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(54) **AIR CURTAIN**

LUFTVORHANG

RIDEAU D'AIR

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(73) Proprietor: **Mechanical&Internal Environmental
Services Ltd
Wellingborough, Northants NN8 5PH (GB)**

(72) Inventor: **MARIS, Richard William
Wellingborough, Northants NN8 5PH (GB)**

(74) Representative: **Smith, Peter James
Serjeants LLP
25 The Crescent
King Street
Leicester LE1 6RX (GB)**

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EP 2 531 778 B1

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Description

Field of Invention

- 5 **[0001]** The invention relates to means for generating a composite air curtain which resists or partially resists the flow of external air past the curtain; and to a range of potential uses for such a composite air curtain.

BACKGROUND

- 10 **[0002]** Air curtains are well known, and are commonly used to provide a non-physical barrier across an entrance to a building. The air curtain barrier provides a limited degree of separation between external and internal environmental conditions, by resisting the flow of ambient air from outside into the building, and resisting the flow of internal air out of the building. Such known air curtains also limit the passage of particles or items entrained in the external ambient air or in the internal air from floating into or out of the building across the curtain. Dust and fallen leaves are, for example, discouraged from floating into the building by the presence of such an air curtain.

- 15 **[0003]** A typical known air curtain generating device comprises a means for directing a narrow curtain of air downwardly across a doorway or entrance to the building. A fan and air handling unit is connected to supply air to a ceiling grille above the doorway. A similar width floor grille may be located immediately beneath the ceiling grille to collect the air curtain air for return back to the air handling unit. Such air curtain equipment requires space for the air handling unit above the ceiling grille, typically received within the confines of a false ceiling; and also requires below-floor depth for housing the duct work for collecting the air through the floor grille and returning it to the air handling unit above the door opening. The air of the air curtain may be heated, in which case the air curtain must be generated at an initial pressure and velocity sufficient to compensate for the natural buoyancy of the heated air curtain. Also the ceiling grille must be at a height of at least 2.5 metres above the floor, to match the height of the doorway. If such an air curtain is designed to be capable of withstanding a crosswind air velocity of about 3m/s, then it has been found that the air curtain must be established with a downward velocity of about 8m/s.

- 25 **[0004]** Published French patent application FR 2757933 A1 discloses an example of an air curtain system, which comprises two pairs of air curtain generators facing across an opening. The pairs are spaced apart from one another and within each pair the two air curtains are directed to converge towards one another.

- 30 **[0005]** Similar designs of vertical air curtain may omit the floor grille, and simply return air from inside the building to the air handling unit and air curtain supply grille. Typically those similar forms of air curtain generators would fail to establish an effective air curtain across the bottom 500mm of the door opening.

- 35 **[0006]** It is also known to establish the air curtain not vertically but horizontally across the width of the doorway. That can be more cost-effective, on the basis that the door width is generally considerably less than its height. Such horizontal air curtains tend to have their principal uses in warehouses and in factories.

- 40 **[0007]** The efficiency of all known air curtains can be assessed on the basis of how effectively they provide an air seal or non-physical barrier across an opening, preventing the passage of a cross-wind or a cross-flow of air across the air curtain. Typically, known air curtain generating devices have high energy demands if an efficient sealing effect is to be obtained. It is an objective of this invention to provide means for generating an air curtain creating an effective seal with lower energy demands.

THE INVENTION

- 45 **[0008]** The invention provides means for generating a composite air curtain as defined in claim 1 herein. The composite air curtain is established across an opening between facing walls, and resists or partially resists the flow of external air between the walls and past the air curtain. The term "external air" herein is meant to include both ambient air attempting to flow into a building from the outside and air within a building or structure attempting flow past the curtain, for example to the outside. The word "external" in that context therefore means simply air that is not part of the air curtain itself.

- 50 **[0009]** If the four individual air curtain generators in the row are notionally numbered 1, 2, 3 and 4, then it will be understood that the air curtains produced by generators 1 and 2 are mutually divergent; the air curtains produced by generators 3 and 4 are mutually divergent; and the air curtains produced by generators 2 and 3 are mutually convergent. As a convenient shorthand form of reference to such an array of air curtain generators and of the composite air curtain they produce, it is appropriate to refer to the four component air curtains as being doubly divergent. The doubly divergent nature of those four component air curtains which make up the final composite air curtain is such as to create alternate zones of relatively low and relatively high air pressure within the composite air curtain. It has been found that this creation of alternating pressure zones within the composite air curtain increases the efficiency of the air seal, and better resists or partially resists the flow of external air and entrained floating particulate matter and debris between the walls and past the air curtain. Moreover this enhanced level of air sealing is achieved economically, without corresponding increases

in the energy required to generate the composite air curtain.

[0010] It is relevant also to consider the positioning of the air collection zone which collects the air forming the composite air curtain and returns it to the air handling unit. If that air collection zone is laterally outwardly of the adjacent but mutually spaced pairs of air curtain generators, then it may consist of a single air collection zone on one side of the row of four air curtain generators or a pair of air collection zones located one on each side of the row of four air curtain generators. In either case, the air pressure in the composite air curtain between the air curtain generator of one pair which is adjacent to but mutually spaced from the air curtain generator of the other pair will be an air pressure which is higher than the air pressure at one or both opposite sides of the composite air curtain. Alternatively if the air collection zone is between the mutually spaced pairs of air curtain generators (i.e. between generators 2 and 3 as notionally numbered above), then the air pressure between those relatively spaced pairs of air curtain generators will tend to be lower than the air pressure at opposite sides of the air curtain generator. Either way, the alternating pressure zones across the composite air curtain are found to contribute significantly to the increased efficiency of the air seal that is established by the air curtain.

[0011] Each air curtain component of the composite air curtain may be established by having the row of four air curtain generators in or on one of the facing walls direct their air curtains completely across the opening between the facing walls, to impinge on the opposite wall. Alternatively a second row of air curtain generators, similar to the above defined first row, may be arranged in two adjacent but mutually spaced pairs on or in the other of the facing walls, the air curtain generators of the two rows facing one another and each establishing its composite air curtain across half or approximately half of the opening.

USES OF THE COMPOSITE AIR CURTAIN GENERATED ACCORDING TO

THE INVENTION

[0012] The above composite air curtain has a variety of uses, including both specialist and generalised uses.

Building Access Lobby Isolation

[0013] An access doorway providing entrance to or exit from a building may be provided with a composite air curtain seal according to the invention. For the most efficient establishment of that air curtain seal, the facing walls should be parallel to one another and defining a short corridor as long as, or longer than, the row of four air curtain generators. The air curtain generator of the invention therefore lends itself to installation in an access lobby for the building. Preferably that access lobby extends slightly outwardly beyond the external wall of the building, so that any wind or other external air movement directed against the external wall of the building flows past the lobby entrance opening before it establishes a high pressure zone where it is diverted by that external building wall.

[0014] The provision of a composite air curtain according to this invention across an access lobby of a building may be accompanied by opening and closing doors to or from the building. For example those doors may be manually or automatically operated sliding or hinged doors designed to open temporarily for a person entering or leaving the access lobby. When the doors are closed, the air curtain may be powered down to run at a reduced air pressure and air curtain speed. When the doors open, the impeller or impellers creating the composite air curtain may be run at an increased speed to create a more efficient air curtain in order the better to resist air flow into or out of the building. A person entering through the lobby will be aware of the air curtain as he or she walks through it, but because it is directed from a side wall or walls and not from above downwardly onto the head of the person passing through, it provides the sensation of merely a mild breeze and the user is far less aware of the existence of the air curtain than he or she would be if it were a conventional air curtain directed downwardly. If the doors are automatically operated, the control may be such that the doors remain open in times of frequent use, and at the same time the impeller or impellers generating the composite air curtain may be set to operate at maximum speed.

[0015] For the above access lobby use, the air collection zone which collects the air forming the composite air curtain for return to the air handling unit is preferably between the pairs of air curtain generators. Such an air collection zone may be provided as a grille and plenum chamber on or in the said one of the walls and/or in the opposite wall, with ducting leading from that plenum chamber to the air flow impeller or impellers. As the air is passed back to the impeller or impellers it is preferably cleaned and filtered.

[0016] The above composite air curtain may be used to maintain different environmental conditions on opposite sides of the air curtain. The impeller or impellers used, which are preferably centrifugal fans, generate a certain amount of heat in use, which is transferred to the air impelled by the fans. That may be the sole heating of the air of the air curtain. If a greater temperature differential is required between the air inside the building and ambient outside air, then advantageously a second air curtain or second and third air curtains is or are established on the inside of the building adjacent to the composite air curtain, the air flow of that second/third air curtain being a flow of heated air between the same two walls. Preferably mutually adjacent second and third air curtains are generated and are mutually divergent, and preferably

the air from those air curtains is collected at an air collection zone within the lobby in the floor, ceiling or walls of the lobby for filtration on its return to the impeller generating those second and third air curtains. By such means the interior of the building can be maintained at a temperature significantly above or below outside ambient temperature.

[0017] The above access lobby installation assumes that there is a short corridor on the inside of the doors to the lobby, formed by the facing walls and a ceiling or false ceiling over those facing walls. If the building interior is significantly higher than the access doorway then a roofless stand-alone air curtain generator may be used. Such a stand-alone air curtain generator comprises a pair of mutually facing walls for positioning immediately adjacent to the doorway for the full height of the doorway, with the air curtain generator of the invention installed between the mutually facing walls. The air curtain generator generates its composite air curtain between the walls for the full height of the doorway. Means are provided within the stand-alone unit for generating a further air curtain, being a generally horizontal air curtain between the walls across the top of the composite air curtain. That further horizontal air curtain acts as a non-physical ceiling for the stand-alone unit, and ensures the coherence at door-top height of the vertical composite air curtain generated by the doubly-divergent air curtain generator.

Underground Railway Tunnel Ventilation for Single Line Tunnels

[0018] In the London Underground railway system, and others like it, trains travel in single track tunnels between stations. Air is forced through the tunnel network by the piston effect of moving trains, with warmer stale air rising to the surface and being replaced by cooler fresh air both at stations and through ventilation shafts. Air replacement through new ventilation shafts is expensive, the expense arising through the initial cost of excavating those shafts, the real estate value of the land at the surface where the shafts emerge to draw in fresh air, and the possible need to pump that fresh air down the shafts. Air replacement at the stations does not rely on pumped fresh replacement air, because it is always possible to utilise natural convection which draws in cooler air from the surface whilst discharging warm air from below. The air in the tunnels is always warmer than at the surface because over prolonged periods of time the tunnel walls are warmed by, and become heat sinks for, the heat generated by the moving trains. The London Underground system has been operating for more than a century, and during that time the tunnel walls have absorbed heat generated by the trains through:

- traction drive and operation of the train's electric motors;
- traction gearboxes;
- after-coolers on air brake compressor sets;
- air compressors;
- friction brakes on the train's wheels;
- passenger comfort heating;
- carriage lighting;
- passengers' body heat; and
- electrical rectification of transformer equipment;

and to a lesser extent by:

- direct current power supply pick-up lines;
- signalling systems;
- the driver's cab cooling unit; and
- safety access lighting.

[0019] The piston effect of a train passing along a single track tunnel has the effect of pushing a column of air along the tunnel in front of the moving train. The column of air is warmed by the tunnel walls, and when it reaches a station platform it rises and is replaced by cooler fresh air which is drawn down into the station by thermal convection. The better stations are designed to take maximum benefit from the thermal convection currents, thus maintaining a strong cycle of cool, fresh air down to platform level. As the train moves out from the platform its piston effect acts to drive the warm stale air in the tunnel on towards the next station up the line, whilst the air change at the station just vacated is continued by the piston effect of the next train down the line. But the above piston effect is enhanced when there is a minimal clearance between the train carriages and the tunnel wall. A typical train carriage might have a cross-sectional area of 5.8 m², and a typical single track deep tunnel may have a free cross-sectional area of 10.5 m², so that in practice the above 'minimal gap' train/tunnel clearance amounts to at most about 55% train occupancy in a deep tunnel between stations. If the efficiency were calculated as the cube of the train occupancy in the tunnel then a 55% occupancy would give a 17% efficiency (0.55³).

[0020] According to the invention there is provided an underground railway tunnel ventilation apparatus comprising

train rolling stock having the cross-sectional outline of a train carriage and, carried by that rolling stock, a doubly divergent air curtain generator as defined in claim 1 herein for establishing a continuous composite air curtain extending in use from the outer periphery of the rolling stock to the internal surfaces of a single track tunnel along which the rolling stock is designed to move. The rolling stock may be an integral part of a train carriage or a self-contained unit mounted on its own short wheelbase railway chassis and designed to be towed between two adjacent train carriages or between a tractor unit and a train carriage. The efficiency of the composite air curtain created by the doubly divergent air curtains between the rolling stock and the tunnel wall, and the resistance of that composite air curtain to the flow of external air past the air curtain between the rolling stock and the tunnel wall, enhances the piston effect of the moving train, thus increasing the movement of warm air along the tunnels until it can rise to the surface under natural convection at a station or ventilation shaft. It will be appreciated that in such an arrangement the wall in which the four air curtain generators of the composite air curtain unit are installed is the wall of the rolling stock and not the tunnel wall.

[0021] Preferably the composite air curtain is shut off when the train enters a double track portion of the tunnel or when it enters a station. The former is preferable simply on the ground of efficiency: in a double track portion of the tunnel the air curtain generators are so far distanced from at least one of the tunnel walls that the air curtain cannot extend completely between the train and the tunnel wall. The latter is preferable for the additional ground that the composite air curtain would be directed against any person or persons on the platform, which may be undesirable. The shutting off may be achieved automatically by means of sensors in the tunnel wall and sensors or transponders in the train rolling stock, so that the train position can be sensed and the impeller motors switched on and off depending on the position of the train in the tunnel or tunnel network.

[0022] Preferably the underground railway tunnel ventilation apparatus of the invention has the air curtain impellers and air curtain generators arranged around the outside of the rolling stock, with a ventilation channel through the centre. Ventilation fans, ducting and air flow control baffles are preferably provided in order to generate, when desired, a forced flow of ventilation air through the ventilation channel. The ventilation fans are preferably reversible axial flow fans together with associated ductwork leading from a grille array at one end of the rolling stock to a grille array at the other end of the rolling stock. The ductwork preferably includes or incorporates filters for the ventilation air. Thus even when the train is stationary the ventilation fans can generate a flow of air through the tunnel and optionally also through the train. The enhanced tunnel ventilation is not therefore totally dependent on the piston effect of the train moving through the tunnel. However whether the air movement along the tunnel is caused by train movement, by the ventilation fans or by both, the efficient air seal between the periphery of the train rolling stock carrying the ventilation apparatus and the tunnel wall is highly instrumental in achieving that air movement.

[0023] The above described array of air curtain impellers, plenum chambers and directional elements of the air curtain generators is more or less a doughnut-shaped arrangement. The air curtain generators which generate the composite air curtain are mounted in the annular ring of the doughnut, with the plenum chambers and exit aperture means facing outwardly from the outer periphery; and the ventilation fans may also be arranged in the annular ring of the doughnut, directing the ventilation air through the central opening which may also be a passage for passengers along the length of the train.

Ventilation Shaft Management for Mines or for Underground Tunnels.

[0024] The above doughnut-shaped arrangement is also of use in apparatus for ventilating underground tunnels and enclosures. Ventilation shafts are commonly provided for mines, underground railway tunnels and other underground facilities. Sometimes those ventilation shafts rely only on convection to draw warm or stale air from the underground facility, and sometimes they utilize pumped air. According to this invention ventilation apparatus is provided which utilizes the above doubly divergent air curtain generator. The composite air curtain created by the doubly divergent air curtains is established around the outer periphery of a doughnut-shaped ventilation capsule, to establish a composite air curtain between the capsule wall and the interior of the ventilation shaft, with alternating zones of relatively high and relatively low pressure across the composite air curtain establishing an efficient air seal between the capsule and the ventilation shaft wall to resist the flow of air across that air curtain. One or more axial flow fans are provided to generate an axial flow of ventilation air through the central core of the doughnut, and the air seal around the periphery prevents appreciable back-flow of that ventilation air between the capsule and the shaft interior wall. It is desirable that such a capsule is capable of complete removal from the ventilation shaft either for maintenance purposes or to leave the shaft unobstructed in the case of a power failure which might cause the ventilation fan to stop. Preferably the capsule is suspended on cables and is counterbalanced so that the counterbalance weight automatically lifts the capsule completely out of the ventilation shaft in the event of a power failure. The capsule does not itself touch the shaft wall in normal use: the air seal is provided by the composite air curtain. Therefore there is no frictional force to overcome when the capsule is raised out of the shaft by the cables and counterweight. If desired guide wheels or rollers may be arranged around the periphery of the capsule to guide the capsule smoothly along the shaft wall as it is raised and lowered, and to protect the shaft wall.

[0025] The apparatus for ventilating underground tunnels and installations may be used to pump cool air from the surface down into the underground installation or to draw warm air up to the surface from the underground installation. For example if the installation is an underground railway then the air in the train tunnels is likely to be very warm, as explained earlier. The heat from that warm extracted air may be beneficially used according to this invention by passing the extracted air through a heat exchange unit before discharge to the atmosphere to extract that heat for use elsewhere, for example for heating municipal facilities such as swimming pools or public buildings.

DRAWINGS

[0026] The invention is illustrated by following drawings, of which:

Figures 1 to 4 are four separate schematic illustrations of alternative means for generating composite air curtains according to the invention;

Figure 5 is a plan view of an access lobby to a building, provided with a non-physical barrier in the form of a composite air curtain according to the invention;

Figure 6 is a vertical section taken along the longitudinal centre line of Figure 5;

Figures 6a and 6b are respectively a schematic plan view from above and a schematic perspective view of a stand-alone air curtain generator according to the invention adjacent an access doorway to a building;

Figure 7 is an enlarged detail of the directional elements in an exit aperture means of the composite air curtain generating means of Figures 1 to 6b;

Figure 8 is a cross-section of a typical underground deep tunnel and station platform, with a train standing at the platform;

Figure 9 illustrates a ventilation apparatus according to the invention carried by rolling stock located between two carriages of the train;

Figure 9a shows the air flows established by the front and rear pairs of air curtain ducts and directional elements of the air curtain generators;

Figure 10 shows at (a) a plan of the connection between two standard carriages indicating the lateral movement at their coupling when travelling round a tight bend, at (b') a plan of the same two carriages with a ventilation apparatus according to the invention on rolling stock between the carriages, and at (b'') an enlarged view of (b');

Figures 11 and 12 show cross-sections through a notional underground train station illustrating expected air movement patterns;

Figures 13 and 14 are respectively a side elevation and a plan view from above of a train carriage in which the pressure fans and ducts of the ventilation car V of Figures 9 and 10 are provided in a short ventilation car section V' of the full length train carriage;

Figure 15 is a schematic illustration of an air ventilation shaft of an underground train tunnel, and ventilation apparatus according to the invention installed near the top of the ventilation shaft;

Figure 16 is an enlarged schematic vertical section through the ventilation apparatus of Figure 15;

Figure 17 is an enlarged horizontal section through the ventilation apparatus of Figure 15; and

Figure 18 is a schematic illustration of the mounting of the ventilation apparatus of Figure 15, enabling it to be withdrawn from the ventilation shaft in the event of a power failure.

[0027] Referring first to Figures 1 to 4, there are illustrated four alternative basic means for generating a double divergent air curtain according to this invention. Considering first Figure 1, a row of four air curtain generators 1 to 4 is shown. Generators 1 and 2 share a plenum chamber 5 and represent a first pair of air curtain generators. Generators 3 and 4 share a plenum chamber 6 and represent a second pair of air curtain generators. An alternative structure (not illustrated) would be for each air curtain generator 1 to 4 to have its own independent plenum chamber supplied through an inlet means with air from an impeller. Each plenum chamber illustrated in Figure 1 has air inlet means (not shown) supplied by an air flow impeller (not shown), and exit aperture means provided with directional elements 7. The directional elements 7 are illustrated in more detail in Figure 7, and comprise sets of mutually inclined louvre vanes which direct their respective air curtains at a divergent angle one relative to the other, the resulting air curtains being illustrated in Figure 1 as air curtains 8 to 11.

[0028] Figure 1 does not show the position of the air collection zone through which the air curtain air is collected for return back to the impeller or impellers, but it is implicit that the air collection zone is above air curtain 8 or below air curtain 11 as illustrated, or both. The air curtains 8 and 9 issuing from air curtain generators 1 and 2 are therefore mutually divergent, as are the air curtains 10 and 11 issuing from air curtain generators 3 and 4. The air curtain 9 issuing from generator 2 and the air curtain 10 issuing from generator 3 are, however, mutually convergent. The result is that the divergent air curtains 8 and 11 impinging on the opposite wall are diverted further apart until they create air flows back to the air collection means; and the convergent air flows impinging on the opposite wall cannot escape though that wall

and are diverted to flow outwardly in the same directions as air curtains 8 and 11 respectively. This creates an array of variable pressure zones across the resulting composite air curtain. The air curtain at **L** has a lower pressure than that at **H**. The result is a significantly better seal being provided by the composite air curtain than would have been provided by a single air curtain directed at a similar air velocity against the same opposite wall. Air attempting to flow in either direction across the composite air curtain has to pass from a zone of relatively low pressure **L** to a zone of higher pressure **H**, and the pressure difference resists that air flow. Similarly the same pressure difference resists the passage of particles or objects entrained in the ambient air, such as fine rain droplets, dust or leaves, across the composite air curtain.

[0029] Figure 2 shows the same four air curtain generators but with an air collection zone (illustrated as 12) between air curtain generators 2 and 3. Air collected at the air collection zone 12 is passed back through ducting and preferably filters to the impeller or impellers which create the air curtain. The locations of the relatively high and relatively low pressure zones across the composite air curtain are reversed as compared with Figure 1. The zone between air curtain generators 2 and 3 becomes, in Figure 2, the relatively low pressure zone **L** and the outer zones are at relatively high pressure **H**. The resistance of the composite air curtain to the passage thereacross of air and entrained debris is however still much better than with a single air curtain. Air at either of the higher pressure zones **H** still has to cross an air curtain 8 or 11 to reach the central zone **L**, but air attempting to cross the next pair of air curtains has to pass both across an air curtain and up a pressure incline, from the zone of relatively low pressure **L** to the zone of higher pressure **H**. Although Figure 2 illustrates the air collection zone 12 as being in the same wall as the air curtain generators, it could equally be in the opposite wall or shared between the two walls, to create essentially the same zones of relatively high and low pressure across the composite air curtain.

[0030] Figure 3 is equivalent to Figure 1 but showing a second row of air curtain generators 1 to 4, similar to the row of air curtain generators 1 to 4, in the opposite wall. The two rows face one another so that each establishes its composite air curtain across half or approximately half of the opening between the two walls. Figure 4 is a similar modification of Figure 2, showing two facing rows of air curtain generators. In practice, the arrangement of Figure 1 or 2 would be preferred if the row of air curtain generators had to be mounted on a single wall, such as a movable wall where it would be impossible to ensure that there was a similar row of air curtain generators on the opposite wall in precisely facing configuration. If the air curtain generator were to be mounted in a situation where there was no relative movement between the two walls, and if the air supply from the impellers were available to the two walls, then the arrangement of Figure 3 or 4 would be preferred.

[0031] Figures 5 to 7 illustrate a first use for the air curtain generator of the invention, to create a non-physical barrier across an entrance or exit from a building. Figures 5 and 6 illustrate an access lobby for that building, the outer wall of the building being shown schematically as 21 and the exterior of the building being on the left as drawn, with the building interior on the right. The layout of the air curtain generators 1 to 4 is as illustrated in Figure 4, with two plenum chambers 5 and 6 being shown on each side of the lobby. In Figures 5 and 6 the initial direction of the air flow creating the air curtain is shown as simple straight arrows 8 to 11 and the air flow (less directional) of the return air that is passed back to the air collection zone is represented by arrows with coils around their tails. Those latter arrows are referred to herein as return arrows.

[0032] It will be understood from the description of Figures 1 to 4 how the composite air curtain between the entrance lobby walls is established with alternate zones of relatively high and relatively low pressure as illustrated in Figure 4.

[0033] Figures 5 and 6 show additional details of the access lobby. The lobby extends outwardly beyond the building outer wall 21. Any wind or air movement against that outer wall creates an area of high pressure alongside the wall 21 where the air flow is deflected by the wall 21, so the extension of the lobby beyond that plane (to the left of the wall 21 as illustrated in Figure 5) means that the air pressure at an access opening into the building is not the maximum local air pressure. An inclined ramp 18 is provided up to the access opening. The access opening is depicted as dotted line 19 which may be closed by sliding doors 20. When the door is open a person may pass into the building through the composite air curtain in the lobby.

[0034] Figure 6 shows some more additional detail. Above lobby ceiling height is a plant area 11 which houses air fan ducting 12, 14 for the two opposite pairs of plenum chambers 5 and 6, and a lobby recirculation air filter, fan silencer and intake duct 13. The impeller or impellers creating the air curtains are not shown, but are preferably centrifugal fan impellers. An area 22 above the access opening 19 houses the automatic sliding door operating equipment.

[0035] Excellent temperature control of the interior of the building is provided by a second air curtain generator in the lobby area immediately inside the doubly divergent air curtain which creates the non-physical barrier for incoming or outgoing air flow. That second air curtain generator creates in each side wall a single divergent pair of air curtains identified as 23 and 24 in Figure 5 and comprises a plenum chamber 25 on or in each side wall of the lobby, and directional vanes similar to the vanes 7 illustrated in Figure 7 for imparting directional flow to the air passing out of the plenum chambers 25, dividing that air flow into two mutually divergent air curtains. The return air flow passes through a grille (not shown) to an overhead air collection zone housing 16 above the lobby ceiling as shown in Figure 6, passing through a filtration and silencer area 17 before supply back to the impeller (not shown) for establishing the divergent air curtains 23 and 24. The establishment of another pair of mutually divergent air curtains inside the lobby adjacent the

doubly divergent air curtains creates further zones of alternating high and low pressure across the composite air curtain that is generated, and this makes it possible to achieve a considerable degree of temperature and climate control between outside ambient conditions and conditions inside the building. Figures 5 and 6 show temperature zones **A**, **C**, **M** and **I**, of which **A** represents outside ambient temperature, **C** represents the double divergent air curtain temperature, **M** represents a middle zone temperature and **I** represents an interior temperature. A temperature gradient (temperatures expressed in °C) can be obtained according to the following Tables, which ignore the contribution of a 0.5 to 0.7°C temperature rise from the fan motors.

Automatic doors permanently open																		
A	45	42	39	36	33	30	27	24	21	18	15	12	9	6	3	0	-3	-6
C	38	36	34	32	30	28	26	24	21	19	17	15	13	11	9	7	5	3
M	31	30	29	28	27	26	25	24	21	20	19	18	17	16	15	14	13	12
I	24	24	24	24	24	24	24	24	21	21	21	21	21	21	21	21	21	21

For lower ambient temperatures: Automatic doors operational								
A	-9	-12	-15	-18	-21	-24	-27	-30
C	1	-1	-3	-5	-7	-9	-11	-13
M	11	10	9	8	7	6	5	4
I	21	21	21	21	21	21	21	21

[0036] Humidity control can also be achieved by including either humidifiers or dehumidifiers in the housing 16.

[0037] Figures 6a and 6b illustrate a modification of the entrance lobby air curtain generating means of Figures 5 and 6. This modification is a stand-alone unit which can be fitted against an entrance door to a building to prevent the ingress of air currents whilst permitting free access to persons entering or leaving the building. The building entrance is illustrated in Figures 6a and 6b as comprising an entrance lobby comprising outer and inner walls 601 and 602 which are of greater height than their entrance doorways 603 and 604. Sliding doors 605 and 606 (shown schematically in Figure 6a only) are provided to close those doorways as required. The doors are preferably automatically operated when sensors (not shown) detect a person approaching the door from either direction. To maintain the building interior temperature and avoid draughts there is provided a stand-alone air curtain generator 607 according to the invention.

[0038] The air curtain generator 607 generates essentially the same doubly divergent air curtains 8 to 11 as those of Figures 5 and 6 except that they are numbered 608 to 611 respectively in Figures 6a and 6b. A pair of air return grilles 612 is provided in each of the opposed walls, leading to an air collection zone as in Figures 5 and 6. The stand-alone unit 607 of Figures 6a and 6b differs from the doubly divergent air curtain generator of Figures 5 and 6 primarily in that the impellers which cause the air flow of the air curtains are provided in the opposed walls rather than in a false ceiling over the unit. The unit 607 of Figures 6a and 6b has no ceiling, and is suitable for a building as illustrated in Figure 6b with a ceiling height well in excess of the door entrance height. To maintain the coherence of the doubly divergent air curtain 608 to 611, the air curtain generator 607 of Figures 6a and 6b includes a horizontal air curtain across the otherwise open top of the unit 607 as depicted by the row of arrows 613 in Figure 6b. A single overhead air curtain is sufficient to maintain the coherence of the double divergent air curtain 608 to 611 because there is no appreciable air flow in a direction perpendicular to that single overhead air curtain. In contrast, the doubly divergent composite air curtain 608 to 611 has to resist the fluctuating air pressure caused by outside wind or breeze directed against the openings of doorways 603 and 604 when the sliding doors 605 and 606 are open.

[0039] A stand-alone unit as shown in Figures 6a and 6b may of course be further enhanced if so desired by the inclusion of a further set of divergent air curtains such as the curtains 23 and 24 of Figures 5 and 6, for even greater climate control within the building.

[0040] Figures 8 to 14 illustrate a second use for the air curtain generator of the invention, to create an underground railway tunnel ventilation apparatus. Figure 8 illustrates a conventional underground railway train at a station platform. The train carriages 100 typically would have a cross-section of about 5.8 m², and the tunnel 95 through which the train runs (seen immediately around the train carriage in Figure 8) would typically have a cross-section of about 10.5 m², so that as the train moves through the tunnel there is about 55% train occupancy in the tunnel.

[0041] Figures 9 and 9a illustrate a tunnel ventilation apparatus V according to the invention. The apparatus V is shown

to be in this example a self-contained ventilation car on a short wheelbase rolling stock coupled between the middle two carriages. Of course the same ventilation car V could be mounted between the tractor car at the front or rear of the train and the adjacent carriage, or between any other pair of carriages. Figures 9 and 9a include an arrow 66 indicating the current direction of movement of the train, although it will be understood that most underground trains are bidirectional, with a tractor unit and a driver's cab at each end. It is to this end that the ventilation car V is constructed with a central plane of symmetry and can be operated in either direction of motion of the train. Figures 9 and 9a, however, illustrate air flows for stationary and left-to-right motion only, as shown by arrow 66.

[0042] Figures 9 and 9a include a number of unreferenced arrows indicating air flows, although some such arrows carry reference numerals in Figure 9a. Those arrows drawn with coils around their tails indicate air flow into the grilles and ducting described below, and those arrows drawn with simple straight tails indicate air flow from the grilles and ducting. It should be understood, however, that there are two distinct air flows through the ventilation car V. On the one hand there are air flows to create the doubly divergent air curtains which seal the air space between the carriage V and the tunnel floor, soffit and wall 95 and which enhance the piston effect of moving a column of air along the tunnel in front of the moving train. On the other hand there is a plurality of air flows which maintain a good supply of replacement breathing air for the passengers in the train carriages. Those individual air supplies will be referred to as air curtain air flows and ventilation air flows respectively (the latter referring to forward/upline tunnel and carriage ventilation).

[0043] Air curtain air drawn in through air grille/filter box assemblies at the leading and trailing ends of the ventilation car V is compressed by centrifugal air fans (not shown) and supplied through two pairs of generally annular outlet ducts numbered 1, 2, 3 and 4 in Figure 9a to create the doubly divergent composite air curtain. Each outlet duct has directional vanes, operating as the vanes 7 of Figure 7, dividing the air curtain air flow into divergent components 72 and 73 angled inboard and outboard with respect to the neighbouring air curtain as shown in Figure 9a. The four air curtains so generated together create a composite air curtain having alternating zones of relatively high and relatively low pressure across the curtain, exactly as described with reference to Figure 1. The zone 68c in Figure 9a, for example, is at a higher pressure than the zones 68a and 68b. Those alternating higher and lower pressure zones across the composite air curtain create an efficient air seal around the moving or stationary ventilation car V.

[0044] The direction of flow of the ventilation air at the train's terminus can be reversed on reversal of the direction of travel 66 of the train. This is achieved simply by reversal of the rotational direction of the impellers, and by moving air filters from the ventilation air grille/filter box assemblies at the rear end of the ventilation car V to front grilles at the other end.

[0045] When a train follows a tight curve the mid-portion of each carriage 100 intermediate the front and rear bogeys pushes to one side of the track centre-line and the front and rear ends which overhang the bogeys push to the other side of the track centre-line as shown in Figure 10a. When the carriages are the same length and the bogeys are positioned the same distance from the front and rear of the carriages this creates no problem, as the connecting doors at the carriage ends remain in mutual alignment. The same is not true for a ventilation car V of short length, coupled between two full length carriages. It will be seen from Figure 10b' and from enlarged plan Figure 10b" that the natural tendency is for the connecting doors to move out of alignment if the ventilation car V remains centrally over the tracks as indicated by the solid line outline 101. According to one preferred aspect of the invention, therefore, the ventilation car V is capable of sliding laterally along its wheel axles to the position indicated by the broken line outline 102 in Figure 10b". This maintains the connecting doors in better alignment for purposes of emergency egress. The mechanism for creating the lateral sliding movement along the axles comprises couplings (not shown) which act to push the ventilation car V to one side or the other on bends, and strong springs (not shown) which act to return it to its central position when the ventilation car reverts to straight line track running again.

[0046] Figures 11 and 12 illustrate how the act of pushing a column of air out of a tunnel into a station platform area contributes to an overall ventilation of the underground system. The air emitted from the tunnel is warmer, having been heated by the train components and the tunnel walls. It is also vitiated, having a depleted level of oxygen and an increased level of carbon dioxide and water vapour caused by the passengers' respiration in the trains and at the station. The warmer lighter air rises as a rising convection current shown by the heavier split arrows 103 and is replaced by the denser cooler fresh air from the surface as shown by the lighter open arrows 104. This will apply throughout the year.

[0047] If the train is stationary between stations, its carriage temperature will soon rise because of the heating effect of the train components, passengers, lighting and tunnel walls. An onboard temperature sensor is preferably provided, which ensures that in such a situation the air ventilation fans and the air curtain fans are automatically activated when the carriage air exceeds certain predetermined thresholds. For practical reasons all fans (ventilation and air curtain) must be switched OFF when the train is at or passing a station platform. The air curtain is effective only when the train is stationary or moving through a tunnel, and has no practical use when the train is at a station platform. Moreover, the air blast from the air curtain supply grilles would be directed against passengers standing on the station platforms. Therefore actuators are preferably provided in the tunnel walls a set distance from each station, and activate onboard transducers to turn OFF all fans when the train is approaching a station and to reactivate the system when the train leaves the station and re-enters a tunnel. Manual over-ride controls are of course also provided.

[0048] Another beneficial use for the tunnel ventilation apparatus as described is in conjunction with a tunnel cleaning

train. Incorporation of the ventilation car V into a tunnel cleaning train has the effect of dislodging any clinging debris, dust and dirt from the tunnel walls and soffit and from electrical power and signal cables suspended therefrom, by the force of the air curtain. The dislodged contaminants may then more easily be picked up by the filtration system in the tunnel cleaning train, which power blasts air and vacuums the tunnel walls and floor but does not treat the soffit.

[0049] It will be understood, of course, that the ventilation car V does not have to be a short wheel base rolling stock coupled between two carriages or between a tractor unit and an adjacent carriage. The ventilation car rolling stock may be of carriage length, and all of the previously described air curtain air pressure fans and ducts together with all of the previously described ventilation air fans and ducts may be incorporated into one small portion of the carriage, isolated from the passenger-carrying areas. Such a combined carriage and ventilation car according to the invention would have to include ducting to permit the intake of air from around the front and rear of the ventilation car section as illustrated in Figures 13 and 14, in which the ventilation car section of a complete passenger carriage 100' is given the reference V'.

[0050] The ducting in the ventilation car section V' differs from that of the car V of Figures 8 to 12 principally in that both the ventilation air and the air curtain air is drawn in through different grilles 104 and 105 depending on the direction of motion of the train. For clarity in Figures 13 and 14 the grilles 104 and 105 are given the additional suffix A or P meaning "Active" or "Passive". When the carriage is travelling from left to right as viewed in Figures 13 and 14, as indicated by the arrow 66, the trailing air grille/filter box assemblies 104 for ventilation air are open and active, and are given the suffix A. The leading air grille/filter box assemblies 104 for ventilation air are closed and passive. The opening and closing of the air grilles can be achieved automatically by means of flap dampers such as the dampers 106 shown in Figure 13. Those dampers 106 when in line with their associated air ducts allow the ventilation air to travel through air filters, and when positioned across the duct direct the air towards supply air grilles 105. The filters can therefore be left in position when the train changes direction at a terminus, without the need to move them from one end to the other of the car V as in the embodiment of Figures 9 to 10. A central corridor 108' is shown through the ventilation car section V', and is provided with two doors 106'.

[0051] The implementation of the device in car V as in Figures 9 to 10 does not affect the passenger carrying capacity of the train, but lengthens the train by approximately 3.1 m. If car section V' of Figures 13 and 14 were to be the same length as car V of Figures 9 to 10 the overall train length would remain unaltered, but the maximum observed passenger capacity would fall by approximately 20 persons. By marginally increasing the length of the ventilation car section V' above that of ventilation car V, the maximum observed passenger capacity would fall by approximately a further 16 persons. The physical space thus released thus permits the inclusion of "either/or" flap dampers 106, and after the air curtain and ventilation air intake grilles 105 and 104 respectively, brush type air pre-filters (not shown), and short bag air filters (not shown) are accommodated allowing greater passenger comfort by increasing air quality, and less maintenance as the filter bags hold much greater mass of particulate matter, and negate the requirement for ventilation air filter relocation at the termini.

[0052] The ventilation car portion V' and shortened passenger compartments 100' are based on a standard trailer carriage 100. The integrity of the structural chassis of the carriage would be maintained, and would include open mesh service and emergency egress flooring areas 110 to allow the through passage of ventilation air. The ventilation car V' may have a greater ventilation air capacity than that of car V, which can be achieved by the inclusion of an extra fan set, located under the corridor.

[0053] Figures 15 to 18 illustrate a third use for the air curtain generator of the invention, to mount an underground installation ventilation shaft fan unit. Figure 15 is a schematic illustration of a ventilation shaft 201 extending from the surface to an underground mine or tunnel 202. A service room 203 is shown at the top of the ventilation shaft 201, and a ventilation fan capsule 204 is shown near the top of the shaft. The ventilation fan capsule 204 is shown in greater detail in Figures 16 and 17.

[0054] The ventilation fan capsule 204 comprises an annular housing 205 with a central axial aperture 206 therethrough. Mounted centrally in the aperture 206 is an axial flow fan 207 which is used to generate the flow of ventilation air upwardly through the ventilation shaft 201 to the surface or downwardly through the ventilation shaft 201 to the underground installation 202. That flow of ventilation air requires a good air seal between the capsule wall and the interior of the ventilation shaft for maximum efficiency, and that is achieved by a composite air curtain generator according to the invention. Within the annular wall of the housing 205 are mounted two vertically spaced apart annular arrays of impellers 210 (three being shown in the top array as seen in Figure 17) which supply a pair of annular plenum chambers 211. Air passes out of each of those plenum chambers 211 past flow diverter vanes 212 which separate it into a pair of mutually divergent air curtains directed against the internal wall of the ventilation shaft 201. The top and bottom air curtains as illustrated send their air directly back through collection zones to intakes for the impellers 210, but the two central air curtains which are mutually convergent create a zone of higher air pressure at the centre of the composite air curtain which is formed by the impellers 210, the plenum chambers 211 and the vanes 212. The ventilation capsule in use is therefore spaced from the inner wall of the ventilation shaft 201 but maintains a good air seal with that wall to resist the back-flow of ventilation air pumped up or down the shaft 201 by the fan 207.

[0055] The ventilation capsule is suspended in the ventilation shaft on cables 220 as shown in Figure 18. Preferably

lightly sprung alignment wheels (not shown) are arranged around the outer edge of the capsule 204 to protect it and the shaft wall as it is moved up and down the shaft 201 to and from its working height. If the capsule needs to be lifted completely out of the ventilation shaft 201 for maintenance purposes, it can be lifted up by those cables 220. If there is a power failure causing the ventilation fan 207 or the air curtain impellers 210 to stop working, the ventilation capsule 204 must be lifted automatically out of the ventilation shaft 201 in order to create an unobstructed passage for natural convection ventilation air. To achieve an automatic lifting of the capsule 204 out of the shaft 201 in the case of a power failure, the cables 220 are preferably connected to a counter-weight 221 (see Figure 18) such that a certain power consumption is needed to lower the capsule into the shaft against the weight of the counter-weight and to maintain it there. In the case of a power failure the counterweight acts automatically to raise the capsule out of the shaft, from the position shown in broken lines to the position shown in solid lines Figure 18.

[0056] If the ventilation capsule 204 is used to draw warm air out of the underground installation, then that warm air is preferably passed through a heat exchanger (not shown) in order to extract the heat for local surface uses such as the heating of municipal buildings, swimming baths, etc. Advantageously the raising of the capsule 204 to the position shown in solid line in Figure 18 is sufficient automatically to move baffles (not shown) which divert away from the heat exchanger any warm air flow rising up the ventilation shaft 201 by convection alone and to discharge that air flow freely to atmosphere.

[0057] The above three illustrated embodiments of alternative uses for the air curtain generator of the invention (Figures 5 to 7, Figures 8 to 15 and Figures 16 to 18) all utilize the advantage of the enhanced air seal created by the doubly divergent component air curtains. The angles at which the component air curtains are presented vary depending on the gap between the walls. For a narrow gap such as that shown in Figure 16 the individual air curtains may be inclined at up to 60° to the normal, whereas for larger sized gaps the individual air curtains are preferably inclined at no more than about 14° to the normal.

Claims

1. An air curtain generator for generating a composite air curtain (8,9,10,11) across an opening between facing walls, which air curtain resists or partially resists the flow of external air between the walls and past the air curtain, comprising:
 - a row of four air curtain generators (1,2,3,4) arranged in two adjacent but mutually spaced pairs (1,2 and 3,4) on or in one of the walls, each pair of generators comprising one or more plenum chambers (5,6) having air inlet means supplied by one or more air flow impellers; and
 - exit aperture means for the or each plenum chamber (5,6) being provided with one or more directional elements for directing the flow of air out of the associated plenum chamber as an air curtain (8,9,10,11) towards the opposite wall; **characterized in that** the directional elements of the air curtain generators of each pair (1,2,3,4) direct their respective air curtains (8,9,10,11) at a divergent angle one relative to the other, with the air curtain generator of one pair (1,2) which is adjacent to but mutually spaced from the air curtain generator of the other pair (3,4) having directional elements which direct their respective air curtains (8,9 and 10,11) at a convergent angle one relative to the other, thereby establishing alternate zones of relatively low and relatively high air pressure within the composite air curtain, the better to resist or partially resist the flow of external air between the walls and past the air curtain (8,9,10,11).
2. An air curtain generator according to claim 1, wherein each of the air curtains (8,9,10,11) is directed by the directional elements at an angle between 14° and 60° to the normal.
3. An air curtain generator according to claim 1 or claim 2, wherein the air curtain generators (1,2,3,4) draw their air supply from one or more air collection zones positioned laterally outwardly of the adjacent but mutually spaced pairs of air curtain generators.
4. An air curtain generator according to claim 1 or claim 2, wherein the air curtain generators (1,2,3,4) draw their air supply from one or more air collection zones positioned between the mutually spaced pairs of air curtain generators.
5. An air curtain generator according to any preceding claim, wherein a second row of air curtain generators similar to the said row of air curtain generators (1,2,3,4) is arranged in two adjacent but mutually spaced pairs on or in the other of the walls, the air curtain generators of the two rows facing one another and each establishing its composite air curtain (8,9,10,11) across half or approximately half of the opening.
6. Means for creating a non-physical barrier across an access to a building to resist the passage of ambient air from

outside into the building and the passage of internal air out of the building, comprising an air curtain generator (607) according to any preceding claim installed between facing walls of an access lobby of the building.

7. Means for creating a non-physical barrier across an access doorway (604) to a building to resist the passage of ambient air from outside into the building and the passage of internal air out of the building, comprising a pair of mutually facing walls for positioning immediately adjacent to the doorway (604) for the full height of the doorway, an air curtain generator (607) according to any of claims 1 to 5 installed between the mutually facing walls for generating its composite air curtain (608,609,610,611) between the walls for the full height of the doorway (604), and means for generating a further air curtain (613), being a generally horizontal air curtain between the walls across the top of the composite air curtain.
8. Means according to claim 5 or claim 6, wherein the air curtain generator (607) is an air curtain generator according to claims 4 and 5.
9. An underground railway tunnel ventilation apparatus comprising train rolling stock (V) having the cross-sectional outline of a train carriage and, carried by that rolling stock, an air curtain generator (1,2,3,4) according to claim 3 which in normal mode of operation draws in air from both ends of the rolling stock and ejects it as a continuous composite air curtain (72,73) extending in use from the outer periphery of the rolling stock to the internal surfaces of a single track tunnel (95) along which the rolling stock (V) is designed to move.
10. A ventilation apparatus according to claim 9, further comprising means (104,105,106) for generating a flow of ventilation air axially through the rolling stock (V).
11. A ventilation apparatus according to claim 10, wherein the means for generating the flow of ventilation air comprises a plurality of reversible axial flow fans and associated ductwork leading from a grille array (104) at one end of the rolling stock (V) to a grille array (105) at the other end of the rolling stock (V).
12. A ventilation apparatus according to claim 11, wherein the ductwork includes air filters for the ventilation air.
13. A ventilation capsule (204) for providing a flow of air to or from an underground installation (202) through a ventilation shaft (201), comprising an annular housing (205) carrying an axial flow ventilation fan (207) at its centre, and an air curtain generator according to claim 3 for creating an annular composite air curtain around the outer periphery of the housing (205) between the housing outer wall and a wall of the ventilation shaft (201), the annular composite air curtain resisting the back-flow of air across that air curtain.
14. A ventilation capsule (204) according to claim 13, which is suspended on cables (220) and is counterbalanced by a counterbalance weight (221) which automatically lifts the capsule (204) completely out of the ventilation shaft (201) in the event of a power failure.
15. A ventilation capsule (204) according to claim 13 or claim 14, wherein guide wheels or rollers are arranged around the periphery of the capsule (204) to guide the capsule smoothly along the ventilation shaft wall (201) as it is raised and lowered, and to protect the ventilation shaft wall.

Patentansprüche

1. Luftvorhangerzeuger zum Erzeugen eines Verbundluftvorhangs (8, 9, 10, 11) quer über eine Öffnung zwischen zueinander zeigenden Wänden, wobei der Luftvorhang der Strömung äußerer Luft zwischen den Wänden und hinter dem Luftvorhang Widerstand entgegengesetzt oder teilweise Widerstand entgegengesetzt, welcher folgende Merkmale aufweist:

eine Reihe von vier Luftvorhangerzeugern (1, 2, 3, 4), welche in zwei benachbarten, jedoch zueinander beabstandeten Paaren (1, 2 und 2, 4) an oder in einer der Wände angeordnet sind, wobei jedes Paar von Erzeugern eine oder mehrere Luftkammern (5, 6) aufweist, welche Lufteinlasseinrichtungen haben, welche von einem oder mehreren Luftströmungsverdichtern gespeist werden, und Ausgangsöffnungseinrichtungen für die oder jede Luftkammer (5, 6), welche mit einem oder mehreren Lenkelementen zum Lenken des Luftstroms aus den zugeordneten Luftkammern hinaus als ein Luftvorhang (8, 9, 10, 11) zu der gegenüber liegenden Wand versehen sind,

dadurch gekennzeichnet, dass

die Lenkelemente der Luftvorhangerzeuger jedes Paares (1, 2, 3, 4) ihre entsprechenden Luftvorhänge (8, 9, 10, 11) unter einem, einer zu dem anderen, relativ auseinander gehenden Winkel lenken, wobei der Luftvorhangerzeuger eines Paares (1, 2), welcher sich in der Nähe jedoch gegenseitig von dem Luftvorhangerzeuger des anderen Paares (3, 4) beabstandet befindet, Lenkelemente aufweist, welche ihre entsprechenden Luftvorhänge (8, 9 und 10, 11) unter, einem zu dem anderen, relativ zusammenlaufendem Winkel lenkt, wodurch wechselnde Zonen mit relativ niedrigem und relativ hohem Luftdruck in dem Verbundluftvorhang geschaffen werden, um der Strömung der äußeren Luft zwischen den Wänden und hinter dem Luftvorhang (8, 9, 10, 11) besseren Widerstand oder teilweisen Widerstand entgegenzusetzen.

2. Luftvorhangerzeuger nach Anspruch 1, wobei jeder der Luftvorhänge (8, 9, 10, 11) durch die Lenkelemente unter einem Winkel zwischen 14° und 60° zur Normalen ausgerichtet ist.
3. Luftvorhangerzeuger nach Anspruch 1 oder Anspruch 2, bei welchem die Luftvorhangerzeuger (1, 2, 3, 4) ihre Luftversorgung von einer oder mehreren Luftsammelzonen, welche seitlich auswärts der benachbarten, jedoch zueinander beabstandeten Paare von Luftvorhangerzeugern angeordnet sind.
4. Luftvorhangerzeuger nach Anspruch 1 oder Anspruch 2, bei welchem die Luftvorhangerzeuger (1, 2, 3, 4) ihre Luftversorgung von einer oder mehreren Luftsammelzonen beziehen, welche zwischen den zueinander beabstandeten Paaren der Luftvorhangerzeuger angeordnet sind.
5. Luftvorhangerzeuger nach einem der vorhergehenden Ansprüche, wobei eine zweite Reihe von Luftvorhangerzeugern ähnlich der genannten Reihe von Luftvorhangerzeugern (1, 2, 3, 4) in zwei benachbarten, jedoch zueinander beabstandeten Paaren an oder in der anderen der Wände angeordnet ist, wobei die Luftvorhangerzeuger der beiden Reihen zueinander zeigen und jede ihren Verbundluftvorhang (8, 9, 10, 11) quer über die Hälfte oder annähernd die Hälfte der Öffnung bilden.
6. Einrichtung zum Herstellen einer nichtphysischen Barriere quer zu einem Zugang zu einem Gebäude, um den Durchgang einer Umgebungsluft von außen in das Gebäude und den Durchgang von innerer Luft aus dem Gebäude hinaus zu behindern, mit einem Luftvorhangerzeuger (607) nach einem der vorhergehenden Ansprüche, welcher zwischen zueinander zeigenden Wänden einer Eingangslobby der Gebäudes installiert sind.
7. Einrichtung zum Herstellen einer nichtphysischen Barriere quer zu einer Zugangstür eines Gebäudes (604), um den Durchgang einer Umgebungsluft von außen in das Gebäude und den Durchgang von innerer Luft aus dem Gebäude hinaus zu behindern, mit einem Paar zueinander zeigender Wände zur Anordnung direkt neben dem Eingang (604) über die volle Höhe des Eingangs, mit einem Luftvorhangerzeuger (607) gemäß einem der Ansprüche 1 bis 5, welcher zwischen den zueinander zeigenden Wänden zum Erzeugen seines Verbundluftvorhangs (608, 609, 610, 611) zwischen den Wänden über die volle Höhe des Eingangs (604) installiert ist, und mit einer Einrichtung zum Erzeugen eines weiteren Luftvorhangs (613), welcher ein im Wesentlichen horizontaler Luftvorhang zwischen den Wänden quer über die Oberkante des Verbundluftvorhangs ist.
8. Einrichtung nach Anspruch 5 oder Anspruch 6, wobei der Luftvorhangerzeuger (607) ein Luftvorhangerzeuger nach Anspruch 4 und 5 ist.
9. Ventilationsvorrichtung für einen U-Bahntunnel, mit Rollmaterial (V), welches den Querschnitt eines Zugwagens und, getragen von dem Rollmaterial, einen Luftvorhangerzeuger (1, 2, 3, 4) gemäß Anspruch 3 hat, welcher im normalen Betriebsmodus von beiden Enden des Rollmaterials Luft einsaugt und sie als kontinuierlicher Verbundluftvorhang (72, 73) ausstößt, welcher sich im Betrieb von dem äußeren Umfang des Rollmaterials zu den inneren Oberflächen eines eingleisigen Tunnels (95) erstreckt, entlang welchem sich das Rollmaterial (V) bewegen soll, ausstößt.
10. Ventilationsvorrichtung nach Anspruch 9, mit einer Einrichtung (104, 105, 106) zum Erzeugen einer Luftströmung axial durch das Rollmaterial (V).
11. Ventilationsvorrichtung nach Anspruch 10, bei der die Einrichtung zum Erzeugen der Strömung der Ventilationsluft eine Vielzahl von umkehrbaren Axialströmungsventilatoren und ein zugeordnetes Kanalsystem aufweist, welches von einer Lüftungsanordnung (104) an einem Ende des Rollmaterials (V) zu einer Lüftungsanordnung (105) an dem anderen Ende des Rollmaterials (V) leitet.

12. Ventilationsvorrichtung nach Anspruch 11, bei welcher das Kanalsystem Luftfilter für die Ventilationsluft aufweist.
13. Ventilationskapsel (204) zum Schaffen einer Luftströmung zu oder von einer U-Bahninstallation (202) durch einen Ventilationsschacht (201), mit einem ringförmigen Gehäuse (205), welches in seiner Mitte einen Axialströmungs-ventilationsverdichter (207) trägt, und mit einem Luftvorhangerzeuger gemäß Anspruch 3 zum Schaffen eines ringförmigen Verbundluftvorhangs um den äußeren Umfang des Gehäuses (205) zwischen der äußeren Wand des Gehäuses und einer Wand des Ventilationsschachts (201), wobei der ringförmige Verbundluftvorhang der Rückströmung von Luft quer zu dem Luftvorhang widersteht.
14. Ventilationskapsel (204) nach Anspruch 13, welche an Kabeln (220) aufgehängt ist und über ein Gegengewicht (221) ausbalanciert ist, welches die Kapsel (204) im Fall eines Stromausfalls automatisch vollständig aus dem Ventilationsschacht (201) hebt.
15. Ventilationskapsel (204) nach Anspruch 13 oder Anspruch 14, bei welcher Führungsräder oder -rollen um den Umfang der Kapsel (204) herum angeordnet sind, um die Kapsel entlang der Wand (201) des Ventilationsschachts gleichmäßig zu führen, wenn sie angehoben und abgesenkt wird, und um die Wand des Ventilationsschachts zu schützen.

Revendications

1. Générateur de rideau d'air pour générer un rideau d'air composite (8, 9, 10, 11) à travers une ouverture entre des parois en vis-à-vis, lequel rideau d'air résiste ou résiste partiellement au flux d'air externe entre les parois et au-delà du rideau d'air, comportant :

une rangée de quatre générateurs de rideau d'air (1, 2, 3, 4) disposés en deux paires adjacentes mais mutuellement espacées (1, 2 et 3, 4) sur ou dans l'une des parois, chaque paire de générateurs comportant une ou plusieurs chambres de répartition (5, 6) ayant des moyens d'admission d'air fournis par une ou plusieurs turbines de flux d'air, et

des moyens d'ouverture de sortie pour la chambre ou chacune des chambres de répartition (5,6) étant munis d'un ou plusieurs éléments directionnels pour diriger le flux d'air à l'extérieur de la chambre de répartition associée comme un rideau d'air (8, 9, 10, 11) en direction de la paroi opposée,
caractérisé en ce que les éléments directionnels des générateurs de rideau d'air de chaque paire (1, 2, 3, 4) dirigent leurs rideaux d'air respectifs (8, 9, 10, 11) selon un angle divergent l'un par rapport à l'autre, avec le générateur de rideau d'air d'une paire (1, 2) qui est adjacent au générateur de rideau d'air de l'autre paire (3, 4) mais mutuellement espacé de celui-ci ayant des éléments directionnels qui dirigent leurs rideaux d'air respectifs (8, 9 et 10, 11) selon un angle convergent l'un par rapport à l'autre, de manière à établir des zones alternées de pression d'air relativement basse et relativement haute à l'intérieur du rideau d'air composite, afin de mieux résister ou partiellement résister au flux d'air externe entre les parois et au-delà du rideau d'air (8, 9, 10, 11).
2. Générateur de rideau d'air selon la revendication 1, dans lequel chacun des rideaux d'air (8, 9, 10, 11) est dirigé par les éléments directionnels selon un angle compris entre 14° et 60° par rapport à la normale.
3. Générateur de rideau d'air selon la revendication 1 ou la revendication 2, dans lequel les générateurs de rideau d'air (1, 2, 3, 4) puisent leur alimentation en air d'une ou plusieurs zones de collecte d'air positionnées latéralement vers l'extérieur des paires adjacentes mais mutuellement espacées de générateurs de rideau d'air.
4. Générateur de rideau d'air selon la revendication 1 ou la revendication 2, dans lequel les générateurs de rideau d'air (1, 2, 3, 4) puisent leur alimentation en air d'une ou plusieurs zones de collecte d'air positionnées entre les paires mutuellement espacées de générateurs de rideau d'air.
5. Générateur de rideau d'air selon l'une quelconque des revendications précédentes, dans lequel une seconde rangée de générateurs de rideau d'air similaire à ladite rangée de générateurs de rideau d'air (1, 2, 3, 4) est disposée en deux paires adjacentes mais mutuellement espacées sur ou dans l'autre des parois, les générateurs de rideau d'air des deux rangées étant positionnés en vis-à-vis et chacun d'eux établissant son rideau d'air composite (8, 9, 10, 11) à travers la moitié ou environ la moitié de l'ouverture.

6. Moyens pour créer une barrière non physique à travers un accès à un bâtiment afin de résister au passage de l'air ambiant depuis l'extérieur dans le bâtiment et au passage de l'air interne à l'extérieur du bâtiment, comportant un générateur de rideau d'air (607) selon l'une quelconque des revendications précédentes installé entre des parois en vis-à-vis d'un hall d'accès du bâtiment.
7. Moyens pour créer une barrière non physique à travers une porte d'accès (604) à un bâtiment afin de résister au passage de l'air ambiant depuis l'extérieur dans le bâtiment et au passage de l'air interne à l'extérieur du bâtiment, comportant une paire de parois mutuellement en vis-à-vis pour un positionnement à proximité immédiatement adjacente à la porte (604) pour la hauteur totale de la porte, un générateur de rideau d'air (607) selon l'une quelconque des revendications 1 à 5 installé entre les parois mutuellement en vis-à-vis pour générer son rideau d'air composite (608, 609, 610, 611) entre les parois pour la hauteur totale de la porte (604), et des moyens pour générer un rideau d'air supplémentaire (613), étant un rideau d'air généralement horizontal entre les parois à travers le dessus du rideau d'air composite.
8. Moyens selon la revendication 5 ou la revendication 6, dans lequel le générateur de rideau d'air (607) est un générateur de rideau d'air selon les revendications 4 et 5.
9. Appareil de ventilation de tunnel ferroviaire souterrain comportant du matériel roulant (V) de train ayant le contour en section transversale d'un wagon de train et, supporté par le matériel roulant, un générateur de rideau d'air (1, 2, 3,4) selon la revendication 3 qui en mode de fonctionnement normal aspire de l'air à partir des deux extrémités du matériel roulant et le rejette en tant qu'un rideau d'air composite continu (72, 73) qui s'étend en utilisation depuis la périphérie externe du matériel roulant jusqu'aux surfaces internes d'un tunnel à simple voie (95) le long duquel le matériel roulant (V) est conçu pour se déplacer.
10. Appareil de ventilation selon la revendication 9, comportant en outre des moyens (104, 105, 106) pour générer un flux d'air de ventilation axialement à travers le matériel roulant (V).
11. Appareil de ventilation selon la revendication 10, dans lequel les moyens pour générer le flux d'air de ventilation comportent une pluralité de ventilateurs de flux axiaux réversibles et des conduits associés qui relient un réseau de grilles (104) à une extrémité du matériel roulant (V) à un réseau de grilles (105) à l'autre extrémité du matériel roulant (V).
12. Appareil de ventilation selon la revendication 11, dans lequel les conduits comprennent des filtres à air pour l'air de ventilation.
13. Capsule de ventilation (204) pour fournir un flux d'air à une installation souterraine (202) ou à partir de celle-ci à travers un arbre de ventilation (201), comportant un boîtier annulaire (205) supportant un ventilateur de flux axial (207) en son centre, et un générateur de rideau d'air selon la revendication 3 pour créer un rideau d'air composite annulaire autour de la périphérie extérieure du boîtier (205) entre la paroi externe du boîtier et une paroi de l'arbre de ventilation (201), le rideau d'air composite annulaire résistant au refoulement d'air à travers ce rideau d'air.
14. Capsule de ventilation (204) selon la revendication 13, laquelle est suspendue sur des câbles (220) et est compensée par un contrepoids (221) lequel soulève automatiquement la capsule (204) complètement hors de l'arbre de ventilation (201) dans l'éventualité d'une panne électrique.
15. Capsule de ventilation (204) selon la revendication 13 ou la revendication 14, dans laquelle des roues ou des rouleaux de guidage sont disposés autour de la périphérie de la capsule (204) pour guider la capsule en douceur le long de la paroi de l'arbre de ventilation (201) lorsqu'elle est montée et abaissée, et pour protéger la paroi de l'arbre de ventilation.

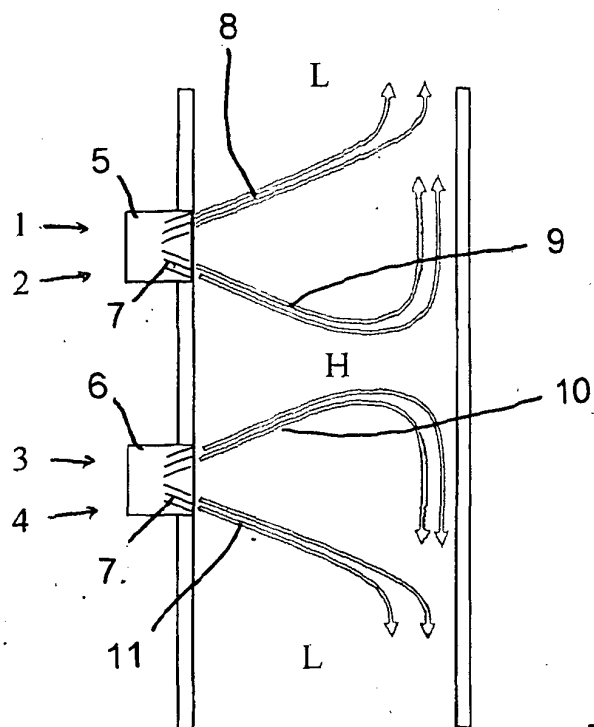


Figure 1

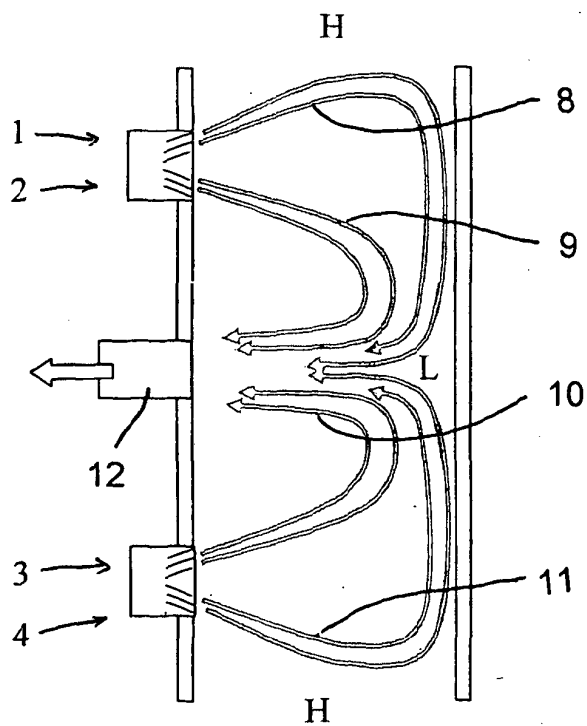


Figure 2

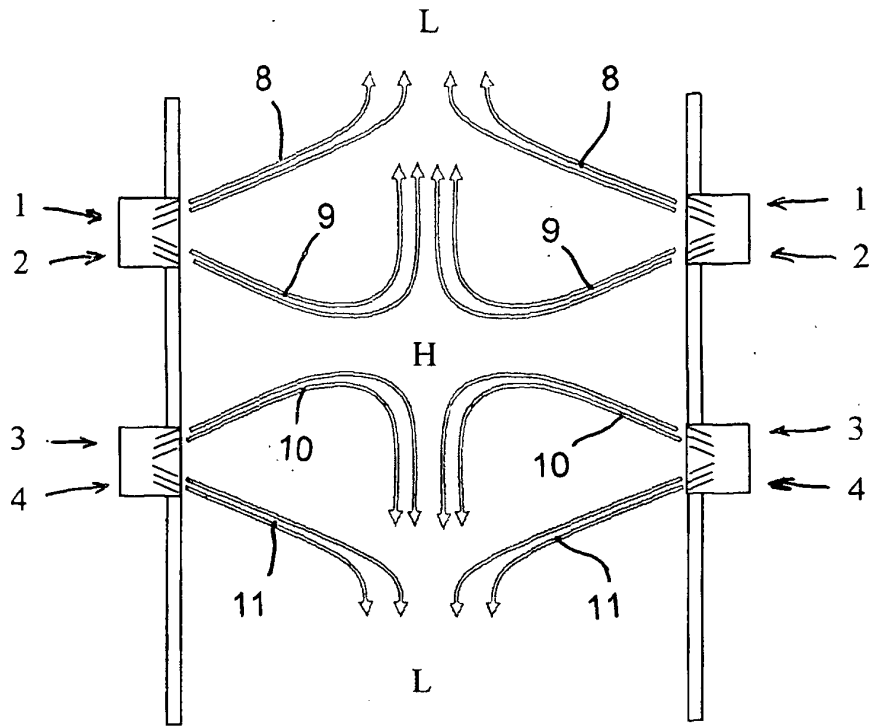


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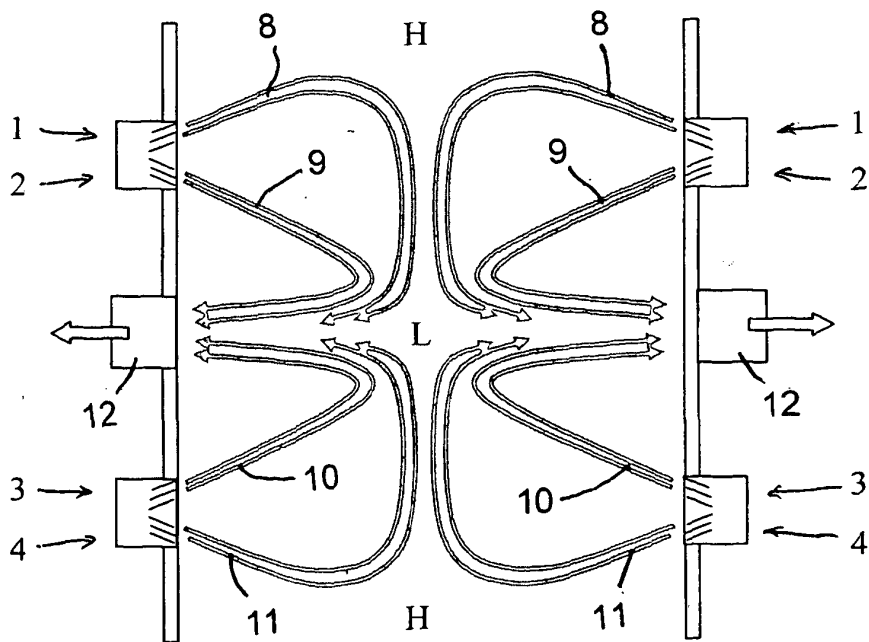


Figure 4

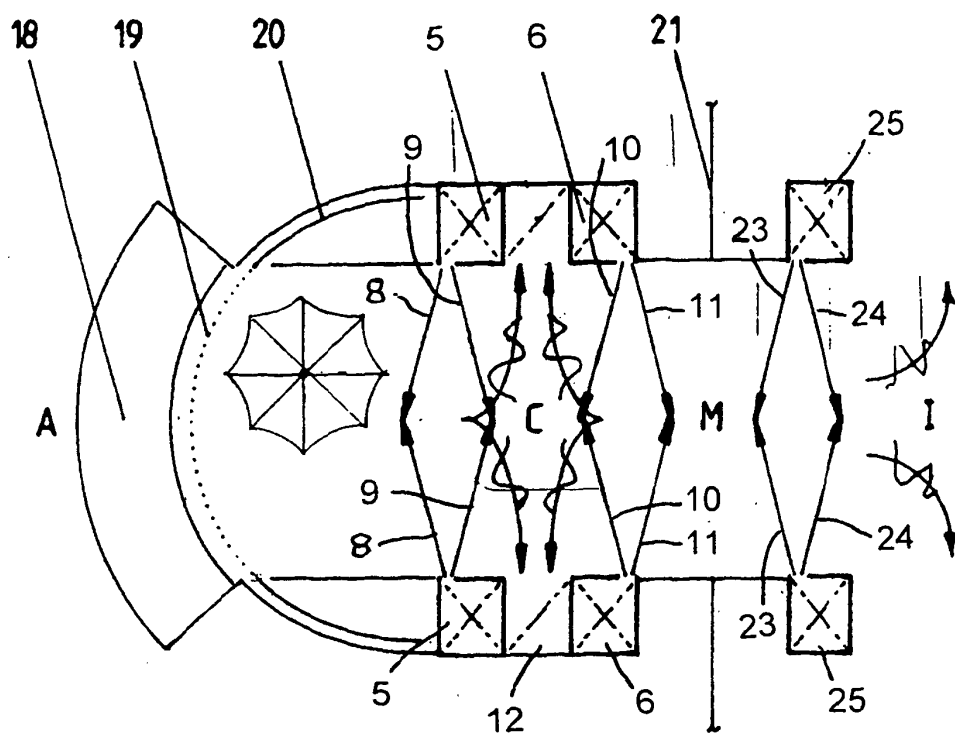


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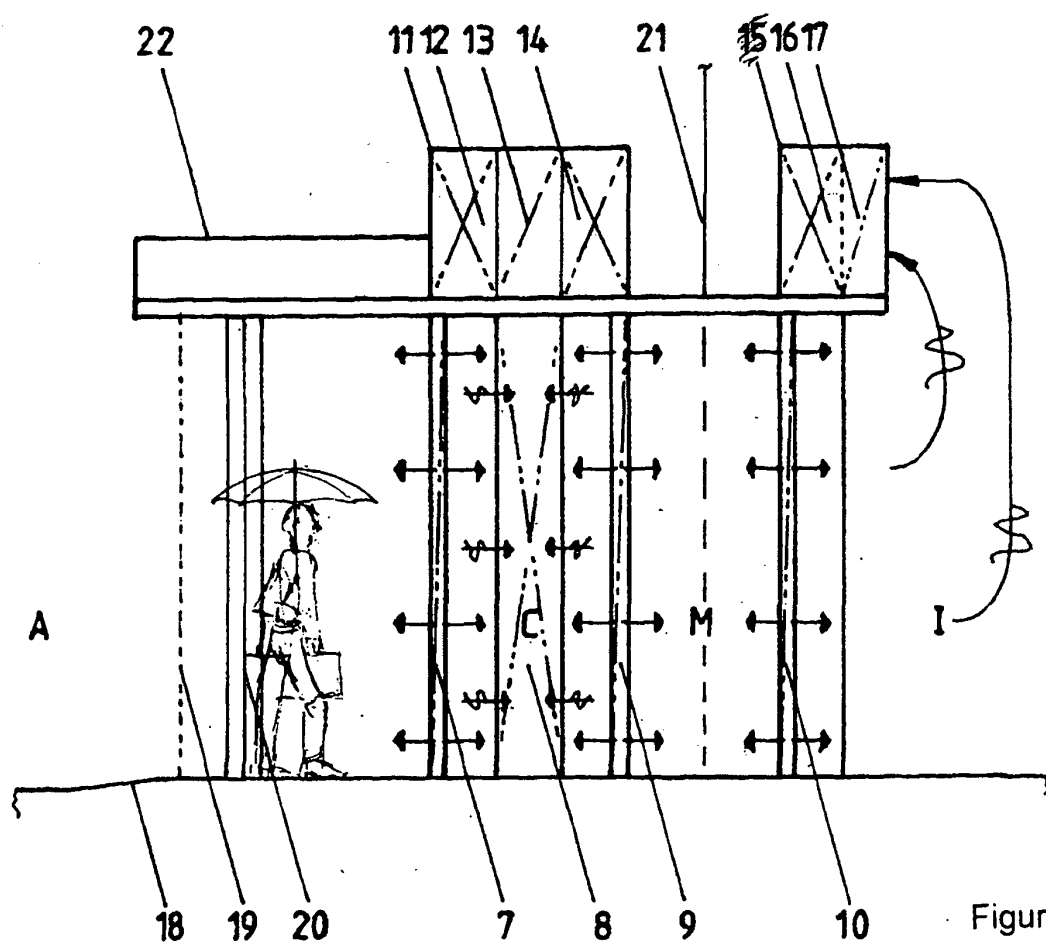
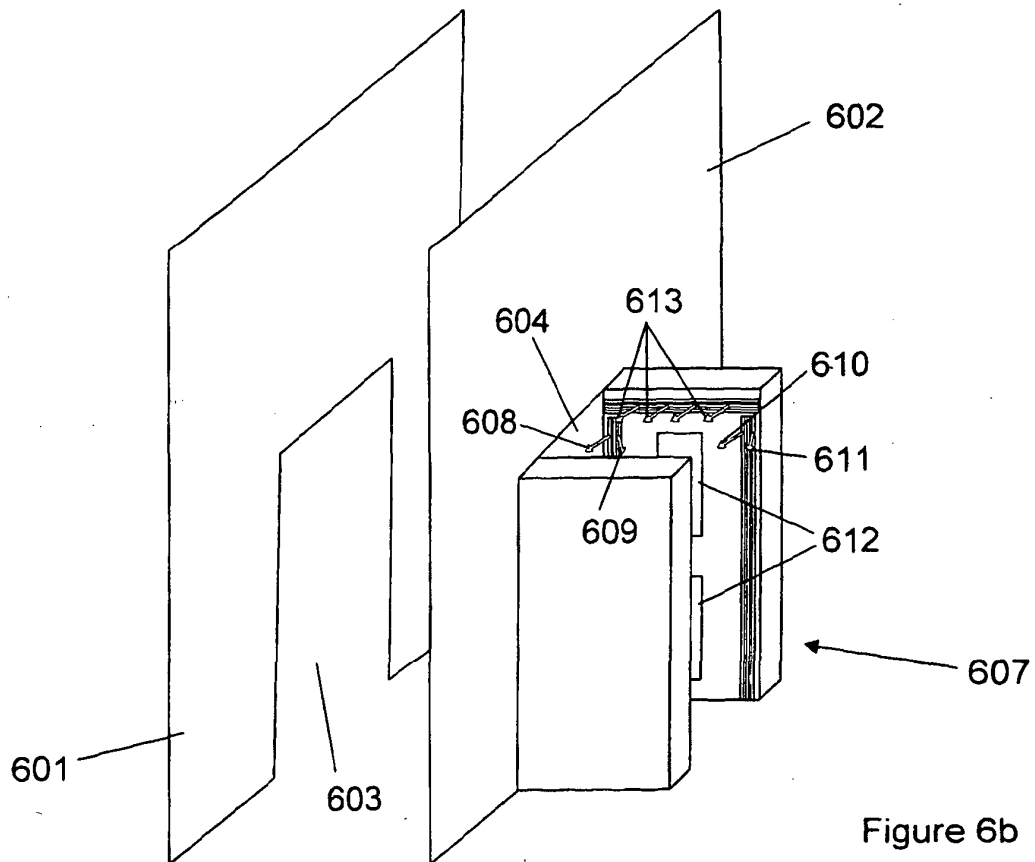
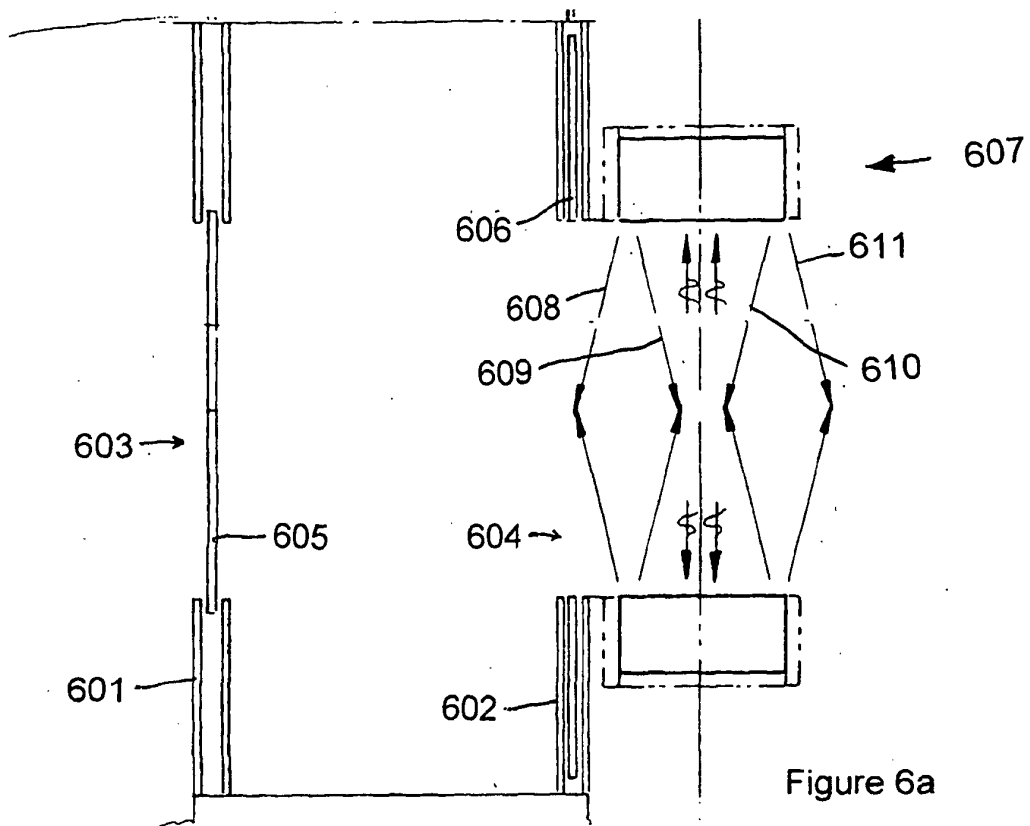


Figure 6



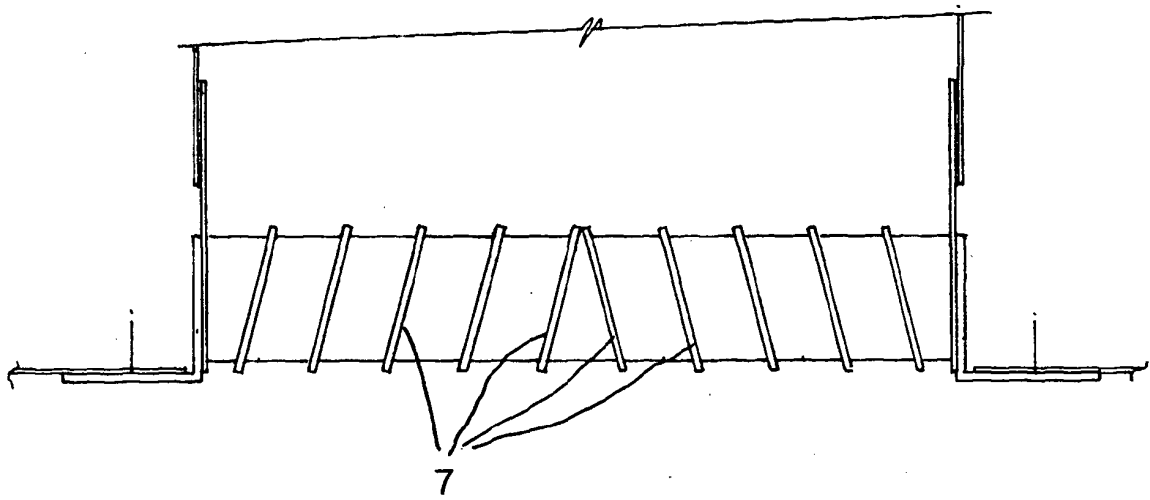


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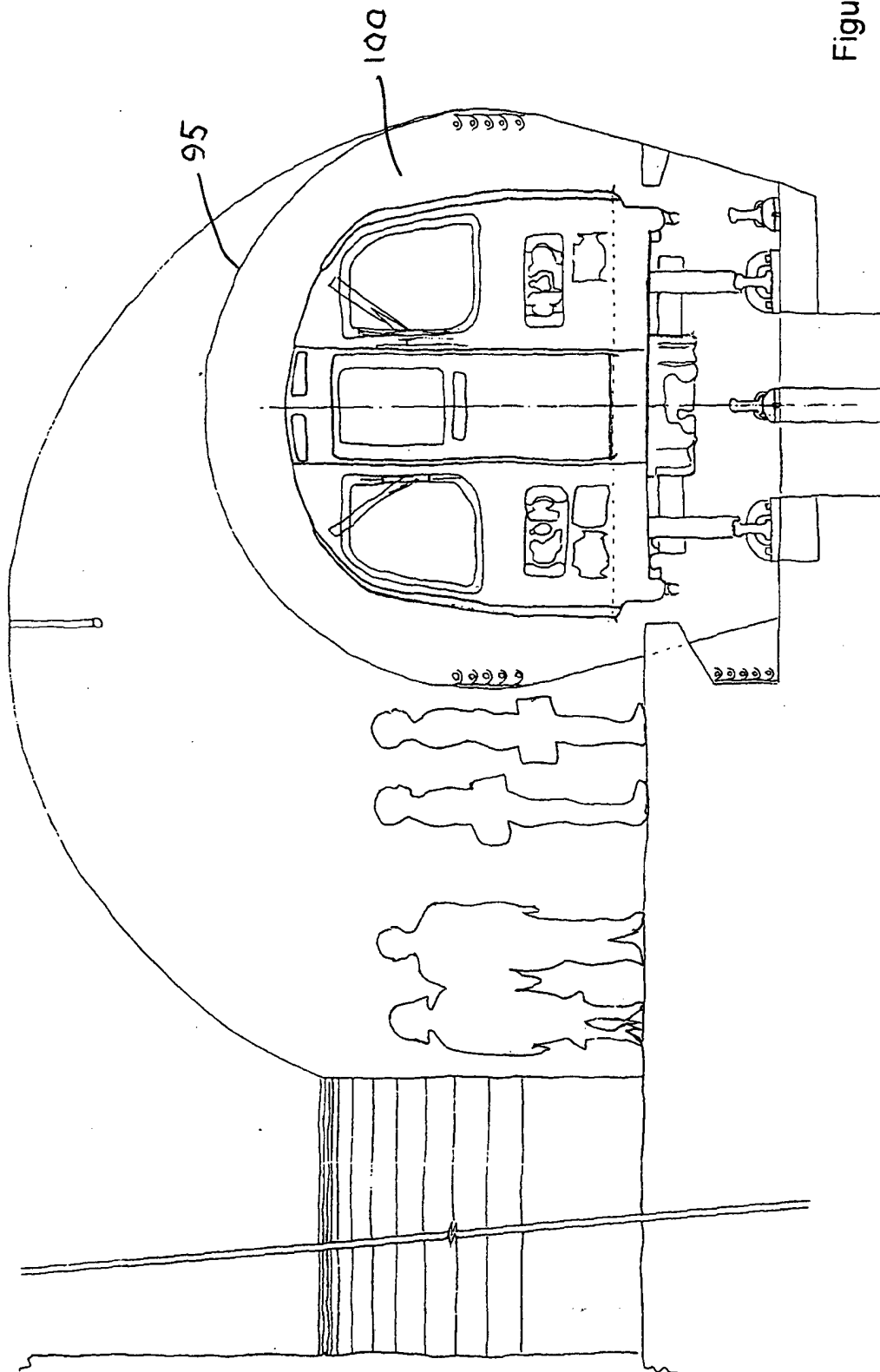
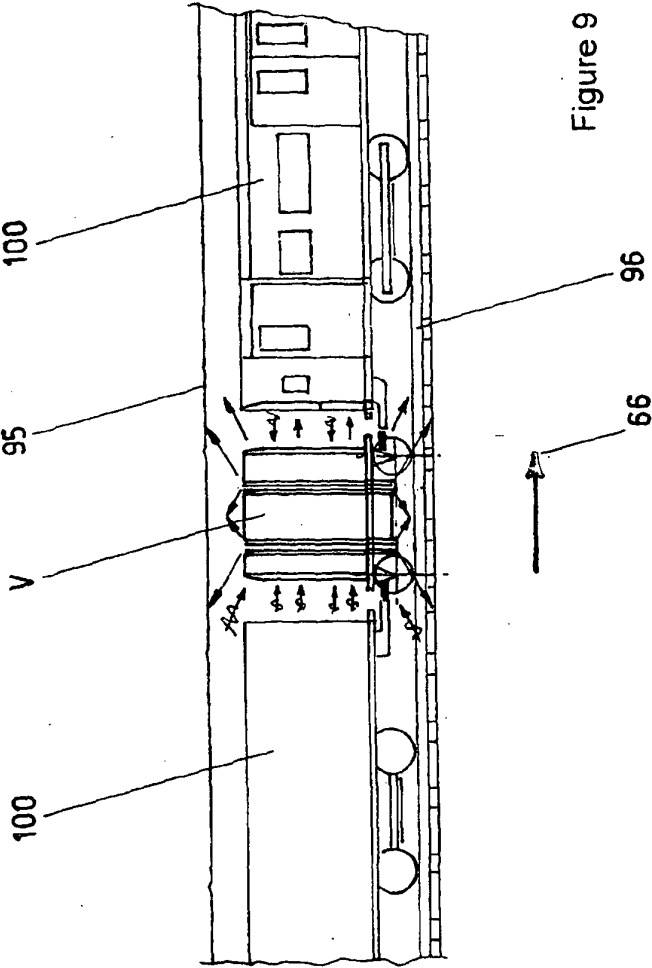
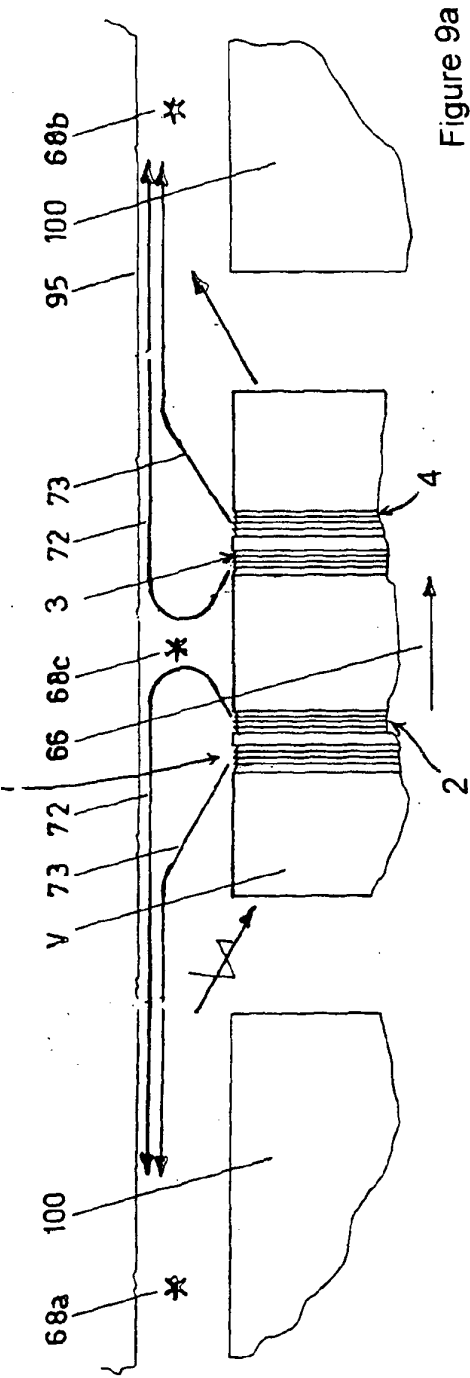


Figure 8



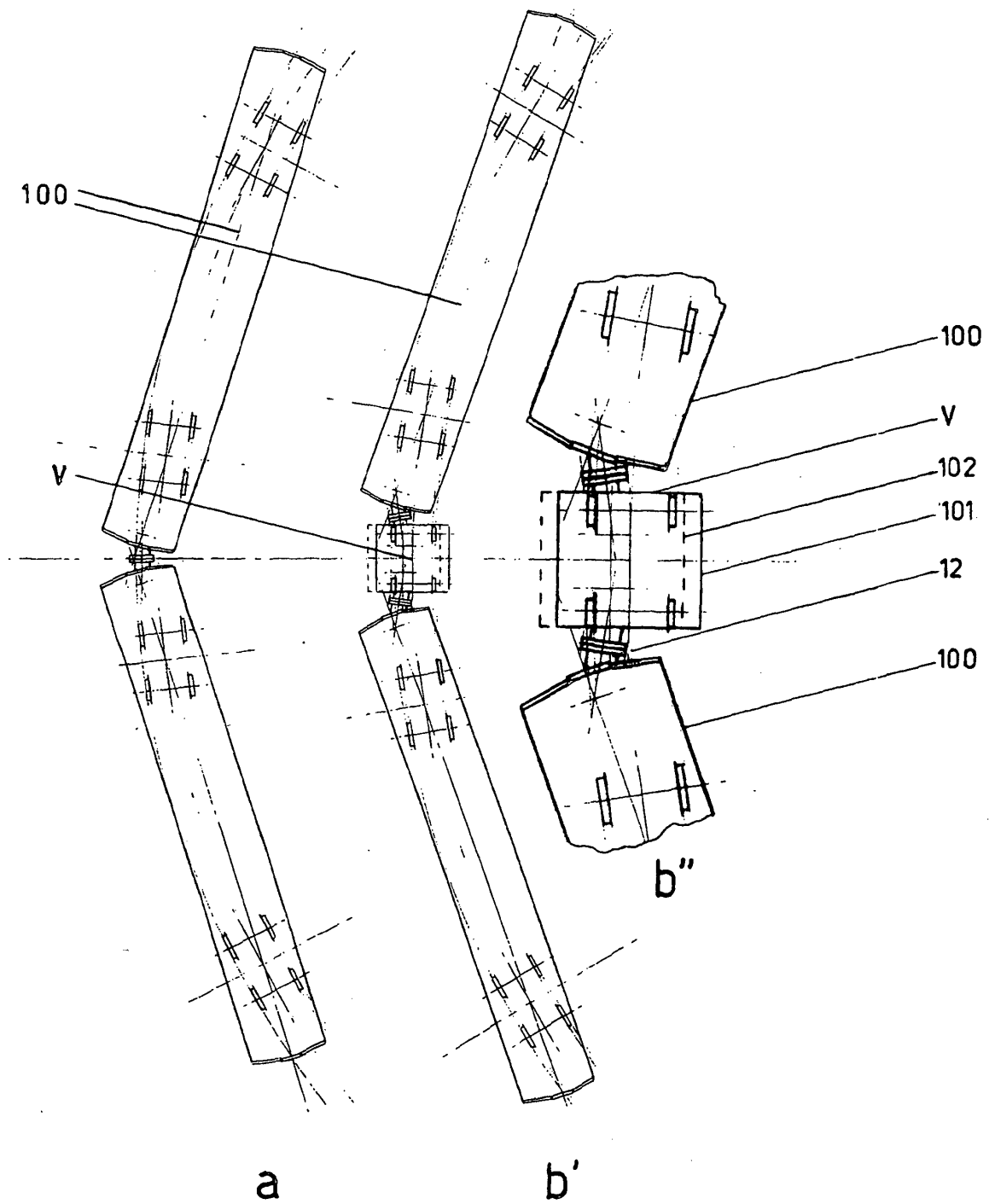


Figure 10

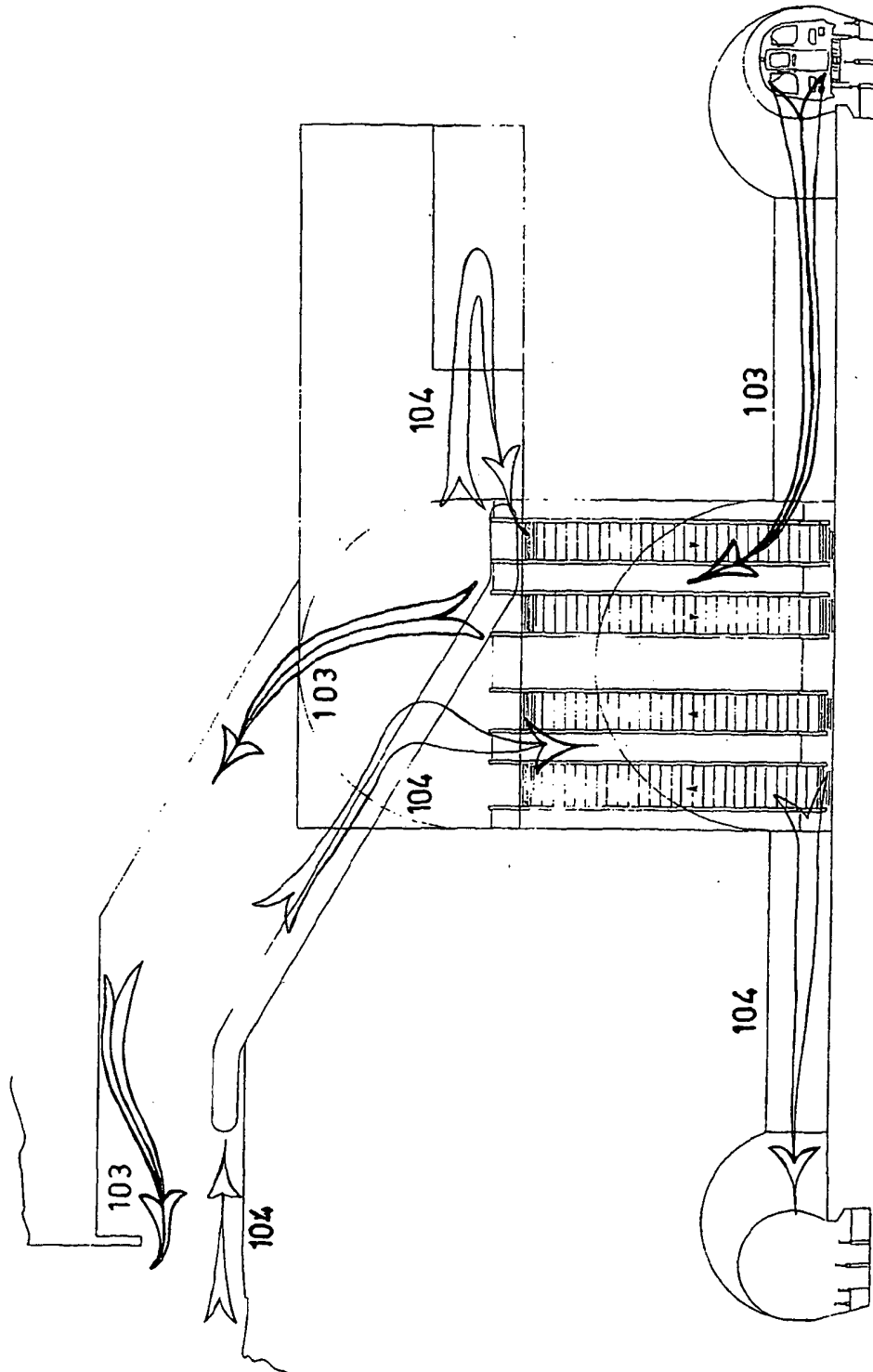


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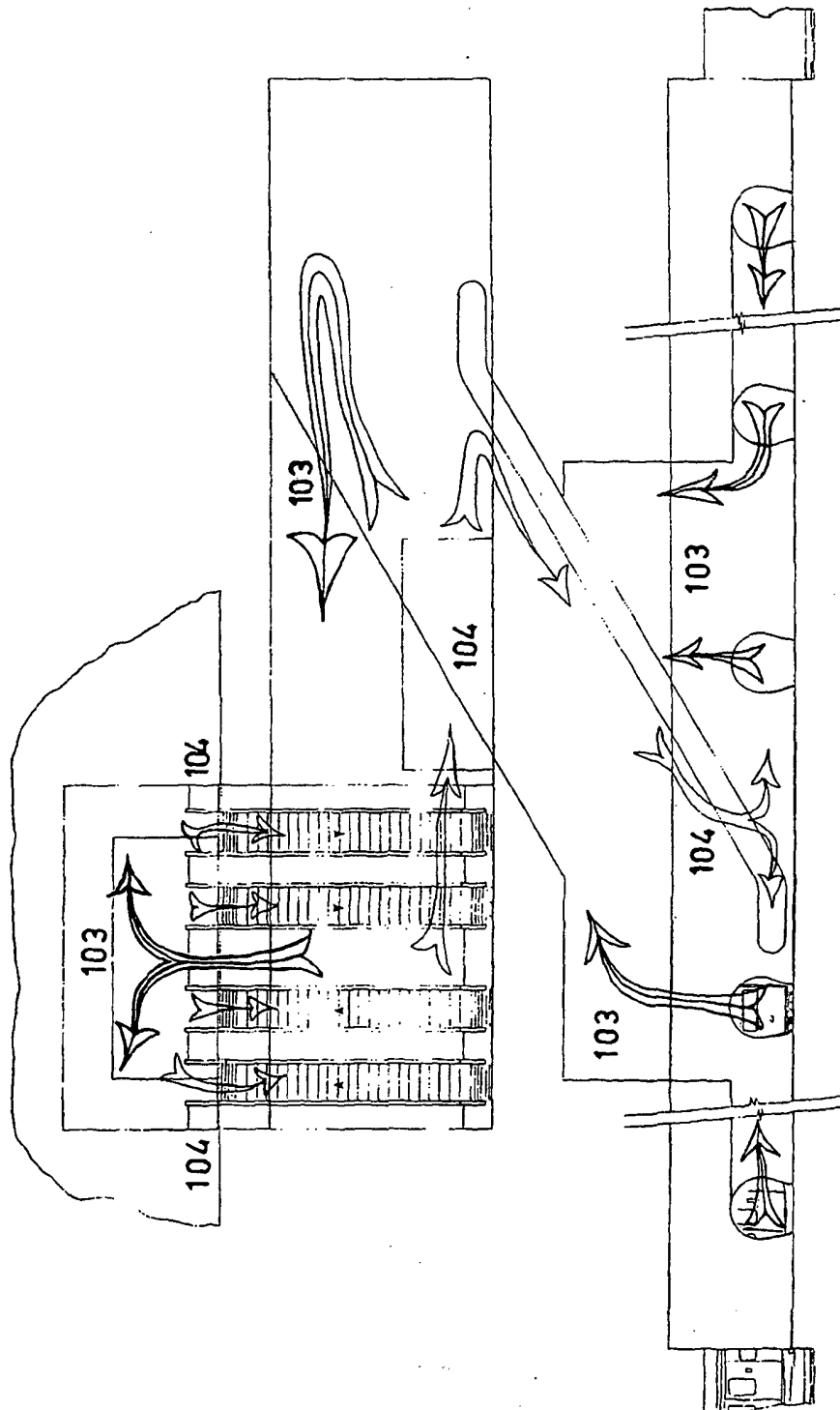


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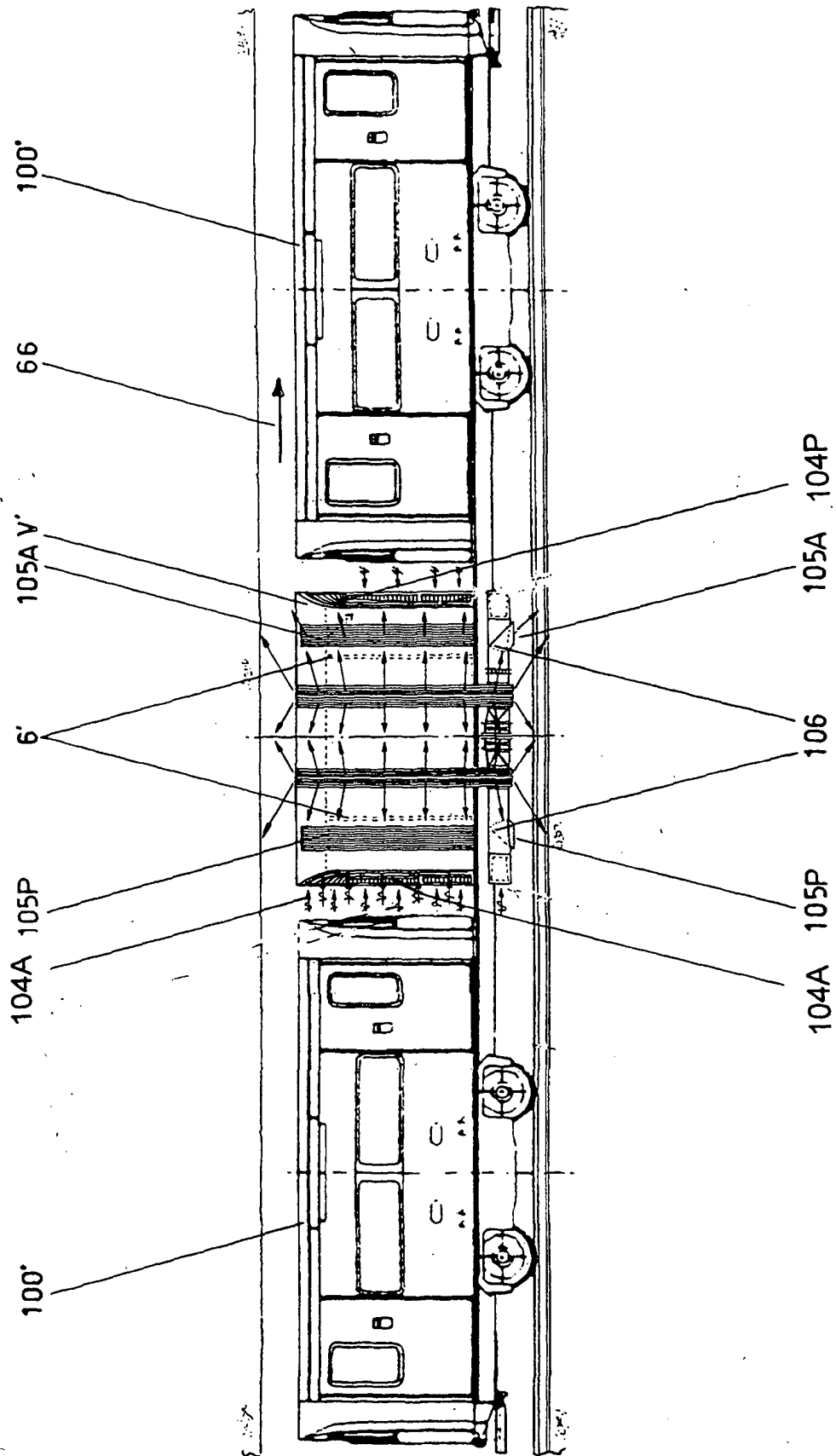


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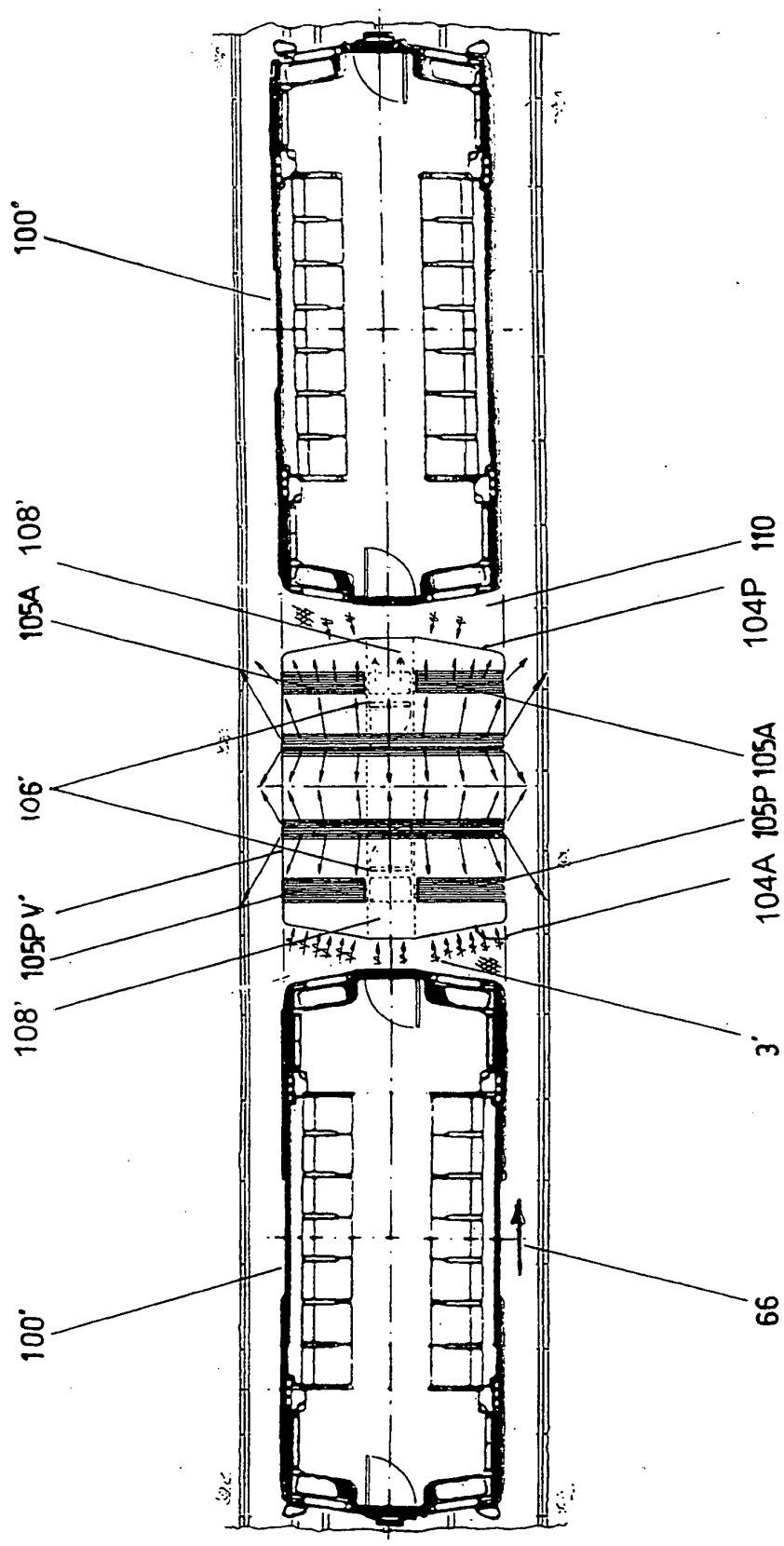


Figure 14

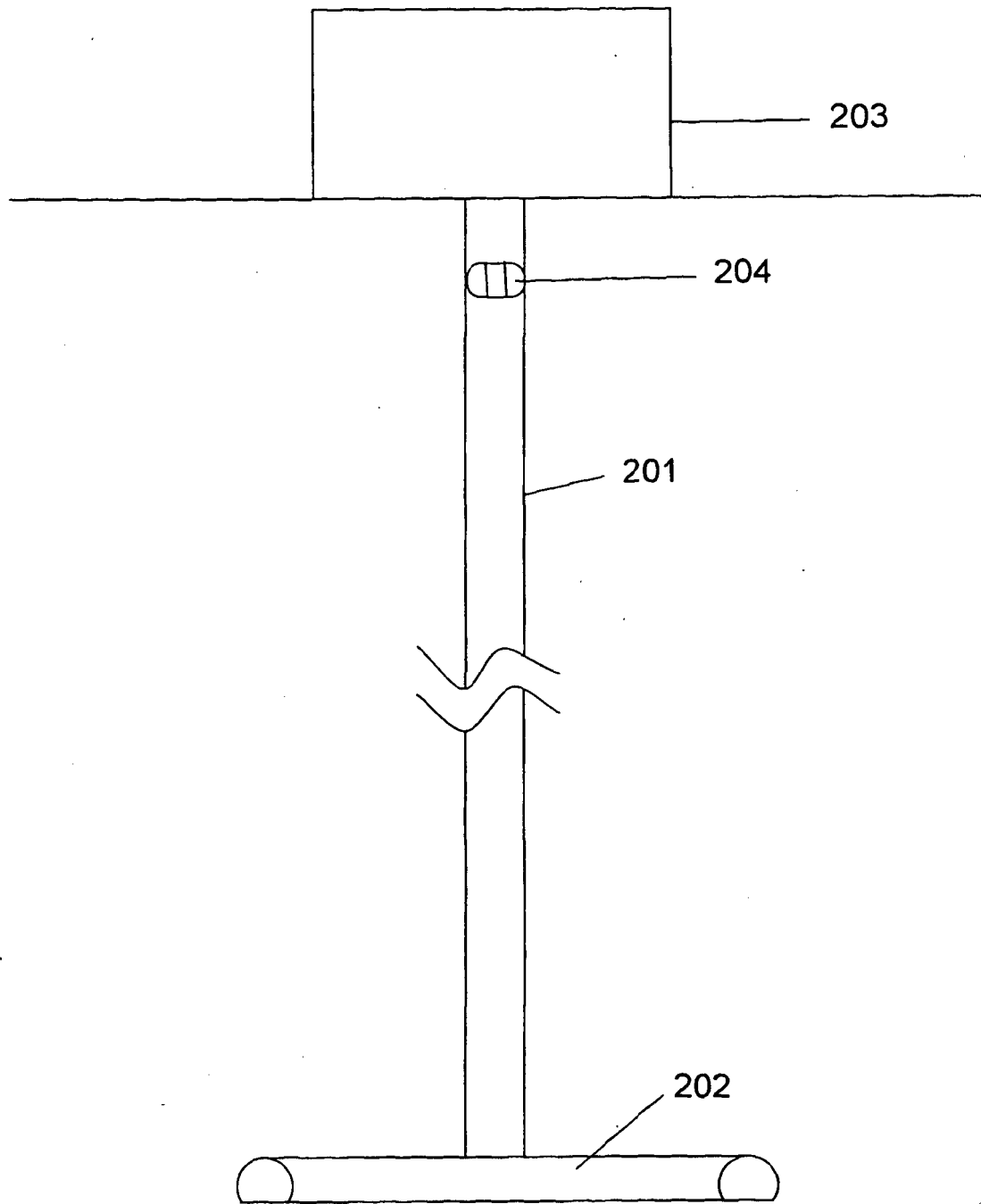


Figure 15

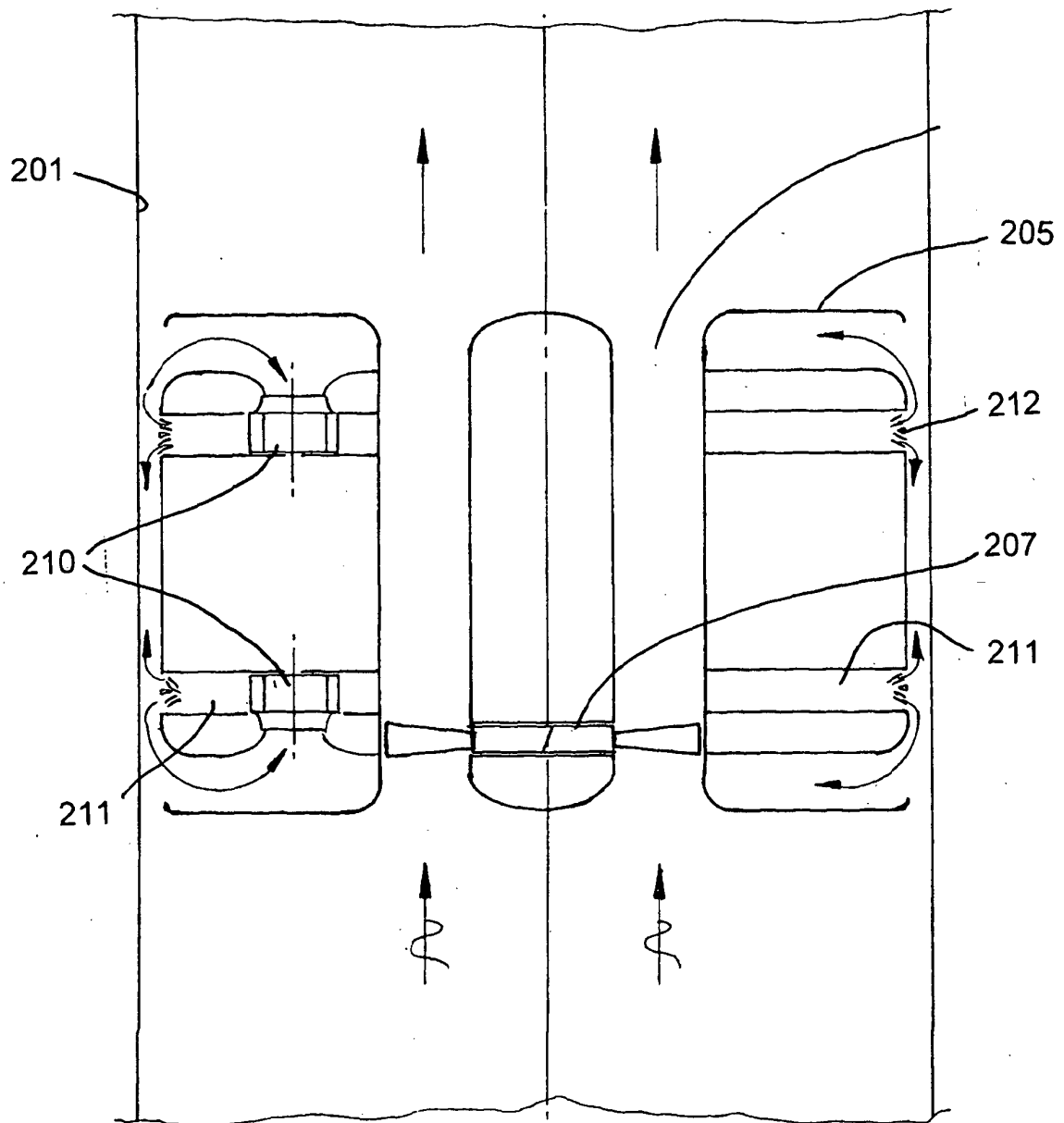


Figure 16

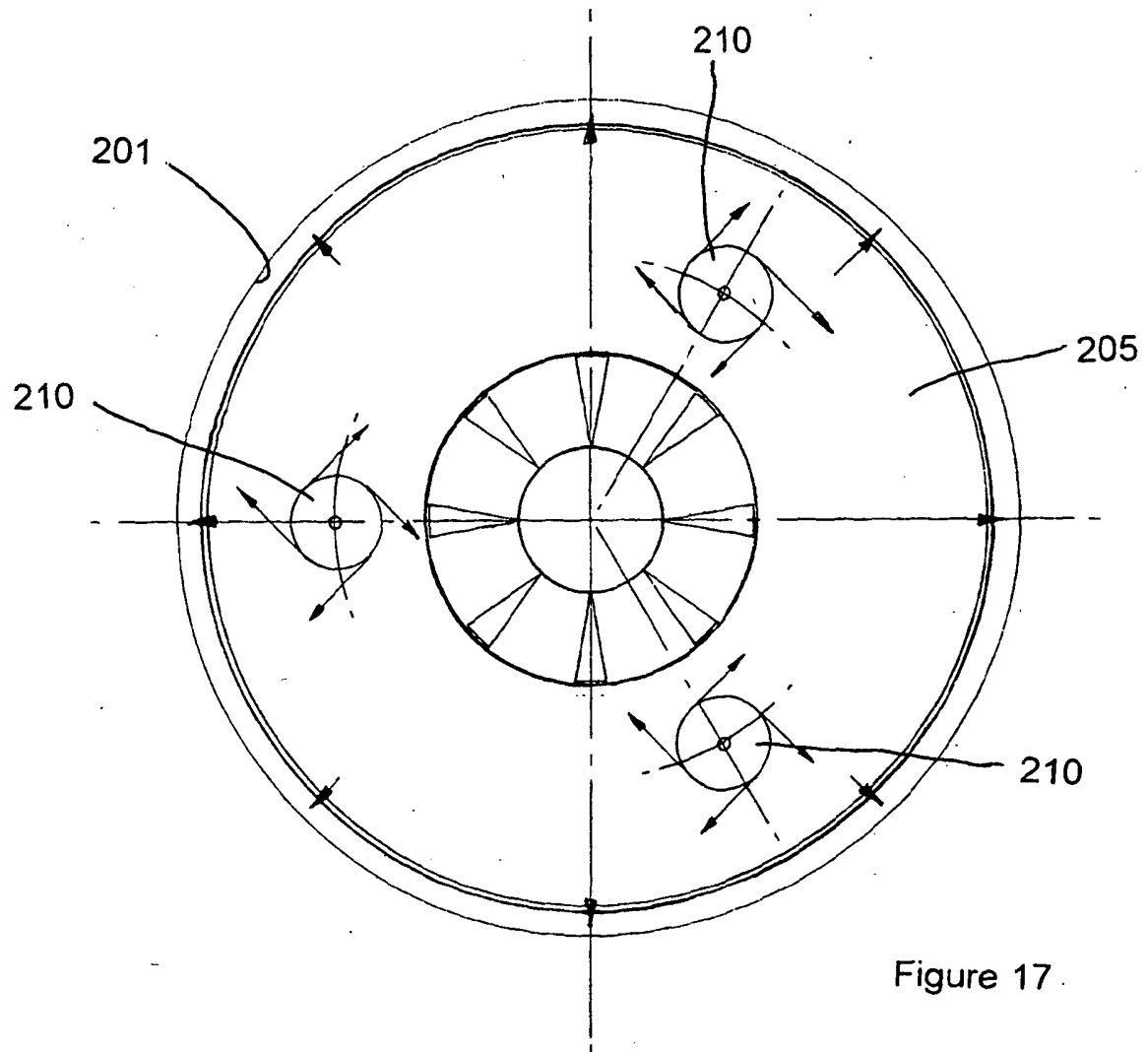


Figure 17.

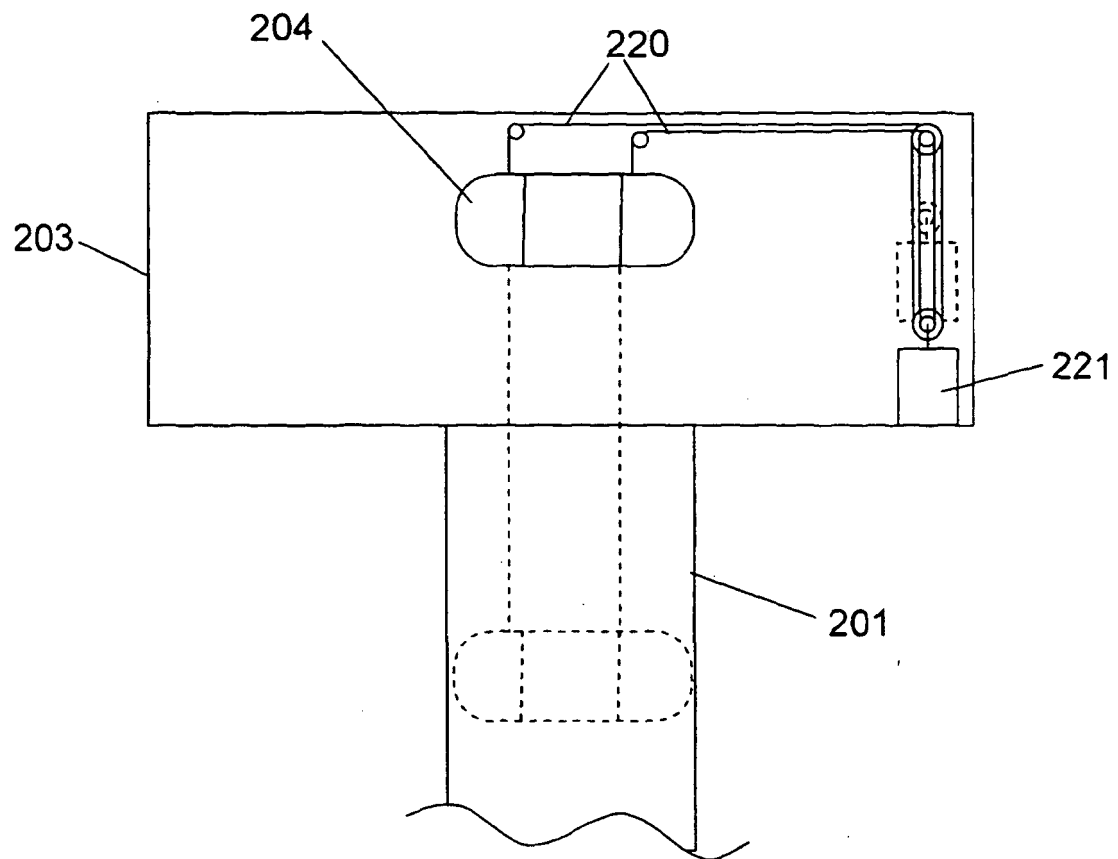


Figure 18

REFERENCES CITED IN THE DESCRIPTION

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