 210.

[0070] The upstream section 230 and the downstream section 232 are positioned on opposite sides of the fan assembly 204 from one another and are such that the upstream section 230 extends towards a side of the fan assembly 204 that faces the inlet 208 and the downstream section 232 extends from a side of the fan assembly 204 that faces the outlet 210. The downstream portion 232 extends such that a cross-sectional area of the outlet portion 224 increases along the general flow direction as the downstream section 232 approaches the cabinet upper wall 228.

[0071] Figure 3 shows a schematic view of a fan coil unit 300 comprising all of the features of the fan coil unit of Figure 2. The fan coil unit 300 shown in Figure 3 further comprises a silencer 350 disposed in the outlet portion 224 of the cabinet 202. The walls of the silencer 350 include a portion of the lower cabinet wall 226, a portion of the upstream section 230 of the separator 220, and a perforated wall 352. The upstream section 230 in this context may be referred to as an end wall 354 of the silencer 350.

[0072] The perforated wall 352 comprises a plurality of perforations or holes. The perforations allow fluid communication between the outlet portion 224 and the inside of the silencer 350. The perforated wall 352, as shown in Figure 3, is disposed parallel to the rotational axis R. In other words, the perforated wall extends perpendicularly away from the lower cabinet wall 226 until it connects with the separator 220. In this way, the silencer 350 is integrated with the structure of the fan coil unit 300.

[0073] The perforations of the perforated wall 352 may each have the same diameter of between 0.25 mm and 3 mm or they may each have a diameter between 0.25 mm and 3 mm. The perforated wall 352 has a thickness of between 0.25 mm and 2.5 mm or optionally between 0.5 mm and 1.5 mm. The perforated wall 352 may have a perforation rate of between 0.1% and 2.5%, or optionally between 0.5% and 1%. The perforated wall 352 may be constructed from metal, plastic, composite, or other appropriate material.

[0074] The silencer 350 of Figure 3 comprises a sound absorbing material 356 which is placed against the end wall 354. The sound absorbing material 356 is a porous material, for example it may be a foam material, a woven material or a felted material, mineral fibre or cotton felts. The sound absorbing material 356 has a density of between 10 kg/m^3 and 150 kg/m^3 or optionally between 20 kg/m^3 and 100 kg/m^3. The sound absorbing material 356 has a thickness between 1 cm and 15 cm or optionally between 2 cm and 5 cm.

[0075] The silencer 350 in Figure 3 is shown as comprising three cells: first cell 360a; second cell 360b; and third cell 360c. The first cell 360a has a cell cavity that is bounded by the perforated wall 352, the lower cabinet wall 226, the end wall 354, and a first cell separation plate 362. The second cell 360b has a cell cavity that is bounded by the perforated wall 352, the first cell separation plate 362, the end wall 354, and a second cell separation plate 364. The third cell 360c has a cell cavity that is bounded by the perforated wall 352, the second cell separation plate 364, and the end wall 354. In this way, the first cell 360a is adjacent to the second cell 360b, the second cell 360b is adjacent to the first cell 360a and the third cell 360c, and the third cell 360c is adjacent to the second cell 360b.

[0076] The first cell separation plate 362 and the second cell separation plate 364 extend from the perforated wall 352 to the end wall 354.

[0077] Each of the cell cavities of the cells 360a, 360b, 360c are in fluid communication with the outlet portion 224 via holes or perforations in the perforated wall 352.

[0078] In the fan coil unit 300 of Figure 3, the first cell 360a and the second cell 360b have trapezoidal cross-sections and the third cell 360c has a triangular cross-section. Therefore, the silencer 350 as shown in Figure 3 has a triangular cross-section overall. Each of the cells 360a, 360b, 360c have differing cell lengths, where the cell length is defined as being the length of the cell from the perforated wall 352 to the end wall 354 as measured from the midpoint of the height of the cell. That is, the first cell 360a has a cell length greater than the second cell 360b, which, in turn, has a cell length greater than the third cell 360c.

[0079] The cell lengths of each of the cells 360a, 360b, 360c are configured to resonate with frequencies in the range 200 Hz to 500 Hz. The presence of the sound absorbing material 356 in each of the cells 360a, 360b, 360c means that resonance in each of the cells is attenuated. In this way, frequencies in the range 200 Hz to 500 Hz which resonate in the cells 360a, 360b, 360c are attenuated, thereby reducing noise generated by the fan assembly 204 in this frequency range.

[0080] The cells 360a, 360b, 360c shown in Figure 3 are one type of layout possible for the cells of a silencer 350 in a fan coil unit 300. Figures 4A, 4B, and 4C depict other possible variations of cell structures in schematic views.

[0081] Figure 4A shows in detail a cell 400a being of the variation depicted in Figure 3. This cell 400a has a trapezoidal cross-section and comprises a cell cavity bound by a perforated wall 402a, an end wall 404a opposite to the perforated wall 402a, and two boundary walls 406a extending parallel to one another and between the perforated wall 402a and the end wall 404a. The cell 400a also comprises a sound absorbing material 408a disposed in the cell cavity, wherein the sound absorbing material 408a abuts the end wall 404a.

[0082] Placement of sound absorbing material 408a in the cell 400a improves the attenuation at the resonance frequency of the cell and widens the peak of maximum attenuation.

[0083] The cell 400a has a cell length configured to resonate with frequencies in the range 200 Hz to 500 Hz, as described above. The cell 400a has a cell length in the range of 1 cm to 15 cm.

[0084] Figure 4B shows a cell 400b which is a variant of the cell 400a in Figure 4A. This cell 400b has a trapezoidal cross-section and comprises a cell cavity bound by a perforated wall 402b, an end wall 404b opposite to the perforated wall 402b, and two boundary walls 406b extending parallel to one another and between the perforated wall 402b and the end wall 404b. The cell 400b also comprises a sound absorbing material 408b disposed in the cell cavity.

[0085] In this cell 400b, the sound absorbing material 408b does not abut the end wall 404b, nor does the sound absorbing material abut the perforated wall 402b. Instead, the sound absorbing material 408b is disposed in the cell cavity some distance from the end wall 404b such that there is a gap 410 between the end wall 404b and the sound absorbing material 408b. The length of the gap is in the range of 1 cm to 15 cm, or optionally in the range of 2 cm to 5 cm.

[0086] Figure 4C shows yet another variation of a cell 400c. This cell 400c has a trapezoidal cross-section and comprises a cell cavity bound by a perforated wall 402c, an end wall 404c opposite to the perforated wall 402c, and two boundary walls 406c extending parallel to one another and between the perforated wall 402c and the end wall 404c. The cell 400c also comprises a sound absorbing material 408c disposed in the cell cavity, wherein the sound absorbing material 408c abuts the end wall 404c.

[0087] The cell 400c further comprises a second perforated wall 412 disposed some distance between the perforated wall 402c and the end wall 404c and extending between the boundary walls 406c. The second perforated wall 412 divides the cell 400c into two sub-cells 414x and 414y, wherein each sub-cell 414x, 414y is in fluid communication with one another via the second perforated wall 412. Each sub-cell has a sub-cell length in the range of 1 cm to 15 cm.

[0088] Notably, one of the sub-cells 414x has a rectangular cross-section, while the other sub-cell 414y has a trapezoidal cross-section. Other alternatives are possible, where one or more of the sub-cells has a trapezoidal cross-section, a rectangular cross-section or a parallelogram-like cross-section. This will be at least partially dependent on the cross-section of the cell within which the sub-cells reside and also on the number of sub-cells present in the cell.

[0089] Further, only one sub-cell 414y comprises sound absorbing material 408c, while the other sub-cell 414x does not. Alternative arrangements may have sound absorbing material in each of the sub-cells, in a sub set of the sub-cells or in none of the sub-cells.

[0090] Figure 4D shows in detail a cell 400d being a variant of the cell 400a depicted in Figure 4A. This cell 400d, like the prior cell 400a, has a trapezoidal cross-section and comprises a cell cavity bound by a perforated wall 402d, an end wall 404d opposite to the perforated wall 402d, and two boundary walls 406d extending parallel to one another and between the perforated wall 402d and the end wall 404d.

[0091] The difference in this case is that the cell 400d does not comprise a sound absorbing material in the cell cavity. The cell 400d is capable of attenuating noise at frequencies for which it is configured.

[0092] Figures 5A and 5B depict alternate possible cross-sectional shapes that the cells described above may take. Figure 5A shows the trapezoidal shape common to the majority of the cells described above.

[0093] Figure 5B shows an alternative cross-sectional shape for a cell, wherein the cross-sectional shape is rectangular. In order to achieve this shape, the end wall of the cell would be parallel to the perforated wall of the cell. Any of the cells described above may be adapted to have a rectangular cross-section. A silencer for a fan coil unit may comprise cells having trapezoidal cross-sections, rectangular cross-sections, or a combination of both cross-sections.

[0094] Figures 6A and 6B depict variations of silencers having cells of only one cross-sectional type. That is, Figure 6A shows a silencer 600a having three cells each having a trapezoidal cross-section, whereas Figure 6B shows a silencer 600b having three cells each having a rectangular cross-section.

[0095] The silencer 350 shown in Figure 3 is integral with the walls of the cabinet 202 and the separator 220. The silencers shown in Figures 6A and 6B may also be integral with the fan coil unit 300 or they may be self-contained units that may be installed in existing fan coil units. That is, a self-contained silencer comprises one or more cells and a sound absorbing material and is bound by a perforated wall, an end wall, and one or more boundary walls.

[0096] An alternate fan coil unit 700 configuration is shown in Figure 7, wherein the fan coil unit 700 comprises the features of the fan coil unit 200 of Figure 2. The fan coil unit 700 shown in Figure 3 further comprises a silencer 750 disposed in the inlet portion 222 of the cabinet 202. The walls of the silencer 750 include a portion of the upper cabinet wall 228, a portion of the downstream section 232 of the separator 220, and a perforated wall

752. The downstream section 232 in this context may be referred to as an end wall 754 of the silencer 750.

[0097] The perforated wall 752 comprises a plurality of perforations or holes. The perforations allow fluid communication between the inlet portion 222 and the inside of the silencer 750. The perforated wall 752, as shown in Figure 7, is disposed parallel to the rotational axis R. In other words, the perforated wall extends perpendicularly away from the upper cabinet wall 228 until it connects with the separator 220. In this way, the silencer 750 is integrated with the structure of the fan coil unit 700.

[0098] The perforations of the perforated wall 752 may each have the same diameter of between 0.25 mm and 3 mm or they may each have a diameter between 0.25 mm and 3 mm. The perforated wall 752 has a thickness of between 0.25 mm and 2.5 mm or optionally between 0.5 mm and 1.5 mm. The perforated wall 752 may have a perforation rate of between 0.1% and 2.5%, or optionally between 0.5% and 1%. The perforated wall 752 may be constructed from metal, plastic, composite, or other appropriate material.

[0099] The silencer 750 comprises a sound absorbing material 756 which is placed against the end wall 754. The sound absorbing material 756 is a porous material, for example it may be a foam material, a woven material or a felted material, mineral fibre or cotton felts. The sound absorbing material 756 has a density of between 10 kg/m^3 and 150 kg/m^3 or optionally between 20 kg/m^3 and 100 kg/m^3. The sound absorbing material 756 has a thickness between 1 cm and 15 cm or optionally between 2 cm and 5 cm.

[0100] The silencer 750 in Figure 7 is shown as comprising two cells: first cell 760a and second cell 760b. The first cell 760a has a cell cavity that is bounded by the perforated wall 752, the upper cabinet wall 226, the end wall 754, and a cell separation plate 762. The second cell 760b has a cell cavity that is bounded by the perforated wall 752, the cell separation plate 762, and the end wall 754. In this way, the first cell 760a is adjacent to the second cell 760b.

[0101] The cell separation plate 762 extends from the perforated wall 752 to the end wall 754.

[0102] Each of the cell cavities of the cells 760a, 760b are in fluid communication with the inlet portion 222 via holes or perforations in the perforated wall 752.

[0103] In the fan coil unit 700 of Figure 7, the first cell 760a has a trapezoidal cross-section and the second cell 760b has a triangular cross-section. Therefore, the silencer 750 as shown in Figure 7 has a triangular cross-section overall. Each of the cells 760a, 760b have differing cell lengths, where the cell length is defined as being the length of the cell from the perforated wall 752 to the end wall 754. That is, the first cell 760a has a cell length greater than the second cell 760b.

[0104] The cell lengths of each of the cells 760a, 760b are configured to resonate with frequencies in the range 200 Hz to 500 Hz. The presence of the sound absorbing material 756 in each of the cells 760a, 760b means that resonance in each of the cells is attenuated. In this way, frequencies in the range 200 Hz to 500 Hz which resonate in the cells 760a, 760b are attenuated, thereby reducing noise generated by the fan assembly 204 in this frequency range.

[0105] Figure 8 shows a schematic view of a variation of a fan coil unit 800 comprising a first silencer 850a in the outlet portion 224 and a second silencer 850b in the inlet portion 222. The first silencer 850a is shown in Figure 8 to comprise the same features of the silencer 350 described in relation to Figure 3. The second silencer 850b is shown in Figure 8 to comprise the same features of the silencer 750 described in relation to Figure 7.

[0106] In this way, the fan coil unit 800 comprises two silencers 850a, 850b which are configured to reduce noise from the fan assembly 204 in the frequency range 200 Hz to 500 Hz. The cells in the first silencer 850a may have cell lengths configured to attenuate noise at the same or different frequencies from the cells in the second silencer 850b.

Claims

1. A fan coil unit for a heating, ventilation, and air conditioning (HVAC) system, the fan coil unit comprising:
   a cabinet having an inlet and an outlet, the cabinet housing:

   a heat exchanger assembly,
   a fan assembly,
   a separator extending across the fan assembly such that the cabinet is divided into an inlet portion and an outlet portion, with the fan assembly being for generating a pressure difference between the inlet portion and the outlet portion, and
   a silencer configured to reduce noise generated in the fan coil unit during use of the fan assembly to move air between the inlet and the outlet of the cabinet, the silencer comprising:
   one or more cells, wherein each cell comprises an end wall, and a perforated wall spaced apart from the end wall.

2. The fan coil unit of claim 1, wherein the silencer further comprises a sound absorbing material occupying at least some of the space between the perforated wall and the end wall of at least one of the cells.

3. The fan coil unit of claim 1 or 2, wherein the cabinet further comprises an inlet end proximate to the inlet and an outlet end proximate to the outlet, and wherein the fan assembly comprises a fan housing and an impeller, wherein the impeller is located in the fan housing and is configured to rotate about an axis of rotation, wherein the axis of rotation is perpendicular to a general flow direction, the general flow direction

being from the inlet end to the outlet end.

4. The fan coil unit of claim 3, wherein the fan assembly is a plug fan.

5. The fan coil unit of claim 3 or 4, wherein the impeller is configured to rotate at speeds in the range 1500 rpm to 3500 rpm when in use.

6. The fan coil unit of any preceding claim, wherein each of the one or more cells has a cell length, wherein each of the one or more cells has a triangular, trapezoidal or rectangular cross-section along their respective cell lengths.

7. The fan coil unit of any preceding claim, wherein each of the one or more cells is bounded on a first end by the perforated wall and on a second end by the silencer end wall, and the cell length of each cell hence extends between the perforated wall and the end wall.

8. The fan coil unit of any preceding claim, wherein at least one of the one or more cells comprises a plurality of sub-cells.

9. The fan coil unit of any preceding claim, wherein the silencer comprises two or more cells, wherein each cell has a different cell length from one another.

10. The fan coil unit of any preceding claim, wherein the silencer comprises a gap between the perforated wall and the sound absorbing material and a gap between the sound absorbing material and the silencer end wall.

11. The fan coil unit of any preceding claim, wherein the sound absorbing material abuts the silencer end wall.

12. The fan coil unit of any preceding claim, wherein the sound absorbing material has a thickness between 1 cm and 15 cm.

13. The fan coil unit of any preceding claim, wherein the perforated wall has a perforation rate of between 0.1% and 2.5%.

14. The fan coil unit of any preceding claim, wherein the silencer is located in the inlet portion or in the outlet portion.

15. A method for noise reduction in a fan coil unit for a heating, ventilation, and air conditioning (HVAC) system, the fan coil unit comprising:

a cabinet having an inlet and an outlet, the cabinet housing:

a heat exchanger assembly,
a fan assembly, and
a separator extending across the fan assembly such that the cabinet is divided into an inlet portion and an outlet portion, with the fan assembly being for generating a pressure difference between the inlet portion and the outlet portion,

the method comprising providing a silencer configured to reduce noise generated in the fan coil unit during use of the fan assembly to move air between the inlet and the outlet of the cabinet, the silencer comprising:
one or more cells, wherein each cell comprises an end wall, and a perforated wall spaced apart from the end wall.

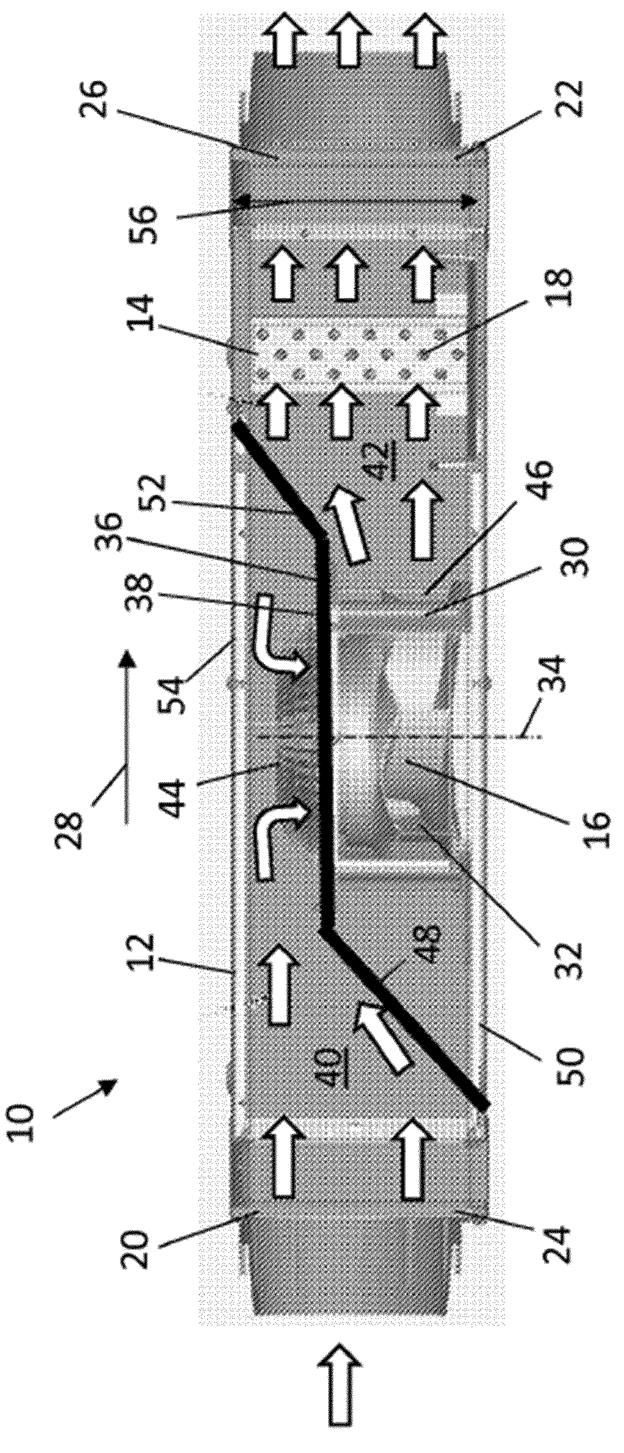

Figure 1

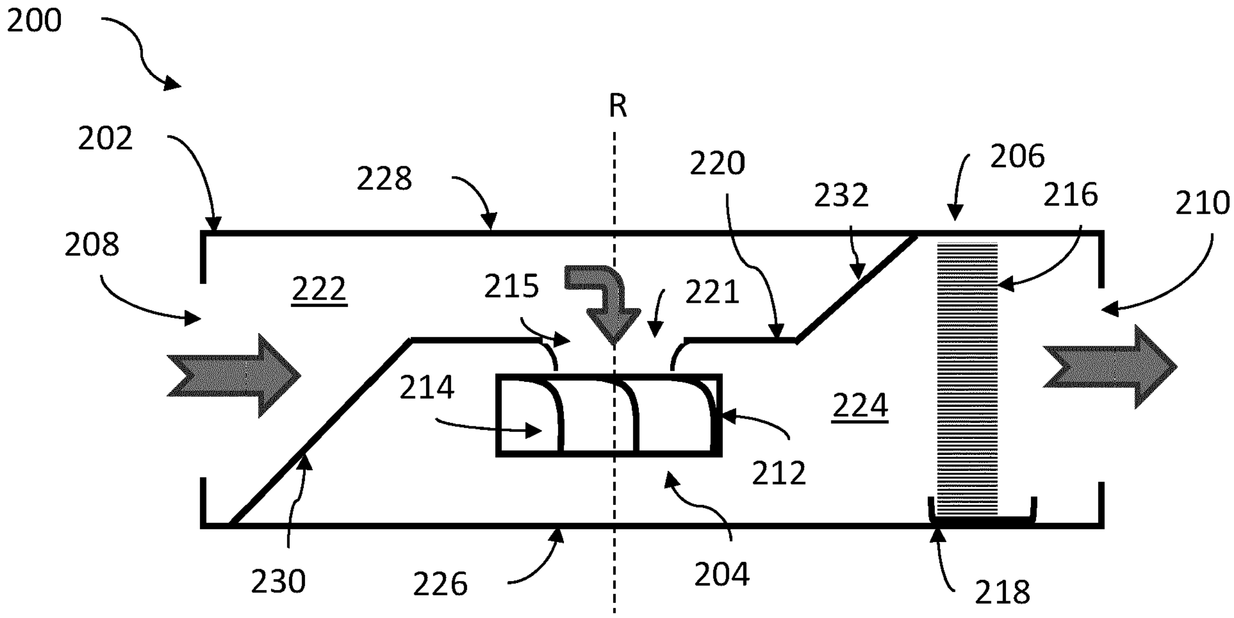

Figure 2

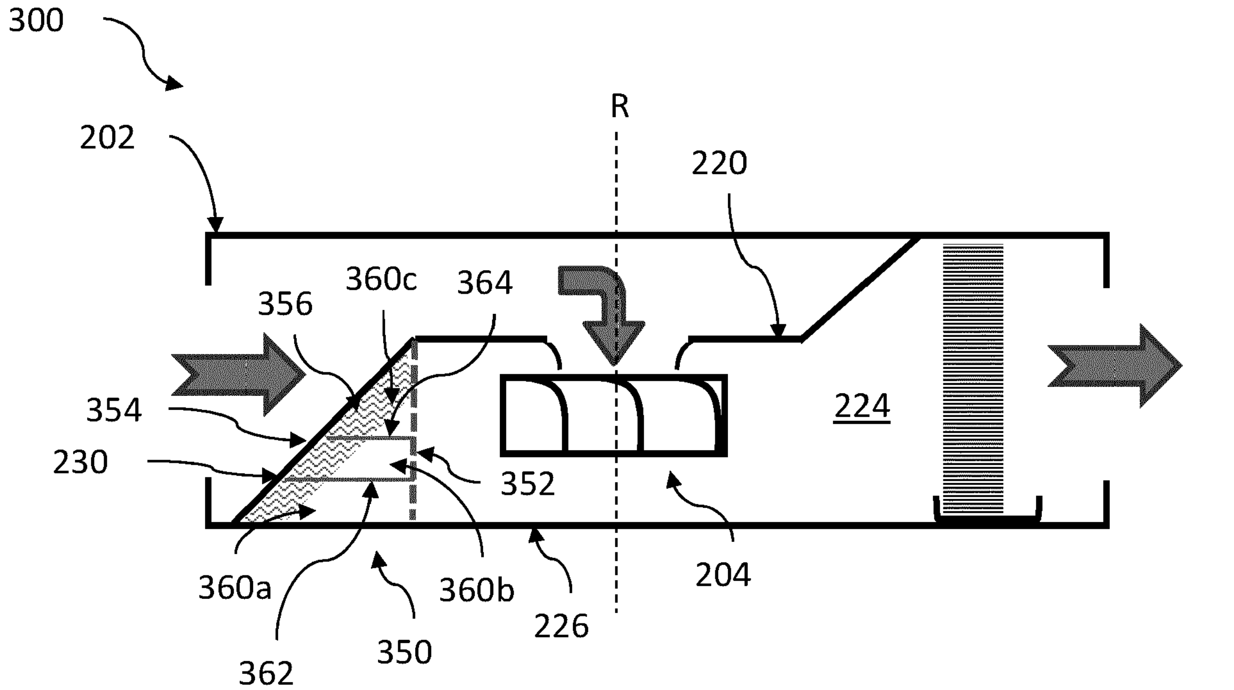

Figure 3

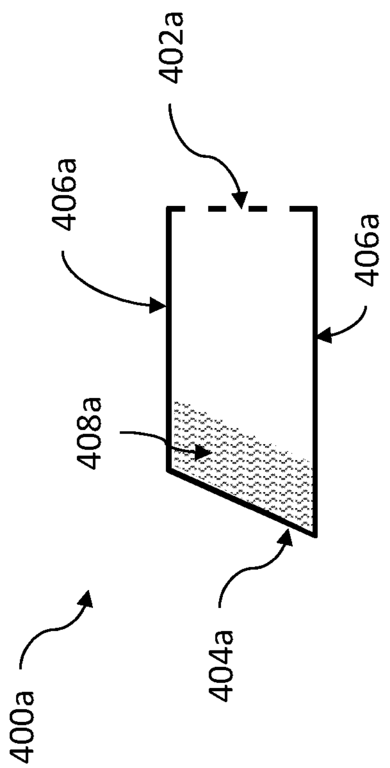

Figure 4A

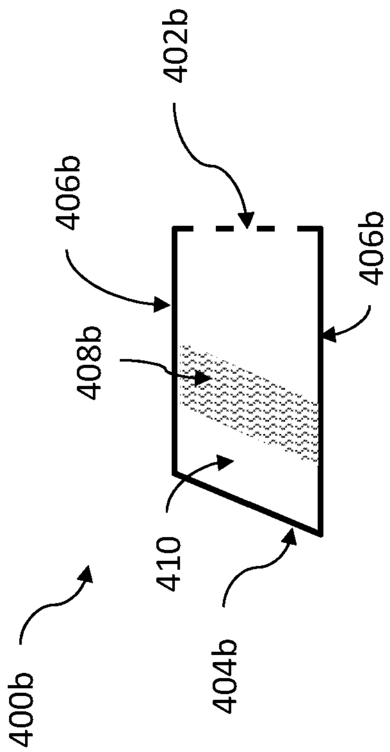

Figure 4B

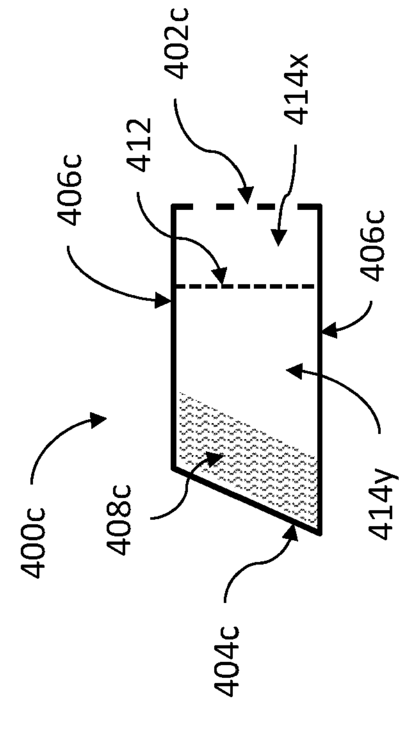

Figure 4C

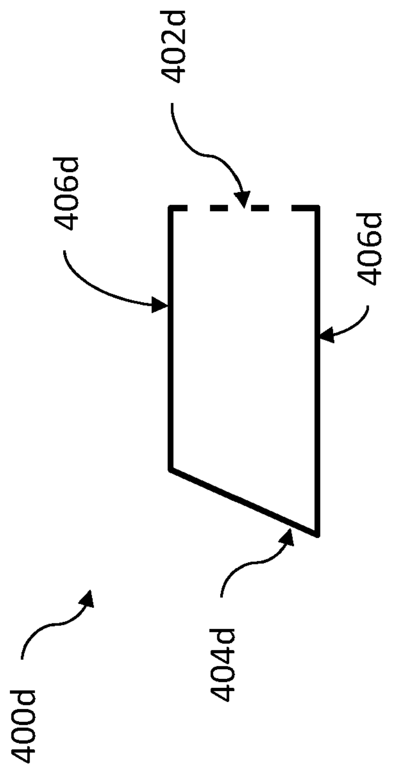

Figure 4D

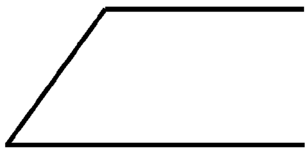

Figure 5A

Figure 5B

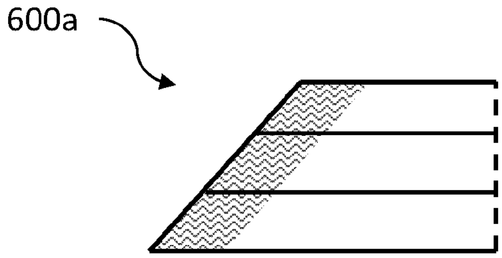

Figure 6A

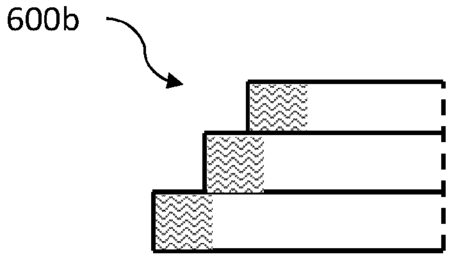

Figure 6B

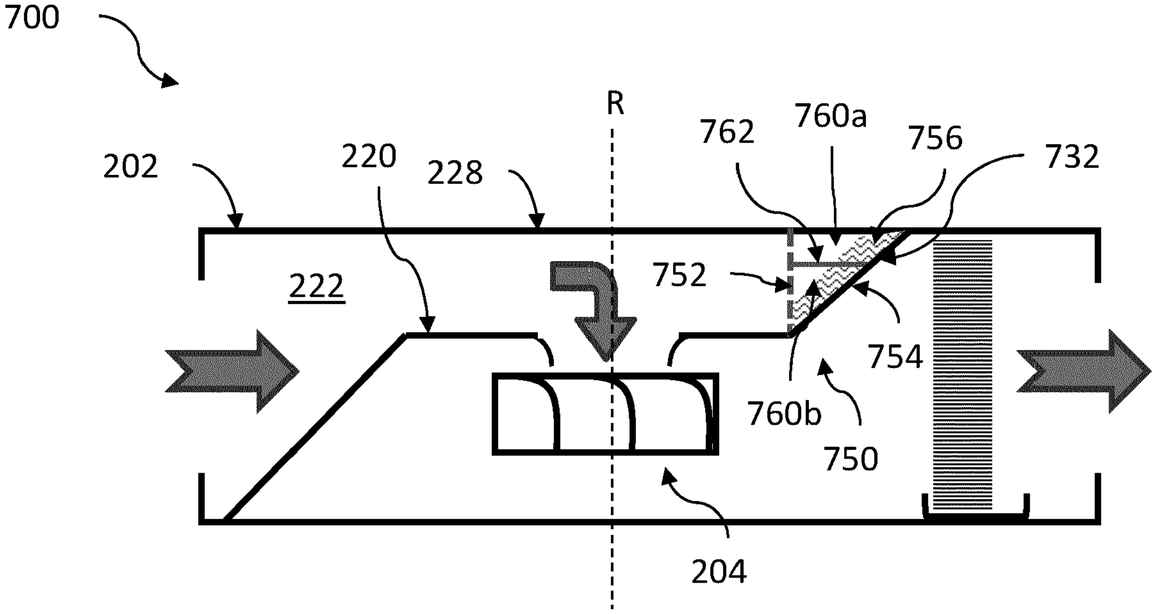

Figure 7

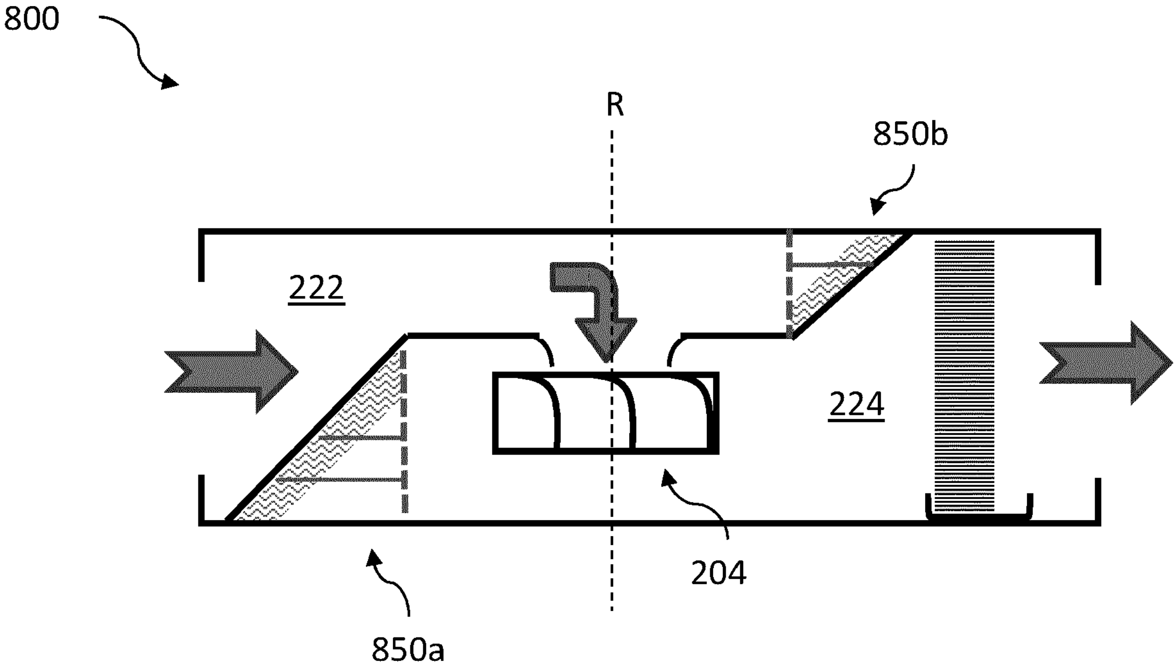

Figure 8

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EUROPEAN SEARCH REPORT

Application Number
EP 20 17 3180

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JP H05 71752 A (SHARP KK) 23 March 1993 (1993-03-23) * paragraphs [0001], [0008], [0013] * * figure 1 * -----	1-15	INV. F04D25/08 F04D29/42 F04D29/66
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A	EP 1 980 755 A2 (KOBE STEEL LTD [JP]) 15 October 2008 (2008-10-15) * paragraphs [0016] - [0021], [0043] * * figures 3, 6, 7 * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC): F04D F24F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	8 October 2020	De Tobel, David

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

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