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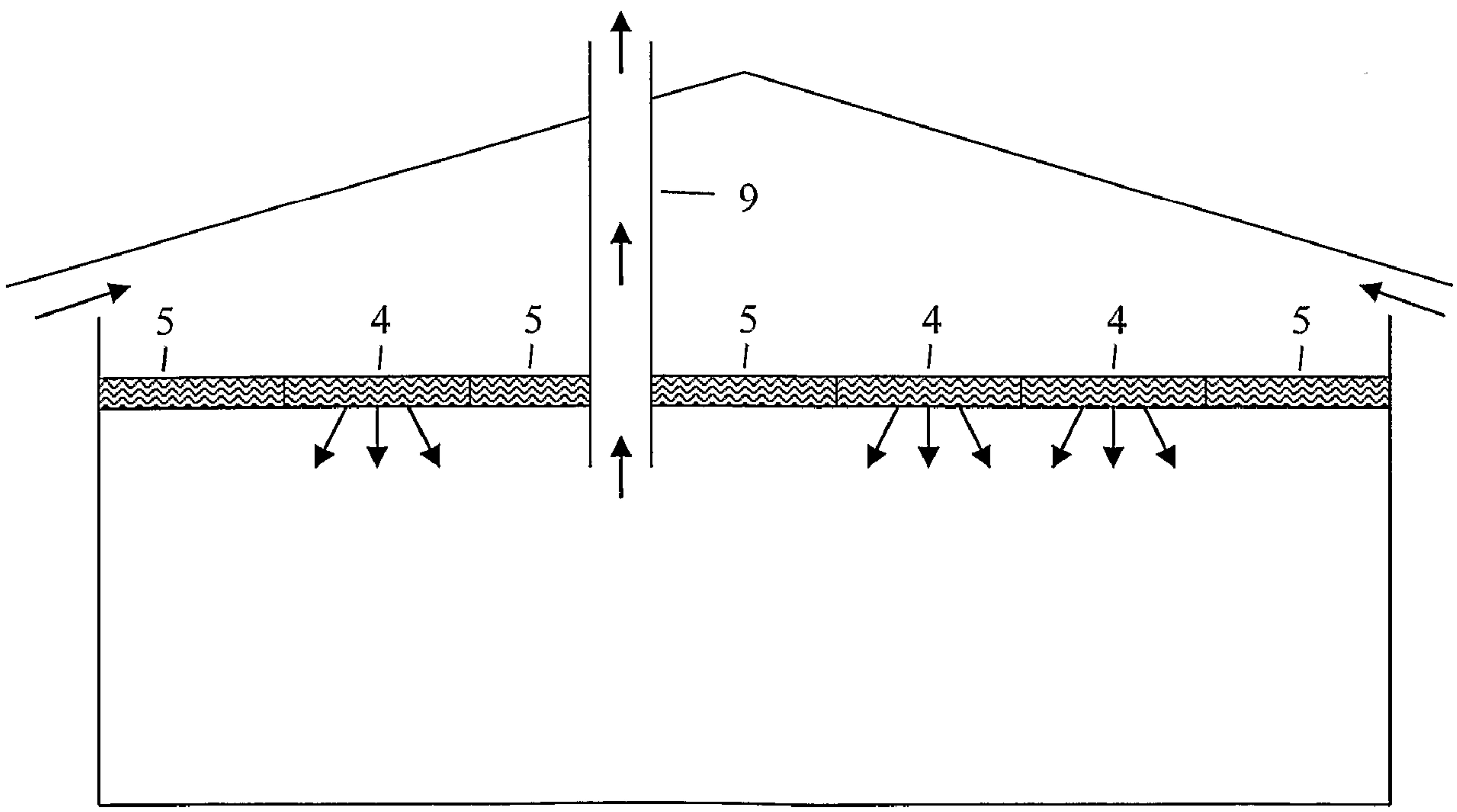
(54) Title: A SET OF CEILING PANELS, A CEILING FOR VENTILATION AND A METHOD FOR MANUFACTURING THE SET OF CEILING PANELS



(57) Abrégé/Abstract:
The invention is related to a set of ceiling panels to be used in a ceiling in a room where the ventilation air for the room is passing through selected parts of the ceiling. The set of ceiling panels comprises separate ceiling panels made of mineral wool. One first portion of the ceiling panels constituting first ceiling panels (4) having a first air flow resistance, and at least one second portion of the ceiling panels constituting second ceiling panels (5) having a second air flow resistance. The invention is also related to a ceiling in a room where the ventilation air for the room is passing through selected parts of the ceiling. Furthermore, the invention is related to a method of manufacturing a set of ceiling panels where the covering layer of the first ceiling panels (4) is added to the surface of the mineral wool before the curing oven and the covering layer of the second ceiling panels (5) is added to the surface of the mineral wool after the curing oven.

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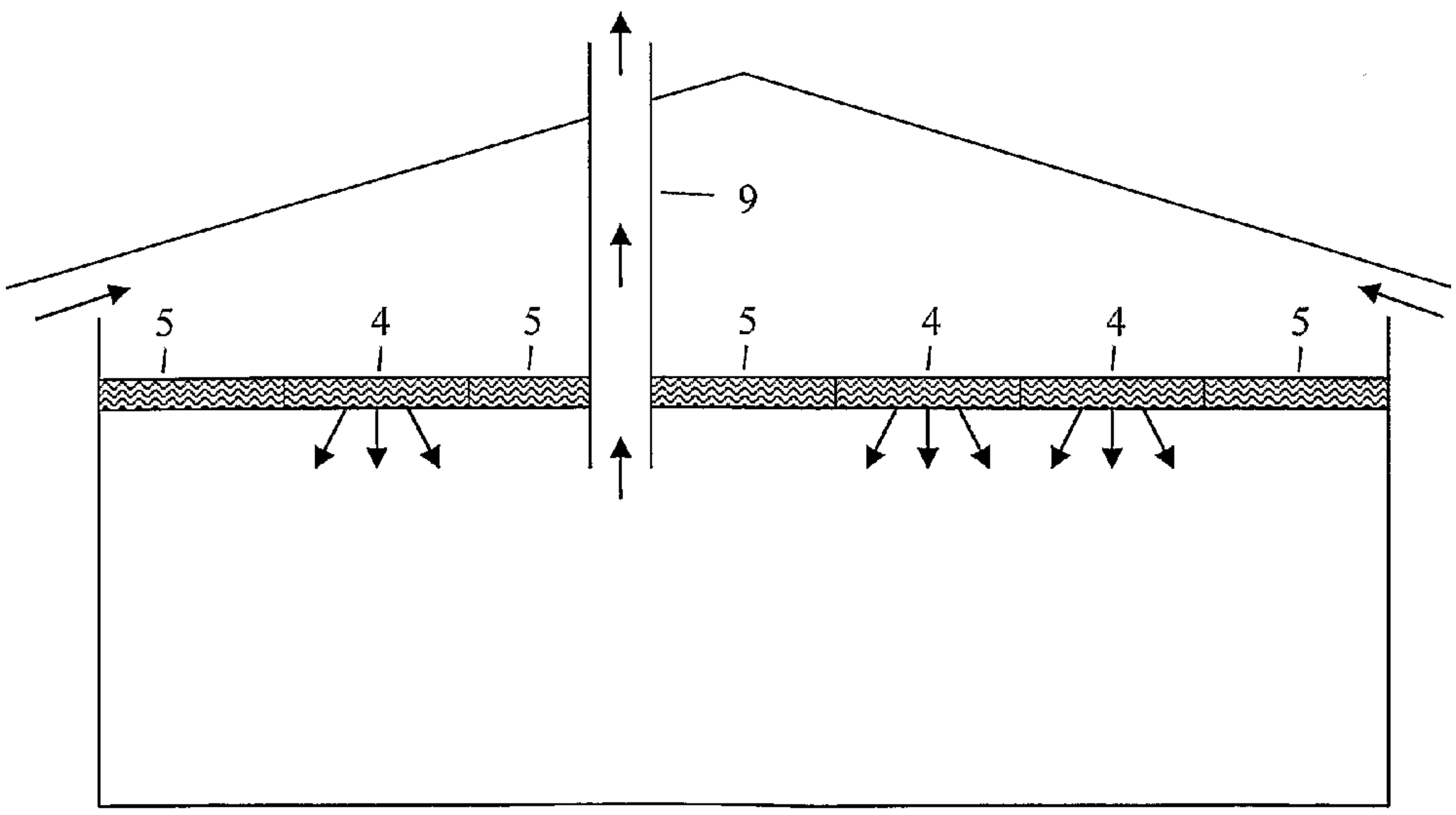
(54) Title: A SET OF CEILING PANELS, A CEILING FOR VENTILATION AND A METHOD FOR MANUFACTURING THE SET OF CEILING PANELS



(57) Abstract: The invention is related to a set of ceiling panels to be used in a ceiling in a room where the ventilation air for the room is passing through selected parts of the ceiling. The set of ceiling panels comprises separate ceiling panels made of mineral wool. One first portion of the ceiling panels constituting first ceiling panels (4) having a first air flow resistance, and at least one second portion of the ceiling panels constituting second ceiling panels (5) having a second air flow resistance. The invention is also related to a ceiling in a room where the ventilation air for the room is passing through selected parts of the ceiling. Furthermore, the invention is related to a method of manufacturing a set of ceiling panels where the covering layer of the first ceiling panels (4) is added to the surface of the mineral wool before the curing oven and the covering layer of the second ceiling panels (5) is added to the surface of the mineral wool after the curing oven.

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A set of ceiling panels, a ceiling for ventilation and a method for manufacturing the set of ceiling panels

The invention relates to a set of ceiling panels and a ceiling system for ventilating a room in which the ventilation air is directed to the needed zones in the room through the ceiling. The different ceiling panels in the ceiling have a difference in the air flow resistance. Above the ceiling panels is a higher air pressure than below, forcing the air to flow through the ceiling panels with a relatively low air flow resistance. Thereby the ventilation air can be guided to zones where needed and avoided in zones where the draught from a high ventilation rate is not wanted.

A further advantage of entering the ventilation air through the ceiling panels is the obtained heat exchanging effect meaning that during the cold season, the mineral fibre ceiling panels will be heated from the heat in the room, mainly by radiant heating. Thereby, the ventilation air passing the ceiling panels will be slightly preheated reducing the need for heating of the room or heating of the ventilation air.

From EP 294 909 B1 a ceiling for livestock sheds is known. In this ceiling the ventilation air passes through a layer of e.g. stone wool placed on a supporting body with perforations. A pressure difference forces the air through the ceiling, and the ceiling has the advantage of distributing the air. However, this is not disclosing the idea of using the ceiling for guiding ventilation air to areas where needed.

The basic principle is known from WO 02/40926 where the ceiling plates are made of wood fibres mixed with cement. In active areas where ventilation air is intended to penetrate, nothing else is done. In passive areas where ventilation air is not intended to penetrate, stone wool plates with low air permeability are placed above the fibre wood plates. This means that two different layers of ceiling plates have to be arranged and installed.

A similar solution for piggeries is also based on wood fibre plates above which a vapour and diffusion proof layer is placed in the area where ventilation air is not needed. This layer may be a plastic foil. On top of this layer mineral wool insulation is placed. However, there will be a risk of cold air leaking to the backside of this vapour proof layer. This may cause condensation of humidity from the room and thereby humidity problems in the ceiling.

Also from clean room purposes the principle is known. However, the high demands for removing all particulate matter from the air mean that these solutions are very complex and too expensive for purposes not having these demands.

The problem with the known solutions is that they are complicated and thereby expensive to install, especially because several layers have to be installed. It is also complicated to change the ventilation set-up of the ceiling at a later time, so that ventilation air is supplied to new areas.

This problem has been solved by a solution according to the invention as described in the characterizing part of claim 1. It has been found that it is possible to manufacture almost identical ceiling tiles, panels or plates (hereafter all referred to as ceiling panels) of mineral wool with a cover layer, where the only difference is their air flow resistance. The difference in air flow resistance may be achieved in different ways according to the different embodiments of the invention. The set of ceiling panels according to the invention is prepared for being placed in one layer and distributing the air supply to a room by having different air flow resistances. The ceiling according to the invention will, therefore, also comprise one layer where ceiling panels having a difference in their air flow resistance, are placed next to each other within this one layer.

Compared to the prior art this invention has the advantage of being faster to install, having the flexibility that the areas with ventilation air may be moved as the need changes, and the risk of cold air leaking to the backside of a vapour membrane is removed.

The ceiling panels may be made of mineral wool such as glass wool or stone wool. This will also give the advantage of having better fire properties than e.g. wood fibres. Especially stone wool provides very good fire properties. Further advantageous of the ceiling panels are that these will be sound absorbing, thereby improving the acoustics of the room, and furthermore the ceiling will improve the heat insulation of the room.

In order to provide space for a closed room with some air pressure above the ceiling, the ceiling panels are suspended from the basic fixed ceiling, or from the beams limiting the room upwards. These beams are typically the lower parts of the rafter (i.e. foot of the rafter). The ceiling panels are installed in a supporting grid fixed to the basic ceiling. The supporting grid may comprise T-profiles turned upside down. In one direction these profiles are fixed directly to the basic ceiling. These profiles are the carrier profiles. In a direction perpendicular to this, the profiles are fixed to the carrier profiles. These profiles are the supporting profiles. There must be sufficient space above the ceiling panels for forming a room where the air can flow without any essential pressure drop from one end of this room to the other.

The ceiling panels may also be installed in other types of grids suspended from e.g. the rafters. In one type of grid the carrier profiles would be replaced by wooden laths secured to the feet of the rafters and extending substantially perpendicular to the feet of the rafters. These laths could also be provided with the T-shape (turned upside down), in order to offer sufficient support for the ceiling panels. This T-shape of the laths may be achieved by combining two laths. These laths may be combined with the T-shaped supporting profiles, preferably of metal, described above. These supporting profiles would be fastened directly to the laths extending perpendicular to the laths, and thereby extending parallel to the feet of the rafters.

The support of the ceiling panels on all four sides has several purposes. One purpose is mechanical stability i.e. make sure that the ceiling panels will not bend. A second purpose is to ensure a relatively air tight connection between two neighbouring ceiling panels. Otherwise, it will be difficult to control the airflow through ceiling panels if there are leakages between ceiling panels. A third purpose is to avoid that dust and fibres from the ceiling panels is entering the room.

One advantage of this last embodiment of the suspension of the ceiling panels, is that it reduces the cold bridging effect. This is due to the fact that laths are secured directly to the feet of the rafters, e.g by screws or nails. It will be possible to arrange the suspension such that no metal parts penetrate from the cold air above the ceiling panels and through the ceiling panels to a metal T-profile extending to the downwards surface of the suspended ceiling. Such penetrating metal parts could be metal fasteners for carrying the T-profiles. One problem with such cold bridging is condensation of humidity to the T-profiles.

Along the walls of the room a special L-shaped profile is used. Between this profile and the wall a joint filler material is placed. This may be a rubber based material or a flexible or resilient plastic based material. The purpose of the joint filler is to avoid leaks through which the air can penetrate. Joint filler material may also be applied between the T-profiles and the ceiling panels. If this is necessary it would be time saving to have these pre-mounted to the profiles. However, typically it will not be necessary as the ceiling panels will have an oversize of a few millimetres, typically 2 – 4 mm, so that they will fit closely to the profiles.

The ceiling panels will typically be rectangular and have a length of 800 mm to 1200 mm, preferably around 1000 mm. The width will be between 400 mm to 800 mm, preferably around 600 mm. The thickness will be 40 mm to 150 mm, preferably 50 mm to 100 mm, and even more preferably 60 mm to 80 mm. The thickness will depend on the density and on the maximum acceptable deflection of the panels. Furthermore, the thickness together with the density will influence the air flow resistance considerably.

The ceiling plates may have different densities depending on whether they are open to air diffusion or not, and whether the ceiling is for e.g. livestock sheds, industrial buildings or office environments.

When the application is for livestock sheds, e.g. piggery and cow houses the ceiling panels open for diffusion will have densities in the range 20 – 45 kg/m^3, preferably 25 – 35 kg/m^3, and even more preferably around 30 kg/m^3. The ceiling panels closed for air diffusion will have densities in the range 45 – 150 kg/m^3, preferably 50 – 120 kg/m^3, and even more preferably around 60 – 100 kg/m^3.

When the application is for office environments the density of the ceiling plates will be in the range 40 – 200 kg/m^3, preferably 60 – 150 kg/m^3. This higher density is due to the fact that the demands for the lower surface of the ceiling being plane are higher. This is more easily achieved with a higher density. Furthermore, the grid system used in office environments will often be covered or hidden by the ceiling panels. This is achieved by providing the ceiling panels with special edges concealing the horizontally protruding part of the upside down T-profile. An example is described in detail in EP 1 261 782 B1, and the present invention could easily be combined with the ceiling system disclosed in EP 1 261 782 B1. In order for these edges concealing the grid to have sufficient strength, a higher density of the ceiling boards is needed.

Typically the ceiling panels having a low air flow resistance, so that ventilation air will pass through these, will cover at least 60 % of the area with ceiling panels, preferably at least 70 % and even more preferably at least 80 %. The advantage of blowing in ventilation air over a large area compared to smaller standard air inlets, is that, at a given ventilation rate, the air velocity will be lower. Thereby the possible discomfort due to draught is reduced. Such draught can be a problem especially in livestock sheds and piggeries where the air exchange rate is up to 40 – 60 per hour [h^{-1}].

In some cases it may be necessary to secure the ceiling panels to the carrier and supporting profiles by e.g. nails or screws in order to avoid that a momentary over pressure in the room compared to the pressure above the ceiling could lift the ceiling panels.

The air flow resistance of a ceiling panel is often measured as the volume of air per hour passing a square meter of the panel at a given pressure difference. This value may be converted to the air flow resistance having the unit [Pascal x seconds / meter]. By dividing by the thickness of the ceiling panel the air flow resistance can be normalised to a value independent of the thickness. This is, however, not relevant to do here because for the ceiling panel with a high air flow resistance, the major part of the pressure drop will often be caused by the cover layer and the gluing used for fixing this layer.

The ceiling panels could be made of any porous material open to air diffusion. The material will typically be a fibrous material preferably mineral wool. The mineral wool used for the ceiling boards according to the invention is manufactured by adding a melt of stone or glass to the surface of a spinning wheel or to a spinning cup with fine holes. The spinning process will create mineral fibres which are blown away from the spinner and mixed with droplets of an uncured binder. This mixture is transported by air to a conveyer belt. The fibres will deposit to the moving belt building up a layer of fibres, i.e. forming a fibre web.

The fibre web may be processed in different ways, e.g. compression in either the direction of the movement of the conveyer belt or in the height direction perpendicular to the belt and the major surface of the fibre web, depending on the properties needed in the final product. After such processing the fibre web enters the curing oven in which the binder is cured. This will give the mineral wool product the necessary strength and ensures that the fibrous material will not disintegrate.

The finished ceiling panels should not be compressed for transport purposes as this might affect their air flow resistance. However, minor compressions during installation will not have any effect.

Thus, the invention covers a set of ceiling panels comprising ceiling panels of mineral wool which ceiling panels have at least two different air flow resistances. The air flow resistance of one first type of panel having a relatively low air flow resistance is in the range 100 – 1100 Pa·s/m preferably in the range 300 – 900 Pa·s/m, and even more preferably 400 – 800 Pa·s/m. The last range is equivalent to an air flow range per square meter of 180 – 360 m^3/h per m^2 at a pressure difference of 40 Pa.

The air flow resistance of one second type of panel having a relatively high air flow resistance of at least 1400 Pa·s/m, preferably at least 2800 Pa·s/m, and even more preferably at least 5700 Pa·s/m. The 5740 Pa·s/m is equivalent to an air flow range per square meter of approximately 25 m^3/h per m^2 at a pressure difference of 40 Pa.

The ceiling panels with the relatively highest air flow resistance should preferably have an air flow resistance which is at least a factor of two higher, preferably at least a factor of three higher, and even more preferably at least a factor of four higher than the ceiling panels with the relatively lower air flow resistance.

In a first embodiment of the invention the difference in the air flow resistance of the two types of ceiling panels needed for the ventilating ceiling is obtained by the way the cover layer or the fleece layer, e.g. a glass fibre fleece, is attached to the surface of the mineral wool ceiling panel. For the panels with a relatively low air flow resistance the covering layer of the ceiling panels have been bonded to the mineral wool by placing it on the surface of the mineral wool before the curing oven used to cure the binder added to the mineral wool. Due to the compression of the mineral wool at the entrance of the curing oven this will bring the fleece layer in close contact with the uncured binder sticking to the fibres, and when the binder is cured, the fleece will be bonded to the mineral wool fibres. This will maintain an open structure between the mineral fibres in the insulation and the fleece layer. Thereby the air flow resistance will be kept relatively low. For the boards with a relatively high air flow resistance the covering layer (e.g. a fleece) of the ceiling panels have been bonded to the mineral wool by placing it on the surface of the mineral wool after the binder has been cured in the curing oven. In order to attach the cover layer to the mineral wool a further adhesive have to be added. This adhesive (e.g. in the form of a hotmelt) will penetrate slightly into the mineral fibre material. Depending on the viscosity of the adhesive when applied it will also form a film layer on the surface of the mineral fibre material. The covering layer is attached to the adhesive. The film layer, also when dried, will have a much higher resistance against air diffusion than the mineral fibre material or the fleece layer.

For office environments where the visual appearance of the ceilings is important ceiling panels of higher density are used. Therefore, the air flow resistance in the mineral wool will be more significant. Furthermore, it is also common to apply paint to the surface covering fleece on such ceiling panels. This will also increase the air flow resistance. However, it might still be possible to manufacture such ceiling panels with different air flow resistances.

Usually, ceiling panels for office environments have been provided with a paint layer. This paint is applied on the production line after mounting of the fleece. However, such application of paint will tend to form a very dense surface with a high air flow resistance. Therefore, it is preferred to apply a pre-painted fleece layer (e.g. spray painted) in order to obtain a more open surface with a low air flow resistance.

In a second embodiment of the invention the difference in the air flow resistance of the two types of ceiling panels needed for the ventilating ceiling is obtained by making a number of holes from the back side of the ceiling panel, preferably penetrating more than half the total thickness of the ceiling panel, but not penetrating all the way through the panel.

In another embodiment of the invention the difference in the air flow resistance of the two types of ceiling panels needed for the ventilating ceiling is obtained by having first ceiling panels made from mineral fibre material having a fibre orientation substantially perpendicular to the two major surfaces of the first ceiling panels and by having second ceiling panels made from mineral fibre material having a fibre orientation substantially parallel to the two major surfaces of the second ceiling panels. The orientation of the fibres in the ceiling panels will obviously influence the air flow resistance. Fibres oriented perpendicular to the direction of the air flow (i.e. fibres parallel to the major surfaces of the ceiling panel) will result in a higher resistance to the air flow. Fibres oriented in the flow direction (i.e. perpendicular to the major surfaces of the ceiling panels) will result in a lower air flow resistance. Methods for manipulating the fibre orientation during production are by compressing the fibre web in different directions, or by cutting the fibre web into lamellas rotating each 90 degrees and gluing these together, or by the method described in EP 741 827 B1 (especially the method mentioned in point e in claim 1).

The invention is illustrated in the drawings, which are examples of the invention.

Figure 1 illustrates a ceiling panel according to the invention.

Figure 2a and 2b illustrates two different ceiling panels according to one embodiment of the invention.

Figure 3 illustrates part of a ceiling with profiles and ceiling panels.

Figure 4 illustrates a cross sectional view of a ceiling with ventilation according to the invention.

Figure 5 illustrates an embodiment of the invention where laths are applied for the support of ceiling panels.

Figure 6 illustrates the embodiment of figure 5 in the sectional view A-A

Figure 7 illustrates an embodiment where the ceiling tiles are arranged between the rafters.

Figure 1 shows a single ceiling panel (1) made of a board of porous insulation material (2) with a covering layer (3) e.g. a non-woven glass fibre fleece.

Figure 2a shows a side view of a ceiling panel (4) with a relatively low air flow resistance, where the cover layer (3') is attached only by us of the binder holding the fibres together.

Figure 2b shows a side view of a ceiling panel (5) with a relatively high air flow resistance, where the cover layer (3") is attached by the application of a further adhesive (6).

Figure 3 shows part of an installed ceiling according to the invention where T-profiles (7) carrying the suspended ceiling are attached to e.g. beams or rafters (not shown) by the use of fasteners (8). Supporting T-profiles (not shown) are arranged perpendicular to the carrier T-profiles, so that each ceiling panel (1) is supported along all four edges.

Figure 4 shows a building with an installed set of ceiling panels (4 and 5) according to the invention. Air is drawn out of the room by a ventilation system (9). This will force air to flow through the ceiling panels (4) having a low air flow resistance. It is seen from the figure that ceiling panels (4) having a low air flow resistance, and ceiling panels (5) having a high air flow resistance are placed next to each other in the same one layer.

Figure 5 - 7 shows embodiments of the invention where laths, preferably of wood, have been applied in the grid or support for the ceiling tiles.

Figure 5 and 6 illustrates an embodiment where first laths (11) have been secured directly to the feet of the rafters (10). Second laths (12) are secured to the first laths (11). The second laths (12) are, as seen in figure 6, wider than the first lath, such that protrusions (14) are formed with each set of a first and a second lath (11 and 12). These protrusions (14) are used for supporting a ceiling panel (1). As illustrated in figure 6 supporting T-profiles (20) are arranged between said sets of first and second laths in order to support the ceiling panels (1) on all four edges. The ceiling panels will thus be arranged between the first laths (11).

If the ceiling tiles are sufficiently rigid, it is possible to replace the supporting T-profiles (20) with a tape, e.g. a self adhesive duct tape. A tape will not offer mechanical support for the ceiling panels (1) but it may provide an air tight connection between two neighbouring ceiling panels, as well as preventing dust and fibres from entering the room.

Figure 5 also illustrates one way of arranging the transition from the ceiling to the walls of the room. This is done by pacing a third lath (15) below and perpendicular to the first lath (11) along the wall of the room. This third lath (15) will also support the ceiling panels (1), and thereby replace a supporting T-Profile (20).

Figure 6 also illustrates one way to secure a first lath (11) to a foot of a rafter (10) without getting any cold-bridging. This is only illustrated for the right first lath 11 in figure 6, where fasteners (18), e.g. screws or nails extend from the first lath (11) into the foot of the rafter (10) in an inclined angle, such that it may be entered through a side surface (19) of the first lath (11) and into the foot of the rafter, such that it will not form any cold bridging.

Figure 7 illustrates a further embodiment where the first lath (11) is omitted and the second lath (12) is placed directly on the foot of the rafter (10). This means that the ceiling panels (1) as well as the supporting T-profiles (20) are placed in the space between the feet of the rafters (10). This will raise the ceiling level in the room.

An example of a ceiling according to the invention is for a livestock shed, e.g. a piggery. In a piggery the air exchange rate may be up to 40 – 60 h^{-1}. Such a high level can easily cause draught, and in some zones this draught is unwanted. In this example carrier T-profiles (7) for holding the ceiling panels is fastened to the lower part of the rafters or to the beams delimiting the room upwards by the use of special fasteners (8). These are placed along a straight line. The carrier T-profile (7) has a length of 5 meters and when longer distances are needed the carrier T-profiles (7) are connected to each other by clips. Supporting T-profiles are mounted perpendicular to the carrier T-profiles (7) and are mounted between two carrier T-profiles (7) and have a length equivalent to the distance between the carrier T-profiles (7). The ceiling panels (4, 5) are placed between the carrier profiles (7), and supporting T-profiles are placed between the ceiling panels (4, 5), so that each ceiling panel (4, 5) is supported along all four edges. The ceiling panels (4, 5) preferably have a size of 600 mm x 997 mm and a thickness of 75 mm. The ceiling panels (4) with the low air flow resistance (i.e. the panels through which the major part of ventilation air will pass) have a density of 30 kg/m^3, and the ceiling panels (5) with the high air flow resistance have a density of 60 kg/m^3. Both types of ceiling panels (4, 5) are covered with a glass fleece (3', 3") on their front, i.e. the major surface visible from the room. For the ceiling panels (4) with the low air flow resistance the fleece (3') is bonded by the binder holding the fibrous mineral wool material together. For the ceiling panels (5) with the high air flow resistance the fleece (3") is added after curing the binder, and therefore an adhesive (6) is used to secure the fleece to the panel surface. This adhesive (6) will tend to form a film layer increasing the air flow resistance of the ceiling panel (5) considerably. Both types of ceiling panels (4, 5) look identical when installed and viewed from the room.

Claims

1. A set of ceiling panels to be used in a ceiling in a room where the ventilation air for the room is passing through selected parts of the ceiling, *characterised in* that said set is prepared for being arranged in one layer and in that said set comprises separate ceiling panels made of mineral wool, one first portion of the ceiling panels constituting first ceiling panels (4) having a first air flow resistance and at least one second portion of the ceiling panels constituting second ceiling panels (5) having a second air flow resistance.

2. A set of ceiling panels according to claim 1 *characterised in* that the majority of the ceiling panels have a covering layer (3) on the surface pointing towards the room.

3. A set of ceiling panels according to claim 1 or 2 *characterised in* that the second air flow resistance of the second ceiling panels (5) is at least a factor of two higher than the first air flow resistance of the first ceiling panels (4), more preferably the second air flow resistance is a factor of three higher than the first air flow resistance.

4. A set of ceiling panels according to claim 2 or 3 *characterised in* that the covering layer (3') of the first ceiling panels (4) with the first relatively low air flow resistance have been bonded to the mineral wool by the binder used for binding the mineral wool fibres together.

5. A set of ceiling panels according to any one of claim 2 – 4 *characterised in* that the covering layer (3") of the second ceiling panels (5) with the second relatively high air flow resistance have been bonded to the mineral wool by the use of a further adhesive (6).

6. A set of ceiling panels according to claim 2 or 3, *characterised in* that the difference in air flow resistance of the ceiling panels have been provided by providing the first ceiling panels with a number of holes, which penetrates the major part or all of the mineral wool layer, but not the covering layer (6).

7. A set of ceiling panels according to any one of claims 1 – 6, *characterised in* that the covering layer (3) has been provided with paint before being mounted on the mineral wool ceiling panel (4, 5).

8. A ceiling in a room where the ventilation air for the room is passing through selected parts of the ceiling by running the air pressure above said ceiling higher than below the ceiling, the ceiling comprising ceiling panels and the ceiling being arranged to have at least two different air flow resistances at two ceiling panels, *characterised in*
that the ceiling panels are made of mineral wool and are arranged to have at least two different air flow resistances, such that the air supply to the room is controlled by placing first ceiling panels (4) with a first air flow resistance over areas where a supply of ventilation air is needed and second ceiling panels (5) with a second air flow resistance in all other areas, where the second air flow resistance is higher than the first air flow resistance, and that ceiling panels having different air flow resistances are arranged in one layer.

9. A ceiling according to claim 8 *characterised in* that the ceiling panels (4) having a first air flow resistance cover at least 60 % of the area with ceiling panels, preferably at least 70 % of the area, and even more preferably at least 80 % of the area.

10. A ceiling according to claim 8 or 9 *characterised in* that the ceiling panels (1) are supported by a grid comprising laths (12) supporting the ceiling panels along at least one edge.

11. A method of manufacturing a set of ceiling panels according to claim 1, *characterised in* that the covering layer of the first ceiling panels (4) is added to the surface of the mineral wool before the curing oven and thereby bonded to the ceiling panel by the binder used for binding the mineral wool fibres together, and that the covering layer of the second ceiling panels (5) is added to the surface of the mineral wool after the curing oven and bonded to the mineral wool by the use of a further adhesive (6).

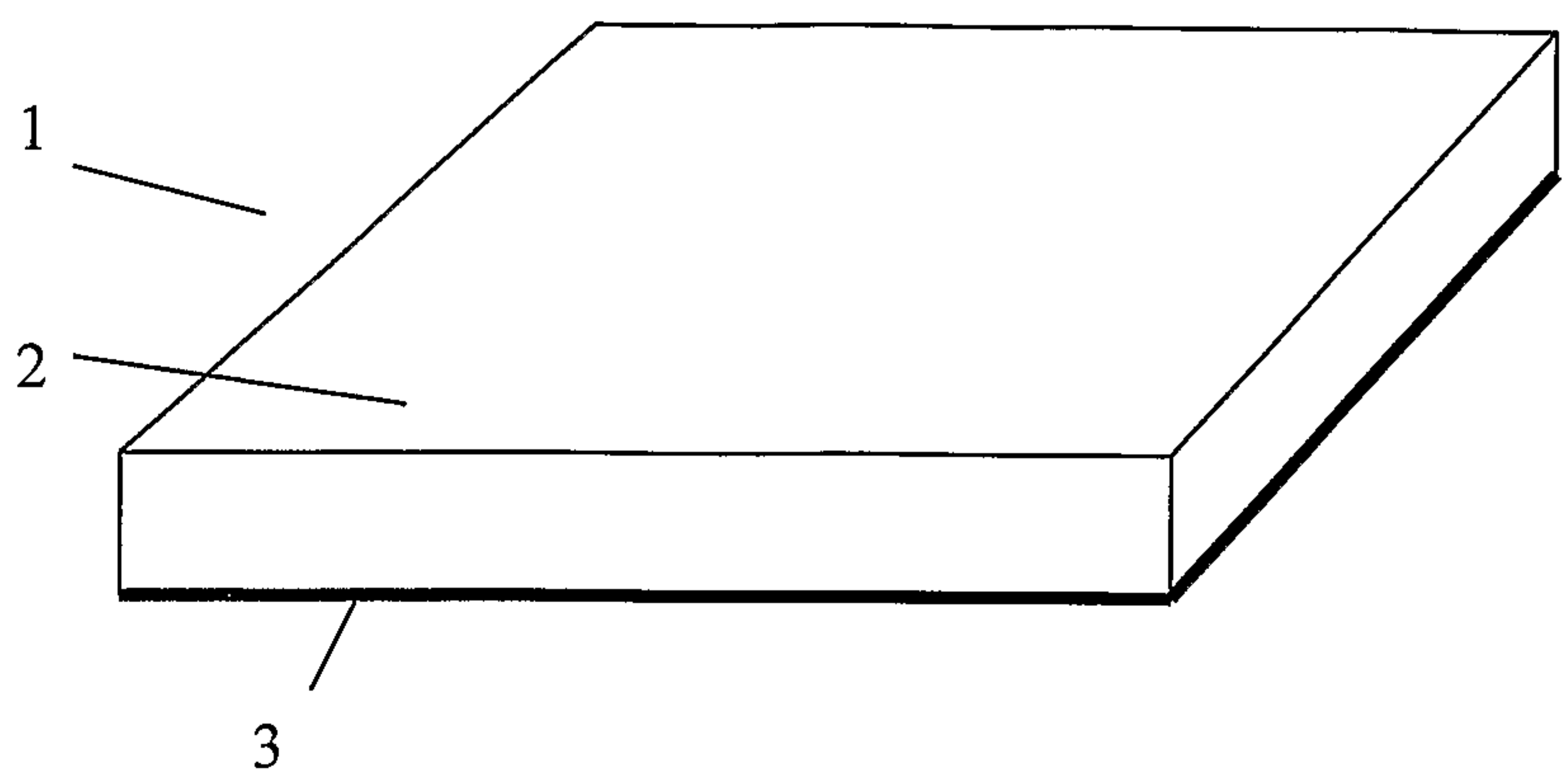


Figure 1

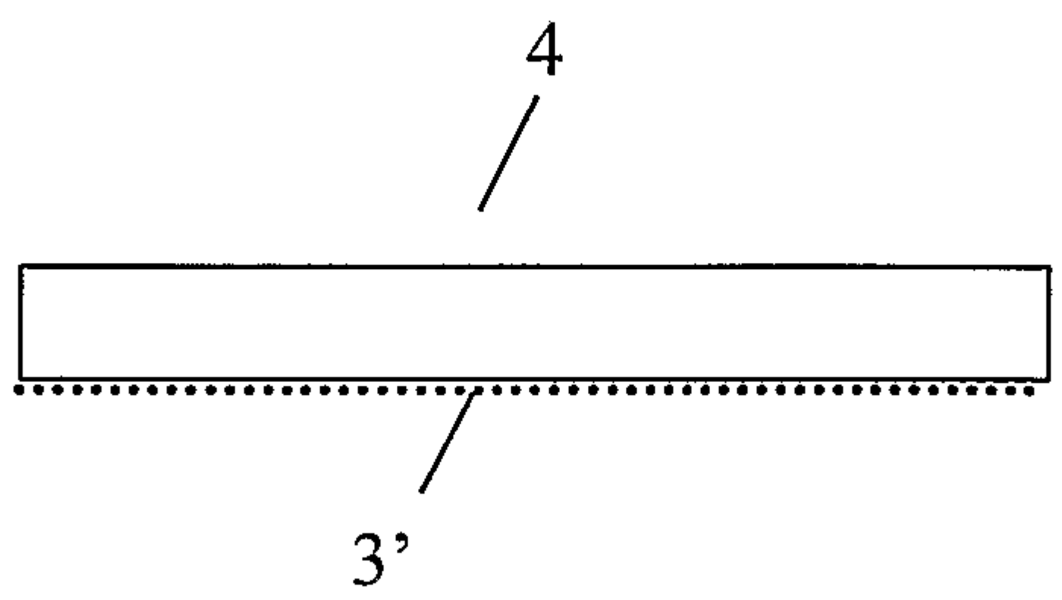


Figure 2a

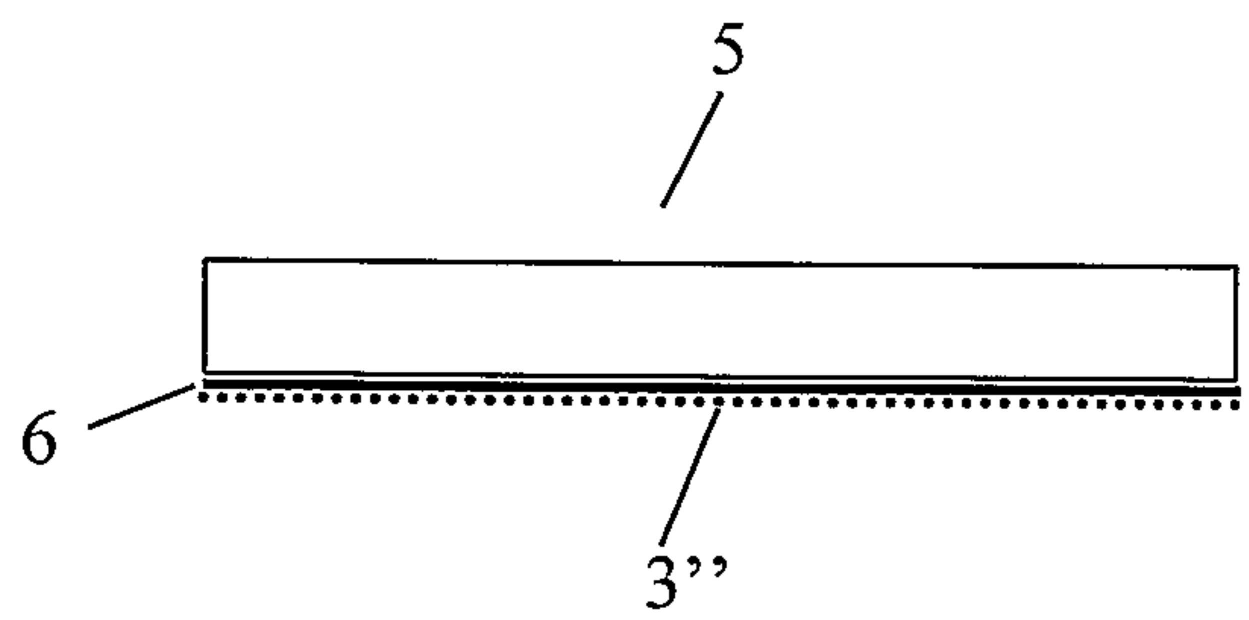


Figure 2b

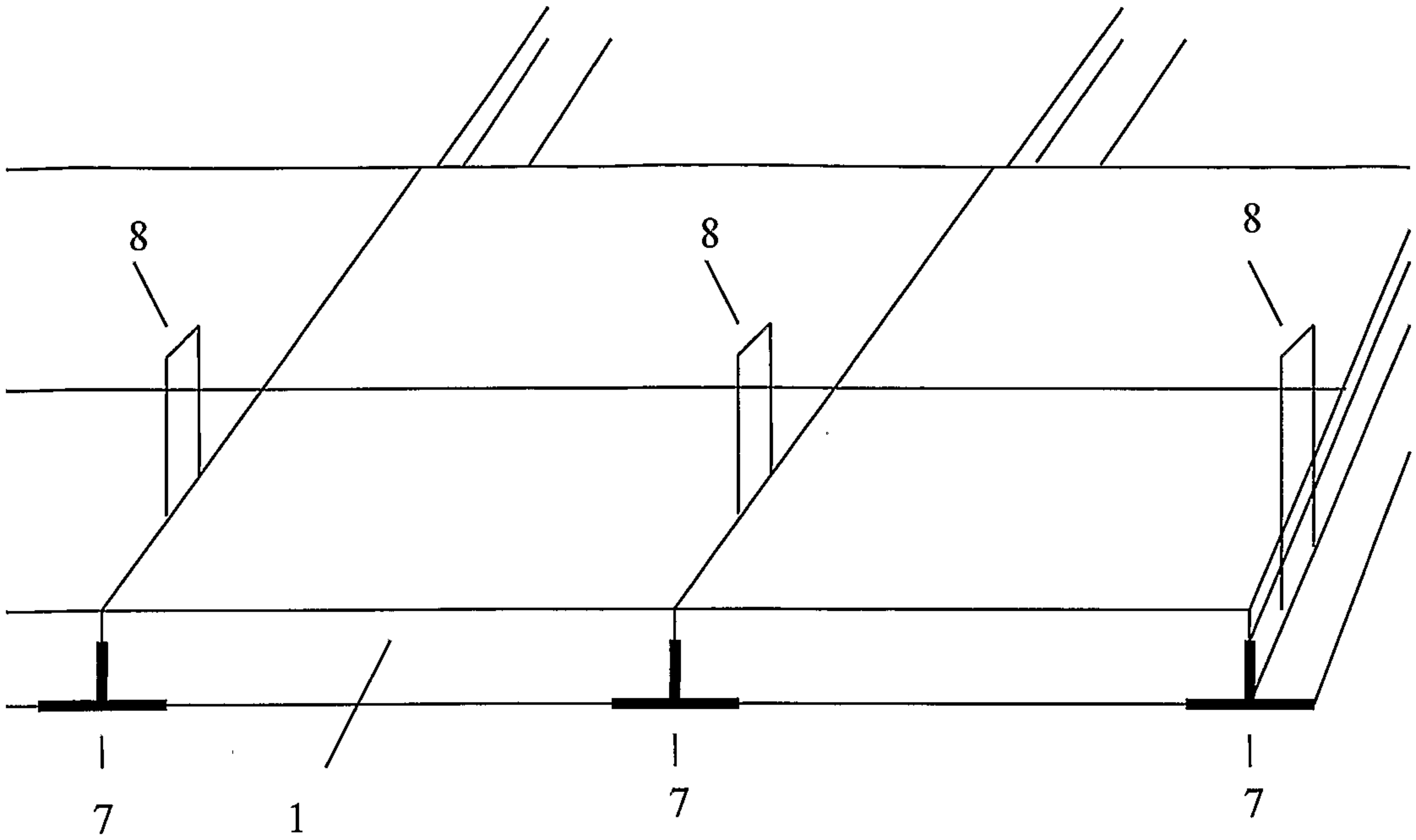


Figure 3

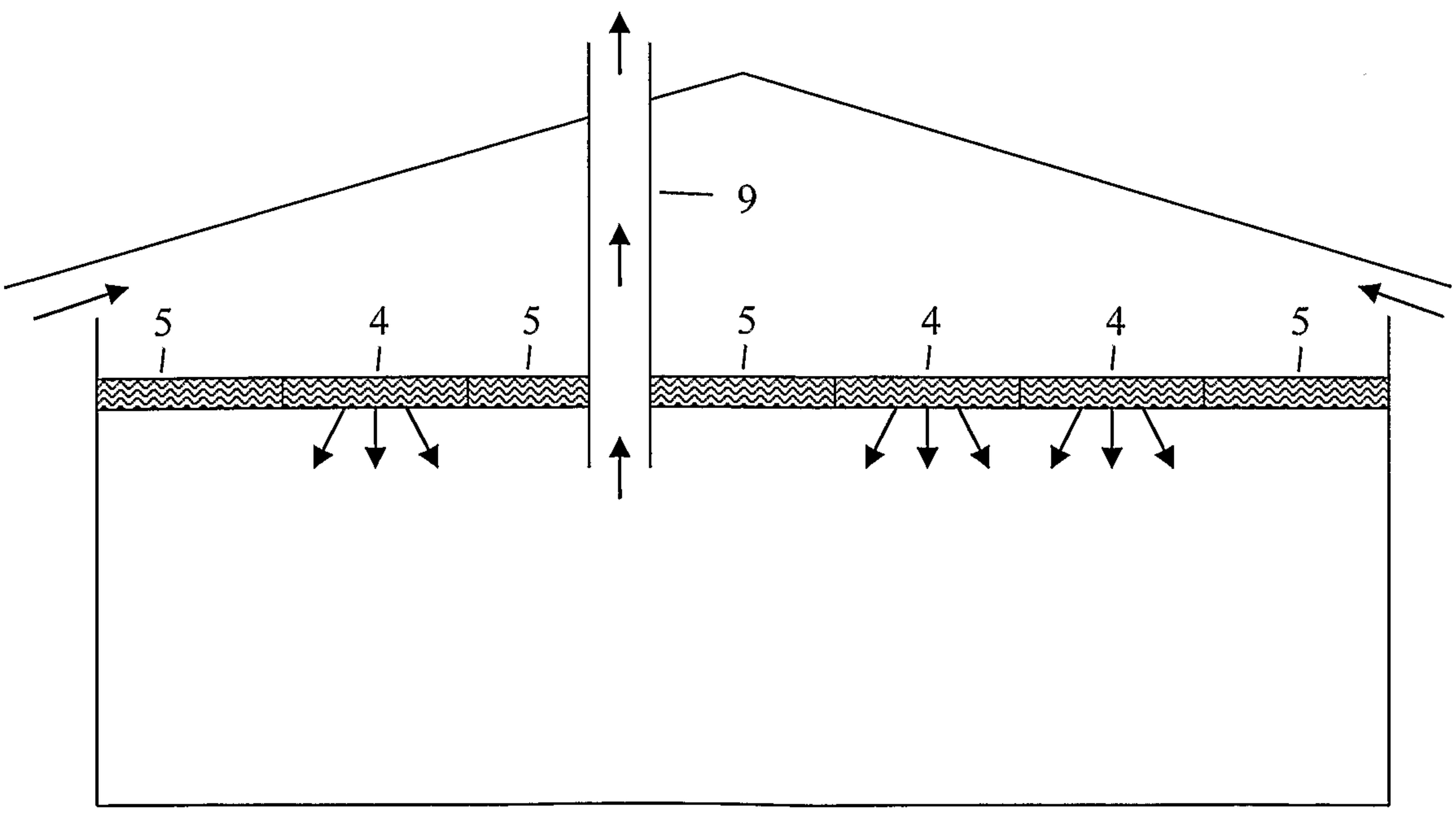


Figure 4

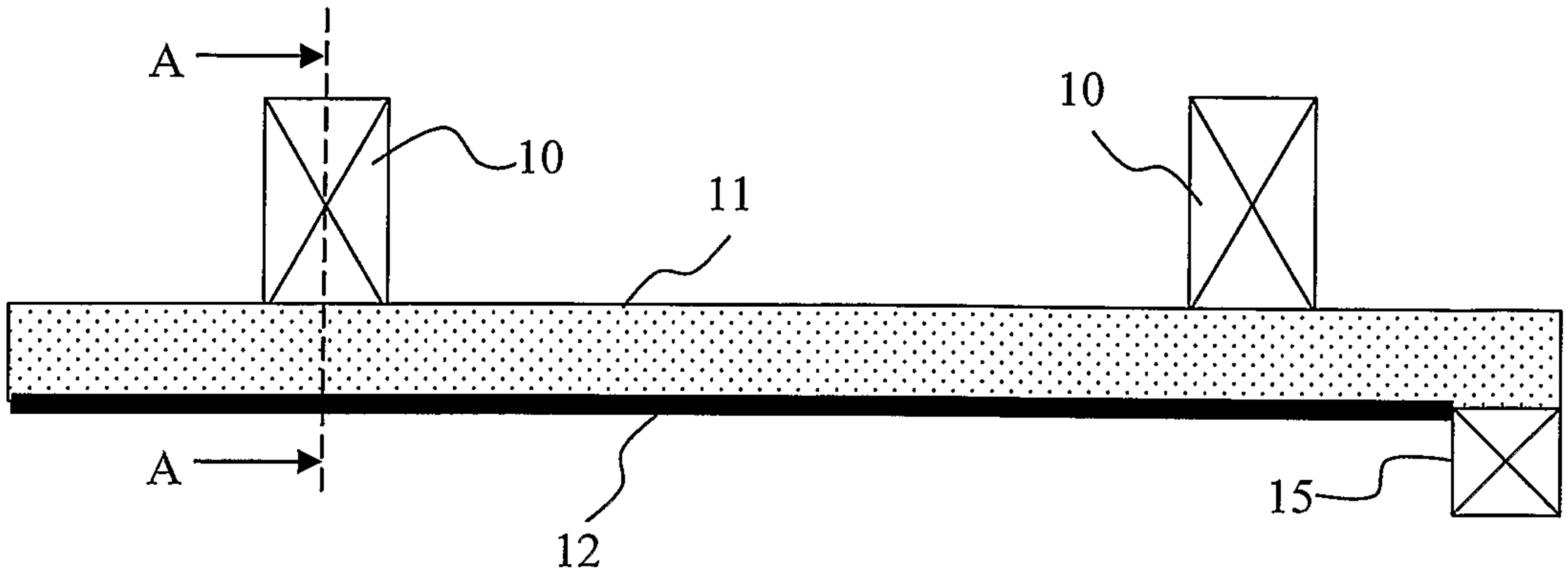


Figure 5

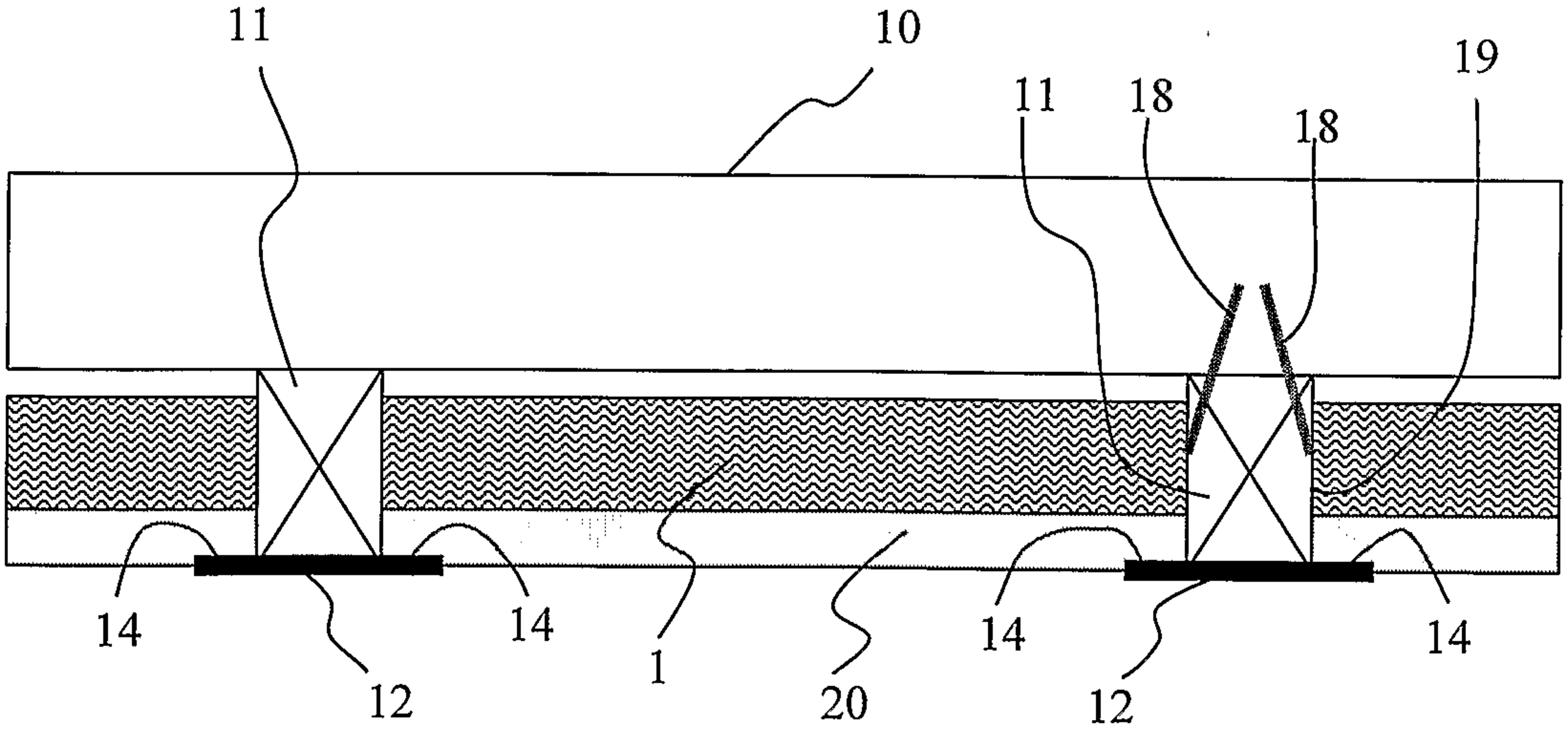


Figure 6

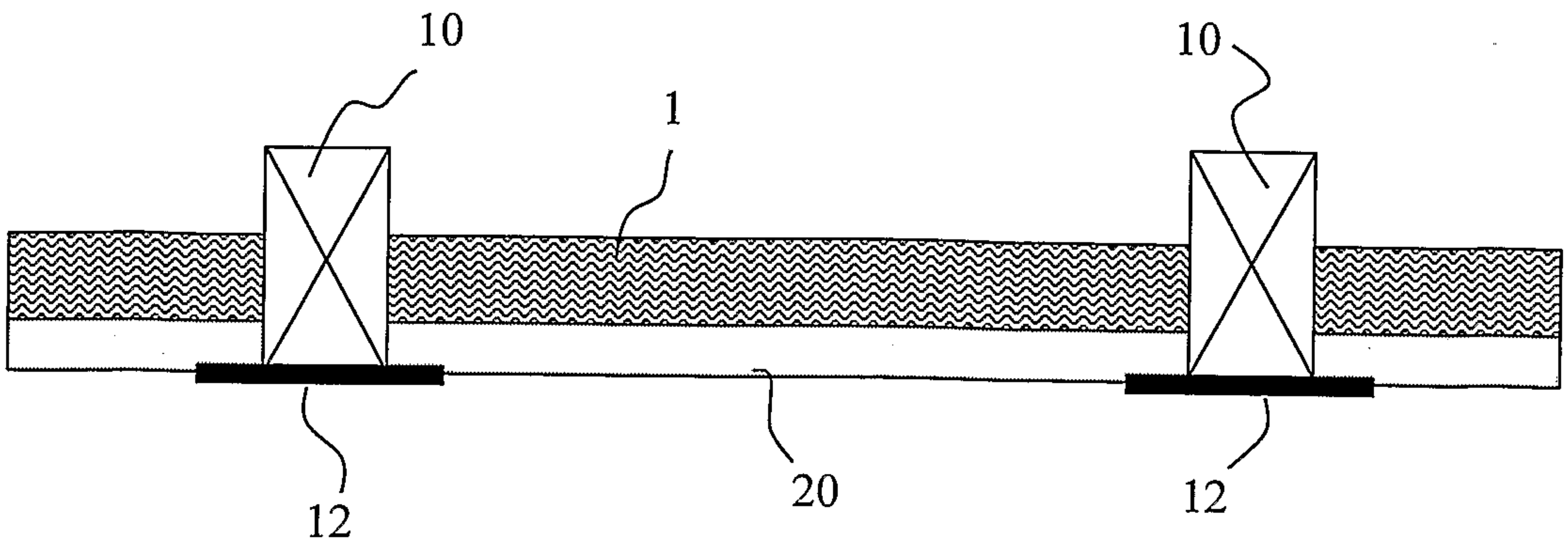
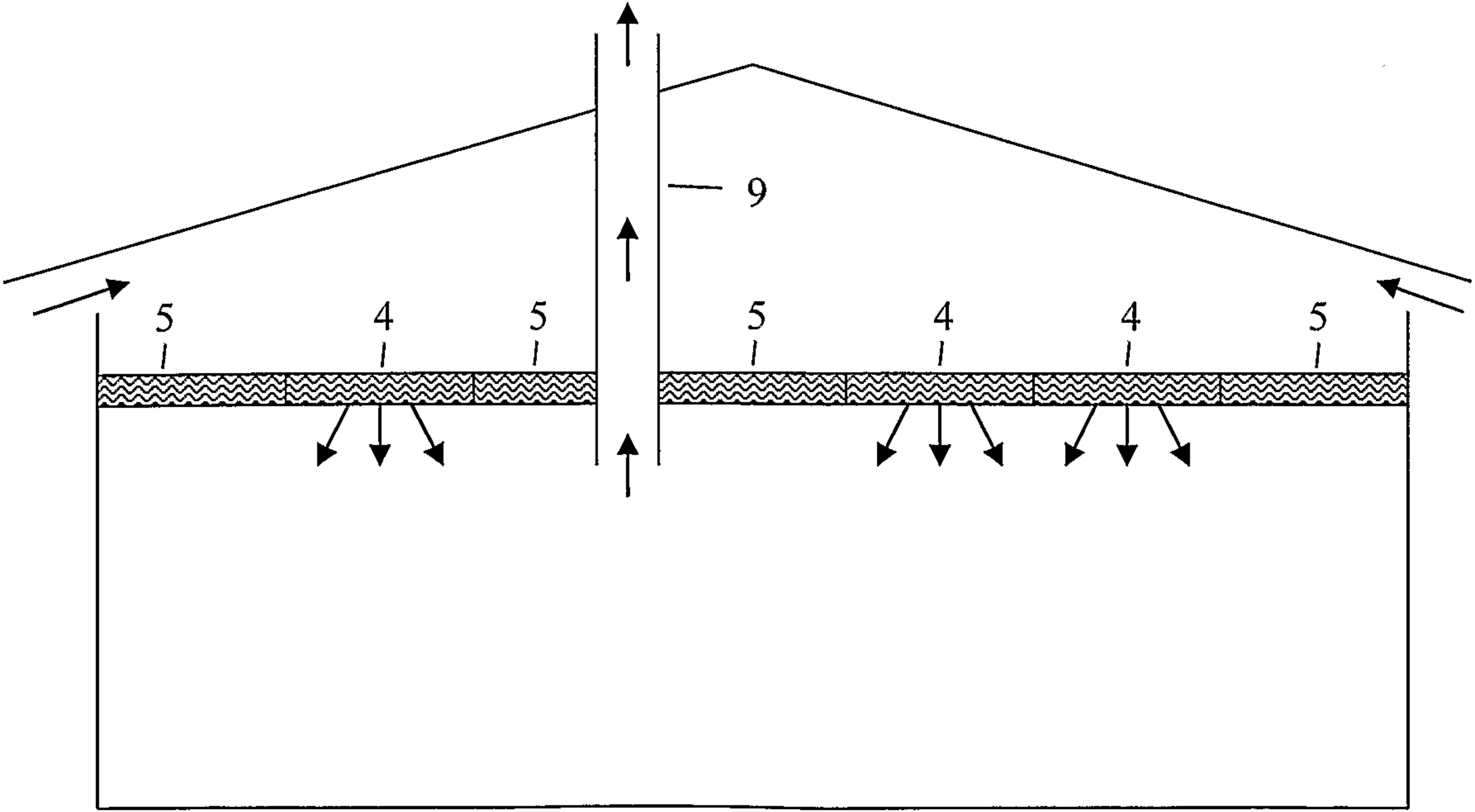


Figure 7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