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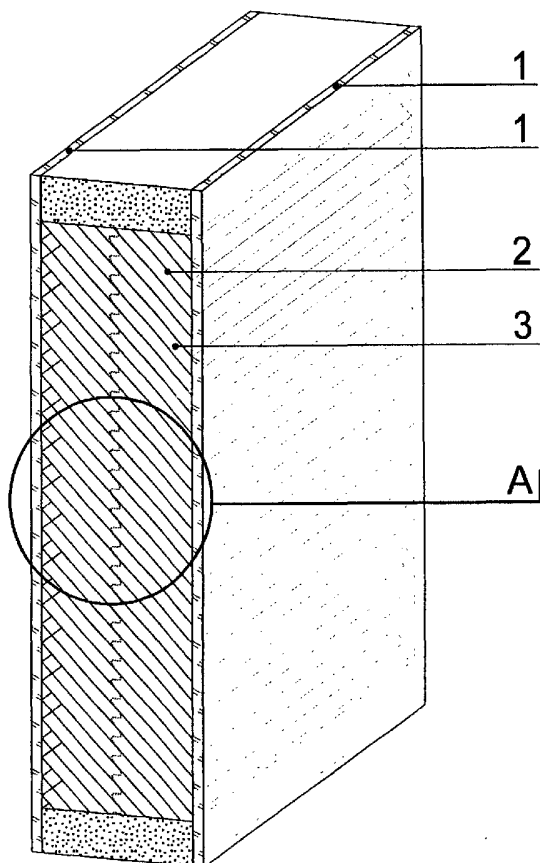
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(54) Title: A SYSTEM OF GASEOUS THERMAL INSULATION, ESPECIALLY OF INSULATED GLASS UNITS



(57) Abstract: This invention solves the problem of introducing an invisible system designed to prevent the possibility of developing thermal convection (in gaseous medium) into the space contained between transparent sheets, especially panes, filled with transparent colourless gas, or designing the geometry of the entire space in such a way, as to prevent the possibility of developing such convection. The system of gaseous thermal insulation has an internal arrangement suppressing thermal convection, in the form of at least one chamber (3) defined by transparent walls (2) parallel to each other and located between the outer panes (1) and inclined to the horizontal, with the bottom edge of the chamber (3) bound along its longer edge with the colder pane, i.e., the one located in the zone of a lower temperature, whereas the upper edge of the chamber is bound with the warmer pane, i.e., the one located in the zone of a lower temperature.

WO 03/104599 A1



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

A system of gaseous thermal insulation, especially of insulated glass units

Field of the invention

The object of this invention is a system of gaseous thermal insulation, especially of insulated glass units, consisting of two transparent sheets with a transparent insulating medium between.

Such thermal insulation is invisible to the user, and, in ideal case, completely transparent, that is it neither diffuses, reflects or refracts visible light, nor does it distort images seen through the glazing. This type of insulation can be applied in particular in the building industry, in structures whose role is to transmit light to spaces inside, and also to permit the building's surroundings to be watched, that is, in windows, skylights, greenhouses, workshops, factory rooms/halls, facades, etc. Such insulation can also be applied in industry and in construction of research instruments, in various sight glasses and inspection openings of reactors, furnaces, cryogenic instruments, etc.

Background of the invention

Numerous known and widely applied thermal insulating materials owe their high thermal resistance, in many cases much higher than that of pure, free gas, to their specific structure containing fine pores, occluding and separating minute portions of that gas, usually air. Thus divided space highly impedes development of thermal convection in the liquid medium as gases are perfect thermal insulators, but only if motionless. Traditional insulating materials, however, have many disadvantages; thicker layers are completely opaque which disqualifies them from many applications. This phenomenon is caused by the contrast between optical properties of the gaseous medium filling the pores and the polymer skeleton whose refractive index is drastically high as compared to gas. As a result of repeated scattering and reflection of light on the walls of pores along the light rays path, light cannot penetrate the insulation, notwithstanding complete transparency of the polymer itself.

Previous attempts made to develop a thermal insulation material containing a system of voids, and useful for a wider range of applications, that is, having high thermal resistance and transparent, have, so far, followed three main directions.

Firstly, to reduce the size of elements of the skeleton in porous materials much below visible light wavelengths. This direction led to the development of a state-of-the-art insulating material, aerogel.

Aerogel is a microporous material of amorphous silica or polymer, with pore size of about 20 nanometres, limited by an organised fractal network of chainlike filaments and diaphragms with a thickness of about 2 nanometres in structures of the lowest order.

Aerogel shows many advantageous properties: very high thermal resistance, low specific weight and negligible light reflection by the surface. The important thing is that it is translucent and in thin layers almost transparent; thicker layers, however, diffuse light similarly to tobacco smoke and that is why it is called frozen smoke. Many commercially available designs have already been developed with glazing filled with aerogel sheets (e.g., by Aspen Systems, Inc.).

An obstacle to wider application of these systems is a very high price of aerogel, its sophisticated production technology, mastered by very few manufacturers, and its extreme brittleness causing problems with transportation and machining, and, lastly, its limited transparency. Slight haziness and bluish or yellowish tint eliminate this material from applications in such cases of glazing where perfect image quality is a prime requirement, that is in shop windows, sight glasses, inspection openings, etc.

Secondly, to create a highly organized structure with controlled and reproducible macroscopic, that is with a capillary or honeycomb structure or comprising a set of parallel, not contacting flat partitions (multiple glazing, filling the space between panes with foil sheets).

The experimentally determined optimal distance between panes in an individual double glazing unit is about 12-16 mm, and it constitutes a compromise between the effect of impeding thermal convection and the increase in the conductive flow of heat as the interpane cavity becomes narrower. Consequently, by making this distance wider, thermal resistance is not improved but, on the contrary, worsened.

To increase thermal resistance of the glazing with spaces greater than 16 mm, additional elements, possibly transparent, should be placed between the panes. Commercially available elements of this type include capillary, canal- and beehive-type sheets, usually with canal axes perpendicular to the pane surface (WO 9402313, DE 19815969, US 5092101) and, less frequently, inclined at some angle (EP 1072752, DE 4103247), large-cell sheets of foamed PMMA (polymethyl methacrylate) (US 4443391) and also multiple pane and multiple sheet systems (US 4433712); discussed by Elmahdy & Cornick, 1900, "Emerging window technology" Construction Canada, 32 (1) p. 46-48).

Such glazing is a compromise solution, but, unfortunately, unsatisfactory in terms of both aspects: optical and thermal. A massive polymer or glass lattice and/or considerable size of elementary cells result in mediocre thermal insulation properties: the material contains numerous massive thermal bridges and convection develops in macroscopic chambers filled with gas. Thermal conductivity coefficient (λ) for such plates is about 0.07-0.1 W/(m x K), just as in multilayer, multiple glazing which is costly and heavy, or glazing equipped with additional sets of polymer foil sheets, placed parallel to the panes.

Any hindrance in the course of rays on surfaces of all additional elements deteriorates the quality of the image seen, as the system absorbs, reflects and diffuses a considerable proportion of light falling on the insulation. For this reason the use of such glazing is limited to applications less demanding in terms of image quality, that is, to roofing and skylights, covers for solar collectors, or greenhouses.

There have also been proposals to use transparent or mirror-like sheets of glass or polymer, to create a system of partitions, parallel to each other, arranged in an echelon pattern arranged in an echelon pattern, at an angle to these panes (EP 1072752). In some embodiments the partitions have an adjustable angle of inclination or have the form of a movable Venetian blind structure (US 4245435) ensuring, when needed, privacy in the room. The division of the interpane cavity into chambers arranged in an echelon pattern has some effect on the thermal resistance of the entire glazing. In the proposed solutions, however, the chambers have considerable dimensions and are almost isometric in cross section, and communicate with each other, whereas the transparent (or mirror-like in other embodiments) partitions hanging by cords, which enclose those chambers, must be rigid and, consequently, massive. The use of the said transparent or mirror-like blinds improves only slightly thermal performance of the window, but dramatically reduces visibility of objects seen through thus constructed glazing.

Thirdly, in the direction of removing air from the space between transparent sheets or panes - that is creating vacuum.

Evacuated glazing (US 4928444, US 6291036 and the papers cited therein, WO 01/61135), are constructed as functional prototypes by several companies in the world, including Saint Gobain and the University of Ulster in Belfast. The research done by R.E. Collins of the Sydney University resulted in a commercial design of

SPACIA glazing of the Nippon Sheet Glass Ltd., which is further developing this technology in its own laboratories (US 6105336). Of the directions presented so far, evacuated windows seem to be the most promising solution to transparent thermal insulation.

The advantages of evacuated glazing and windows include a considerably good quality of the image, small thickness of the glazing and a reasonably high thermal resistance. It is not, however, an ideal solution and this is for several reasons. The need to create and maintain high vacuum for many years requires perfectly tight seals, impermeable to gases diffusing through the entire edge circumference of the glazing. Metal seals made of indium or its alloys, or glass welds (as in kinescopes), made, e.g., with a laser, have, however, poor thermal properties and such thermal bridges are a serious source of heat loss. There has been an attempt to solve this problem by making pane edges in the form of flexible foamed seals with embedded spacers controlling the distance between the panes.

To prevent implosion of the evacuated pane unit due to atmospheric pressure (100 kN/square metre), a system of spacers has to be placed between panes. They usually take the form of columns, cylinders, glass beads or elements of metal or monocrystals (WO 01/61135) arranged in regular patterns (cf. SPACIA) or at random (cf. US 4786344). They impair to some extent the quality of the image seen through such a glazing, but, above all, they constitute a system of thermal bridges. In the vicinity of such thermal bridges, under conditions of supersaturation, water vapour tends to condense locally on the panes of evacuated glazing, thus markedly impairing the quality of the image seen through such glazing. Consequently, the heat transfer coefficient through evacuated double glazing, as calculated for the pane centre, is about $U = \sim 0.7$, which is close to argon-filled triple glazing of classical design; however, the actual, combined U-value for the entire window is much higher than that measured for the centre of the pane.

Periscope windows make another class. Windows of that design, although known and even installed as prototypes in the few buildings, have no thermal insulating properties; they were designed for other purposes and differ markedly from the currently filed solution.

A design of a periscope window was disclosed (DE 19932054), but in the presented embodiment the window cannot have thermal insulating properties - this aspect was not

even mentioned – the window is designed only for watching objects outside the building by occupants of rooms in the basement. A similar function has a known periscope window (US 4921339) and the one awarded by Window Fashions Magazine, designed by Houston & Heyne Associated Architects of the United States.

Disclosure of the invention

The overview of transparent insulation technologies presented above shows that no satisfactory solution has been found so far that would combine the conflicting requirements of high optical quality and high thermal resistance while maintaining low costs.

The object of this invention is to introduce to the space between transparent sheets, especially panes, filled with transparent colourless gas, i.e., a medium with low thermal conductivity, an invisible system that would prevent the development of thermal convection in that medium, or to design such a geometry of the entire space that would prevent the possibility of convection.

The successively discussed variants of embodiments of the invention, in spite of some differences in design, share the same inventive concept: a system that suppresses thermal convection, invisible to the user and placed in the gaseous medium filling the insulation.

The system of gaseous thermal insulation, especially of insulated glass units, according to this invention, consists of two transparent outer sheets in the form of panes, with transparent gaseous medium between.

The essence of the solution according to this invention is that the system has an internal arrangement suppressing thermal convection, in the form of at least one chamber defined by mutually parallel transparent walls, situated between outer panes at an angle to the horizontal, where the bottom edge of the chamber is bound along its longer side with the colder pane – situated in the zone of influence of a lower temperature, and the upper edge of the chamber is bound to the warmer pane, located in the zone influenced by a higher temperature.

The transparent walls are oriented at an angle of 45° to the horizontal,

The transparent walls define many chambers insulated from each other,

The transparent walls have the form of membranes whose thickness does not exceed 0.1 micrometer,

The transparent walls can have the form of membranes equipped with anti-reflex coating.

The inner walls can have a relief in the form of a system of bumps and hollows with dimensions below visible light wavelengths.

The inner walls can have the form of a film of transparent aerogel with low refractive index.

In another variant of the embodiment, the chamber has the form of a rhomboid, vertically elongated, constituting an optical system of the periscope.

The chamber has the form of a box with insulating outside walls.

The chamber is filled with a heavy gas, in particular dry air.

A sorbent/desiccant can be placed in the chamber.

The chamber can have a system allowing the orientation to be changed.

The chambers define continuous bands of frontage and roof glazing.

In another variant, the system of thermal insulation has an internal arrangement designed to block thermal convection conduction in the gaseous medium, in the form of at least one chamber with extremely reduced width of 10 to 20 nanometres, with one of the outer panes thicker and stiffer, the other one thinner and more flexible, and spacers placed between these panes.

Spacers can be arranged in a regular manner.

Spacers can also be arranged in an irregular manner, randomly.

The system of thermal insulation is closed at the edges with strips with developed inner surface which defines the closure of the space between the panes .

The outside closure can have a rigid protective covering.

The outside closure can be equipped with a stub pipe.

The gap can be filled with a light gas, in particular hydrogen or helium.

In another embodiment, a set of transparent foils, permanently delaminated, can be placed between the outer panes.

The transparent foils are delaminated by means of a network of ultrathin fibres, pierced through the set, on which tensile forces are exerted.

The transparent foils, similarly charged in a permanent manner, can be delaminated under the action of electrostatic repulsion.

The transparent foils can be delaminated by magnetostatic repulsion.

Transparent dielectric foils can be placed between transparent electrodes and delaminated by the action of forces that delaminate dielectrics when placed in electrostatic field.

The invention solves the issue of introducing a system preventing the development of thermal convection (in the gaseous medium) into the space between transparent partitions, especially panes, filled with transparent, colourless gas, and of designing such a geometry of the entire space that would prevent the possibility of convection.

Brief description of the drawings

The solution according to this invention is explained in sample embodiments shown in drawings, where the figures present:

fig. 1 – an insulated glass unit with a system of inner parallel chambers, in perspective view,

fig. 2 – detail A of fig. 1 – the inner structure of the thermal insulation system with schematic representation of gas density,

fig. 3 – detail B of fig. 2 – a variant of the membrane in the form of an anti-reflex surface relief,

fig. 4 – detail B of fig. 2 – a variant of the membrane in the form of an aerogel sheet,

fig. 5 – roof glazing with a system of membranes, shown in cross section,

fig. 6 – rigid or flexible (suspended from the rigid one) roof glazing with a system of membranes, in longitudinal section,

fig. 7 – flexible inflated roof glazing with a system of membranes, in longitudinal section,

fig. 8 – detail G of figs. 6 and 7 – vertically arranged membranes,

fig. 9 – detail H of figs. 6 and 7 – diagonally arranged membranes,

fig. 10 – a roof window with a system of membranes,

fig. 11 – a rhomboidal chamber of a periscope window,

fig. 12 – the chamber in the “summer” arrangement,

fig. 13 – the chamber in the “winter” arrangement,

fig. 14 – the chamber with outriggers,

fig. 15 – the chamber with guide rails,

fig. 16 – rhomboidal chambers built into a roof of a hall/workshop,

fig. 17 – rhomboidal chambers built into the wall of a building,

- fig. 18 – the roof of a hall/workshop with suspended column-like chambers in the form of a honeycomb,
- fig. 19 – an insulated glass unit with a nano-gap, with a regular arrangement of spacers; perspective view with a partial cross section,
- fig. 20 – an insulated glass unit with a nano-gap, with an irregular arrangement of spacers; perspective view with a partial cross section,
- fig. 21 – detail E of figs. 19 and 20; a variant without polyurethane foam protective covering,
- fig. 22 – cross section F-F of figs. 19 and 20; a variant with polyurethane foam protective covering,
- fig. 23 – a system of insulating glass unit; perspective view with a partial cross section,
- fig. 24 – a variant of the unit with a set of foils,
- fig. 25 – detail G of fig. 24,
- fig. 26 – detail H of fig. 25 – a variant with a network of thin threads piercing through the set,
- fig. 27 – detail I of fig. 25, a variant with similarly charged electret foils,
- fig. 28 – detail I of fig. 25, a variant with foils of hard-ferromagnetic material, with successive layers oppositely magnetised,
- fig. 29 – detail I of fig. 25, a variant with dielectric foils positioned between oppositely charged flat electrodes,
- fig. 30 – detail G of fig. 29,

Description of the embodiments of the invention

According to the first embodiment of this invention, as presented in figs. 1 through 10, two parallel membranes 2, defining a system of mutually insulated chambers 3 are situated between panes 1 covered with low-E coating. The membranes 2 are thin, their thickness is about 0.1 micrometer, and almost perfectly transparent owing to destructive interference. Also, the membranes 2 are equipped with an effective anti-reflex coating, which makes them practically invisible.

One of the proposed ways to eliminate disadvantageous reflexes is to make a relief 2a on the membrane surface – a texture in the form of a regular system of bumps and hollows with dimensions below the wavelength of visible light, most favourably below 50 nanometres. The simplest optical method is to make a smooth membrane extremely

thin, to a width resulting in complete destructive interference of the light reflected from the surface.

Another favourable embodiment involves making an invisible membrane as a thin film 2b – a foil of transparent aerogel with a very low refractive index and surface reflectivity, and also providing thermal insulation to neighbouring chambers 3 filled with gas. Due to the extremely small total cross section area and the negligible degree of space filling (the system's density is about 100 grams per cubic metre), the system of membranes 2 does not practically introduce any thermally conductive bridges. The polymer membranes 2 are arranged in an echelon pattern, at an angle of 45° to the panes 1, bound with the glass along its longer edge and stretched.

As shown in figs. 1 and 2, the membranes 2 divide the space inside the glazing into flat, thin (with a thickness of 0.5 to 5 mm) mutually insulated chambers 3, with their bottom horizontal edge bound with the colder pane 1 (in winter the outer one and in summer the inner one), and the upper edge is bound with the warmer pane 1, that is one that is the inner one in winter and the outer one in summer. With such a diagonal configuration of chambers 3 a stable temperature- and density-related stratification develops in the gas filling each of the chambers 3, and thermal gradients between neighbouring chambers 3 disappear almost completely. Fig. 2 shows visualises schematically with dots the zones of denser (colder) and lighter (hotter) gas.

Isotherms in the space between the panes run most smoothly and parallel to the outside pane when chambers 3 are inclined at an angle of 45° to the horizontal; that is why that optimal angle should be maintained, irrespective of the orientation of the inclination of the entire glazing to the vertical.

In this case thermal convection is blocked in a static manner through stabilization of the system. In contrast to the static mechanism proposed in this application, the suppression of turbulent gas flow with decreasing size of convection cells that develop in the glazing of typical design, is an aerodynamic phenomenon -- the result of internal friction (viscosity) of the gaseous medium enclosed in a space of small dimensions, while maintaining thermal gradients which drive convection.

Basically, vertical orientation is the most advantageous for the operation of glazing with membranes 2 arranged in an echelon pattern, but it is also possible to configure inclined glazing 4 while maintaining the requirement of inclining all membranes 2 at an angle of

45° to the horizontal. Thus inclined glazing is useful in covering sloping roofs or factory workshops, greenhouses, cold stores or sports halls - fig. 5.

In the variant described above, the entire glazing inclined to the horizontal can be made in the form of integrated sheeting 5 suspended from the structure (fig. 6.) or even self-supporting, light flexible pneumatic sheeting 6 (fig. 7), inflated with dry air and made of two foils of greater thickness with considerable mechanical strength, connected by a system by thinner membranes 2 arranged in an echelon pattern, inclined at an angle of 45° to the horizontal, or vertically, especially in the case of cold stores or air-conditioned buildings, in tropical climate. The low specific weight, low material consumption and the simplicity of the structure of flexible thermal insulation combined with its considerable thermal resistance, result in very low costs of such a system as compared with other transparent insulation.

The solution according to this invention is also suitable for insulating inoperable roof windows 7, mounted directly into a steep (at an angle greater than 60°) roof surface – fig. 10.

In order to drastically improve thermal properties of windows, the entire depth of window openings (wall thickness) can be used, as this space is usually used to a negligible extent only. For this end, this space can be filled with the above-described structure arranged in an echelon pattern, which prevents formation of convection. This solution is advantageous, especially to improving thermal properties of existing casement windows, for instance in historic buildings. As such modification results in establishing a relationship between thermal resistance of the glazing and the distance between the panes, it becomes reasonable and economically justified to maximize this distance.

Another proposed embodiment involves shaping the entire glazing in such a way as to block thermal convection without introducing to it additional elements. The glazing according to this example, presented in figs. 11 through 17, has the form of a rhomboidal, vertically elongated chamber 33 (well, shaft or chamber) filled with dry gas only (dry air or, better, argon, xenon, etc.) in the optical system of the periscope, with side walls 11, closing the chamber 33 with mirrors 8. Such a glazing can be defined as a “periscope window”.

The chamber 33 of the window has the form of a tight box 9 with walls 10 composed of outer insulating layer (corrugated or honeycomb-like, multilayer polymer foil or plate) and an inner one of regular rigid thermal insulating material (polymer foam), with a thickness of at least 10 to 15 cm, with blackened or matt white surfaces. The edges of the structure, the mirror 8 and the glazing made of low-emission panes can be reinforced with appropriate metal frames, but in order to counteract heat conduction it is necessary to break thermal bridges present in the section that is built in, or the one built into the building wall. A desiccant with appropriate capacity is placed in the chamber 33, which maintains low levels of water vapour inside the glazing throughout its useful life. The window casing should be hermetically sealed at the bottom and top with vertical sheets of glazing and mirrors.

The mirrors 8 are made of high-quality, parallel sheets of flat, float glass, which are either metalized or covered with multilayer dielectric reflexive surfaces, most favourably on the inner side of the casing, and inclined at an angle of 45° to the horizontal. The system of mirrors, based on the principle of the periscope, permits unobstructed view of outside objects, only slightly reducing their brightness.

Such a casement window can be built in a wall as a kind of bay; in summer (fig.12) the outer panes should be installed in the upper part of the window body, whereas in winter (fig. 13) the outer panes should be installed in the bottom part of the window body. In a moderate climate, with different seasons, it is expedient to install a movable window structure with a vertical, vertically movable axle held in bearings on sliding outriggers 12 (fig. 14), or fitting the casing with horizontal guide rails 13 (fig. 15) resting on bearings, operating like a drawer, which can be easily slid out from the window opening, so that its orientation can be easily changed depending on the season.

The good thermal insulation properties of the glazing described in this embodiment stem from its stable temperature- and density-related stratification, which develops spontaneously in the gas filling the window chamber, thus completely preventing thermal convection of this gas. This design ensures maximum total thermal resistance of the entire glazing – almost equal to the resistance of a 1 m or thicker layer of dry, motionless air. The important thing is that this layer is completely transparent and invisible and the medium used to fill the window chamber (dry air) is the cheapest possible environmentally friendly material.

Periscope windows can be primarily used in places where the cubature of a building is not a critical factor, and no traditional visual appearance of the facade glazing is required. The most rational application of this technology is in industrial buildings, such as factories, cold stores or greenhouses. In vast halls, natural light is admitted via vertical windows, roof-mounted windows or skylights; periscope windows are particularly useful in this type of glazing – fig. 16 .

Also, in newly erected multi-storey buildings, especially in public buildings, offices, individual window structures can be connected vertically, thus forming continuous glazing bands, in the form of pilasters or bays. In horizontally arranged continuous window bands, individual casements can be combined into complete double (consisting of two layers), highly insulating walls – fig. 17.

In existing buildings, balcony openings can be used for periscope windows to be installed in them. This type of windows can not only be permanently mounted; they can be mounted for the winter season only, and removed for the summer to allow the normal use of the balcony.

The box-type insulation presented in this embodiment, employing thermal resistance of a vertical air column with stable thermal stratification can be directly built into the ceiling, without additional mirrors, consisting of vertical, honeycomb columns of thin foil – fig. 17. Such a simplified configuration is efficient, as inside cold rooms or cold stores temperatures are lower than outside temperatures, above the roofing. A flexible structure can be suspended under flat glazing or can be designed as a stiffer, inflated, self-supporting structure, e.g., the membrane of a building with inflated walls (cold store) with thicker outer envelopes, stiffened by a slight overpressure. The column-like envelope can be integrated into a single continuous structure, alongside with the above-described membranes arranged in an echelon pattern (fig. 6, 7), which insulate side walls of the hall. The very low specific weight of such column-like insulation reduces heat losses due to conduction, and consumption of materials. Also, the strength requirements of the ceiling are lower, which results in lower costs of insulation: both absolute and relative (referred to a given thermal resistance and per unit surface area).

The third embodiment is a structure involving an extremely narrowed interpane cavity, as show in figs. 19 through 30.

There are two identified maximums of thermal resistance, associated with the width of gap between the panes: in addition to the distance of 12-16 mm mentioned above,

generally used in double glazing designs, there is another one, much higher, identifiable in the nanometre scale only. The reason why this maximum exists is the so-called turbomolecular effect which, among other factors, makes thermal properties of aerogels so unusual.

In a gap narrowed to tens of nanometres, comparable to the mean free path travelled by molecules of gas at room temperature and under normal atmospheric pressure, heat transfer through the gas falls dramatically to values comparable to that for vacuum, due to complete suppression of convection and absence of intermolecular collisions. As atmospheric pressure prevails in the gap, the structural design does not require supports, which constitute permanent thermal bridges and, consequently, the walls of the gap do not have to be in contact with each other. It is essential, that the gas filling the gap should be completely dry and have the longest possible free path of its molecules. These conditions are met primarily by nonflammable, though more expensive, helium, and cheaper, but flammable, hydrogen, that is gases which in larger volumes exhibit the poorest thermal insulation properties. The quantity of gas needed to fill the gap, even under atmospheric pressure, is very low -- about 2 cubic millimetres, which corresponds to only 0.0001 milligram per 1 square metre of glazing. At such trace quantities, the price and the flammability of the gas has no important consequence for operating safety or the cost of the glazing.

Between panes 101 and 111 there is a flat and parallel gap 103 with a width of 10 to 20 nanometres and a considerable surface area. Both a larger-scale departure from flatness, and local unevenness of the surface, even in high quality commercially available float glass are by order of magnitudes greater than the minimum requirements needed to create such a nano-gap by simply assembling two glass sheets. As it is impossible to obtain two perfectly flat glass sheets of considerable surface area, it is advisable to use technologies resulting in matching of the two sheets, that is manufacturing two perfectly parallel surfaces, although not necessarily flat ones.

The component panes should be made of the same glass, but of different thickness: the main pane 101 should be thicker (about 8-10 mm) and more rigid, whereas the cover sheet 111 should be thinner (about 0.6-0.8 mm) and more flexible and yielding. The panes should have hard, low-E coating; optionally the inner surfaces of gap 103 can be

coated with a soft, but more effective low-E coating, provided the layer is sufficiently smooth and has a uniform thickness.

Spacers 114 introduced into the space between panes 101 and 111 should be as small as possible, spaced possibly in a uniform manner, arranged in a regular network (fig. 19) or randomly (fig. 20), and should occupy the lowest possible proportion of the glazing area. This fraction can be much lower than in evacuated glazing, where immense mechanical stress exists. Spacers 114 should be made in the form of isometric nano-columns with a circular, star-shaped, tubular cross section, or as flattened balls. These elements should be made of a rigid material with possibly highest thermal resistance, most advantageously of transparent polymer properly protected from photodegradation, e.g. polystyrene, PMMA, or of glass.

Some modification of an individual gap glazing, which multiplies its thermal resistance, can be a structure in the form of a set of thin, but relatively rigid, panes covered with effective anti-reflex coating, perfectly parallel and separated with a nano-gap with spacers.

Edges of both component panes must be hermetically bound without creating major thermal bridges in the sealant. One of the proposed embodiments involves making the edges and closing the sides of panes 101 and 111 by welding to them longitudinally folded foil strips 115, preferably of glass foil (fig. 21), which at room temperatures constitutes a very efficient obstacle for gas diffusion and also provides space for placing substance absorbing water vapour and other harmful, i.e., other than hydrogen and helium residual gases.

The strip can also be made of a multilayer, polymer foil that prevents diffusion, but in such a case it is recommended to provide the gap 103 with a desorptive or chemical hydrogen generator to make up for its losses due to diffusion through the sealant.

The folds along the strips 115 extend the path of heat transfer between the panes and also increases thermal resistance of the closure. Delicate, vulnerable to mechanical damage surfaces of the glass bellows or polymer strip 115 must be embedded in a protective covering of rigid polyurethane foam (fig. 22). An important element is a stub pipe 117 soldered with indium or welded into the pane sealant (fig. 22), or the pane itself (close to its edge), used to initially purge the gap 103 with hydrogen to remove

gases and water vapour adsorbed at the surface, and primarily to finally fill the gap with the working gas (hydrogen or helium).

It is recommended to use such a nanogap-separated pane pair just like an evacuated pane, wherever single glazing is required (e.g., in historic buildings, in casement windows, or wherever thin and light glazing is required).

Gap panes can also be mounted as components of regular dual- (fig. 23) or triple-insulated glass unit. In such a case the inner surfaces, which are protected against damage, can be covered with soft, but very effective low-E coating.

An equally effective solution involves filling the space between panes 101 and 111 with a set of invisible, ultra-thin transparent membranes 118 made of polymer or inorganic foil. Such a set of foils or membranes separated by hydrogen-filled nano-gaps must be permanently delaminated.

In the case foils that are stiffer and/or put under additional stress by forces that stretch the edges and individual sheets of the set, delamination can be achieved by means of a network of ultra-thin threads piercing through the set and anchored in the cover panes, on which not squeezing, but rather under tensile forces are exerted (figs. 25, 26).

Permanent delamination of the set can also be achieved without any spacers or contact, by employing only electrostatic forces (fig. 27). Similarly charged individual foils 118 of the electret type, with a structure folded in a nanometre scale, produced by injecting electric charges into the dielectric polymer and then immobilising them to form homopolar electrets, can be quite flexible (fig. 28). If semidielectric foils are used, connected and charged by means of conductors – employing classical methods, the charge which is lost by leakage can be replenished, on a continuous basis, from a high voltage source, e.g., a cell with an appropriate transducer characterised by a very low power consumption.

Forces that delaminate a set of dielectric foils can be produced by placing the entire set in an electrostatic field between oppositely charged transparent electrodes (figs. 29, 30). A similar, contact-free delamination effect can be produced by a magnetostatic field; this is accomplished by oppositely magnetising successive sheets of hard ferromagnetic material (or only parallel bands of hard ferromagnetic material within the sheets, perpendicular to each other in successive sheets).

It is also possible to delaminate a set transparent sheets made of soft ferromagnetic material, using an outside magnetostatic field produced by permanent magnets.

Patent Claims

1. A system of gaseous thermal insulation, especially of insulated glass units, consisting of two outside transparent sheets in the form of panes, with transparent gaseous medium between, characterised in that it has an internal system for suppressing thermal convection, in the form of at least one chamber (3) defined by mutually parallel transparent walls (2), located between outer panes (1) and inclined to the horizontal, with the bottom edge of the chamber (3) bound along its longer edge with the colder pane – located in the zone affected by a lower temperature, and the top edge is bound with the warmer pane – located in the zone affected by a higher temperature.
2. The system of gaseous thermal insulation of Claim 1, characterised in that the transparent walls (2) are inclined at an angle of 45° to the horizontal.
3. The system of gaseous thermal insulation of Claim 1 or Claim 2, characterised in that the transparent walls define a large number of chambers (3) insulated from each other.
4. The system of gaseous thermal insulation of Claim 3, characterised in that the transparent walls (2) have the form of membranes with a thickness not greater than 0.1 micrometer.
5. The system of gaseous thermal insulation of Claim 4, characterised in that the transparent walls (2) have the form of membranes equipped with anti-reflex coating.
6. The system of gaseous thermal insulation of Claim 3, characterised in that the inner walls (2a) have a relief in the form of a regular system of bumps and hollows with dimensions smaller than visible light wavelengths.
7. The system of gaseous thermal insulation of Claim 3, characterised in that the inner walls (2b) have the form a film of transparent aerogel with a low refractive index.
8. The system of gaseous thermal insulation of Claim 1, characterised in that the chamber (33) has the form of a vertically elongated rhomboid, constituting an optical system of the periscope.
9. The system of gaseous thermal insulation of Claim 8, characterised in that the chamber (33) has the form of a box (9) whose walls have an insulating outer layer.
10. The system of gaseous thermal insulation of Claim 8, characterised in that the chamber (33) contains a heavy gas, in particular, dry air.

11. The system of gaseous thermal insulation of Claim 8, characterised in that there is a sorbent/desiccant in the chamber (33).
12. The system of gaseous thermal insulation of Claim 8, characterised in that the chamber (33) is equipped with devices (12), (13) permitting reorientation of the system.
13. The system of gaseous thermal insulation of Claim 8, characterised in that the chambers (33) define continuous bands of frontage or roof glazing.
14. The system of gaseous thermal insulation of Claim 1, characterised in that it is equipped with an internal arrangement designed to block thermal convection, in the form of at least one chamber (103) with a gap narrowed to an extreme degree to a clearance of 10 to 20 nanometres, with one outer planes (101) being thicker and stiffer and the other one (111) being thinned and flexible, and with spacers (114) between the panes.
15. The system of gaseous thermal insulation of Claim 14, characterised in that the spacers (114) are arranged in a regular manner.
16. The system of gaseous thermal insulation of Claim 14, characterised in that the spacers (114) are arranged in a random manner.
17. The system of gaseous thermal insulation of Claim 14, characterised in that its edges have a closure in the form of strips (115) with a developed inside surface defining the closure of the gap (103) between the panes.
18. The system of gaseous thermal insulation of Claim 14, characterised in that outer closure has a rigid protective covering (116).
19. The system of gaseous thermal insulation of Claim 14, characterised in that the outer closure is equipped with a stub pipe.
20. The system of gaseous thermal insulation of Claim 14, characterised in that the gap (103) is filled with a light gas, in particular hydrogen.
21. The system of gaseous thermal insulation of Claim 14, characterised in that the gap (103) is filled with a light gas, in particular helium.
22. The system of gaseous thermal insulation of Claim 14, characterised in that between the outer panes there is a set of foils (118), which are transparent and permanently delaminated.
23. The system of gaseous thermal insulation of Claim 14, characterised in that the transparent foils (118) are delaminated by means of a network (119) of ultra-thin threads, which are under the action of tensile forces.

24. The system of gaseous thermal insulation of Claim 14, characterised in that the transparent similarly charged foils (118) are delaminated by the action of electrostatic repulsion force.
25. The system of gaseous thermal insulation of Claim 14, characterised in that the transparent similarly charged foils (118) are delaminated by the action of magnetostatic repulsion force.
26. The system of gaseous thermal insulation of Claim 14, characterised in that the transparent dielectric foils (118) are placed between transparent electrodes and delaminated by forces that delaminate dielectrics in an outside electrostatic field.

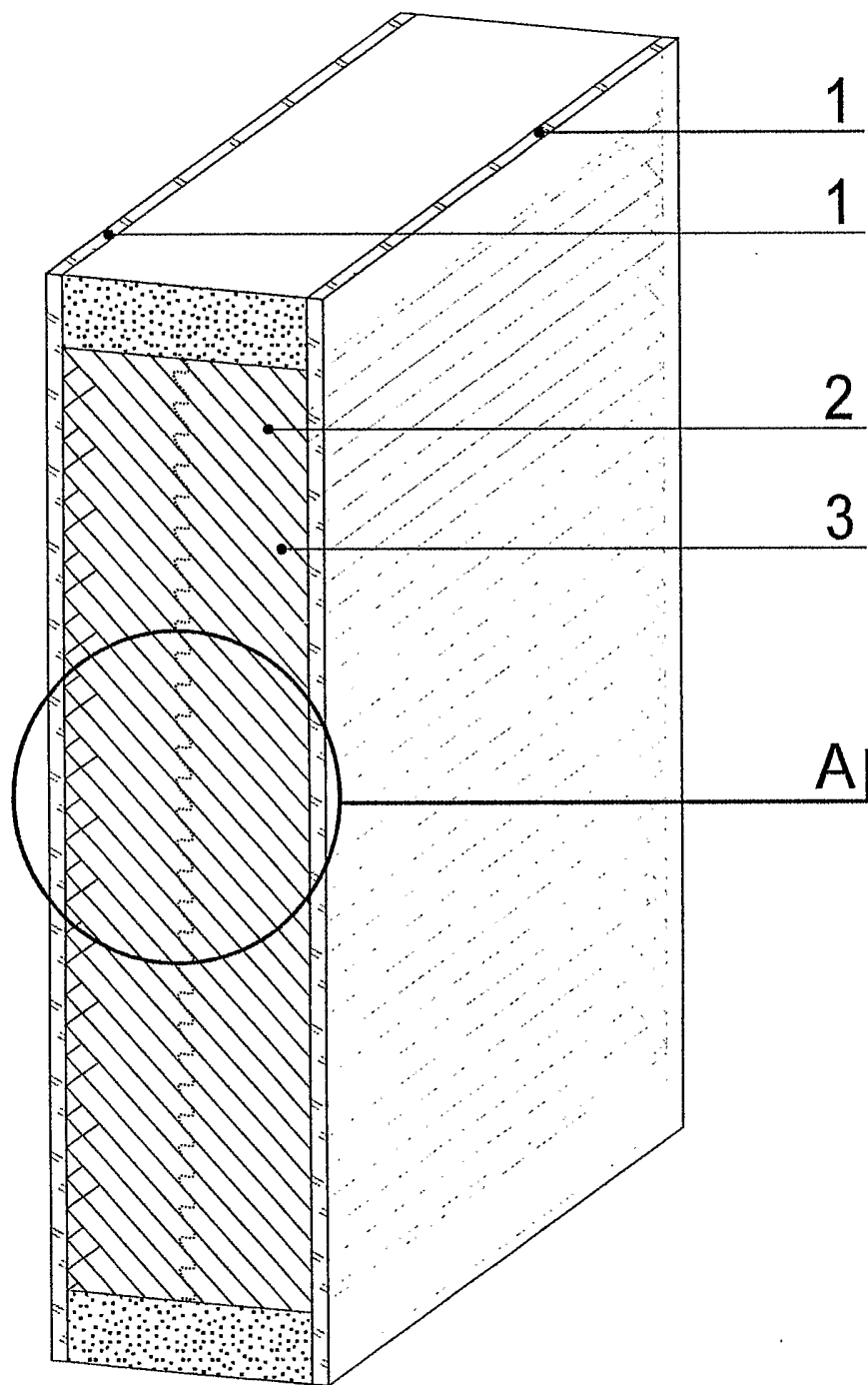


fig. 1

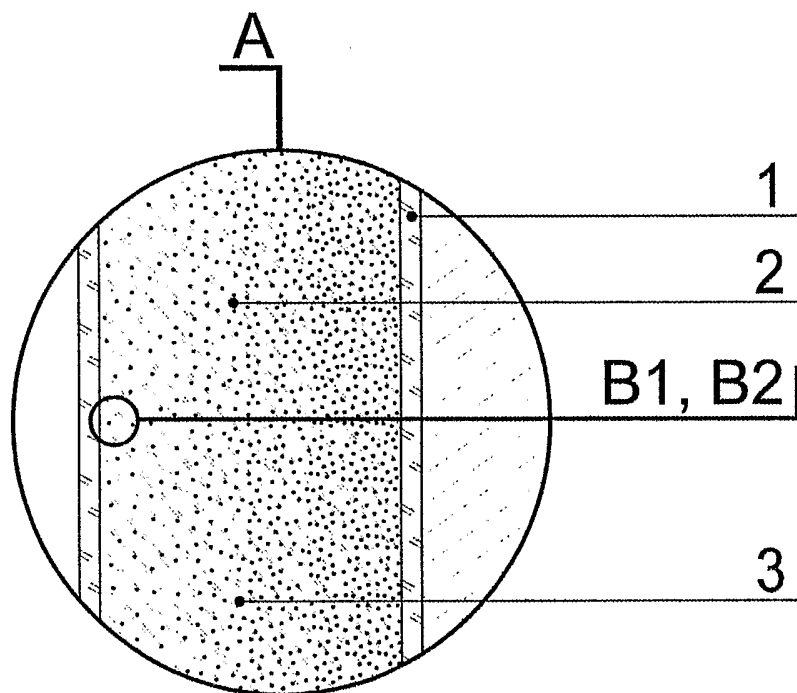


fig. 2

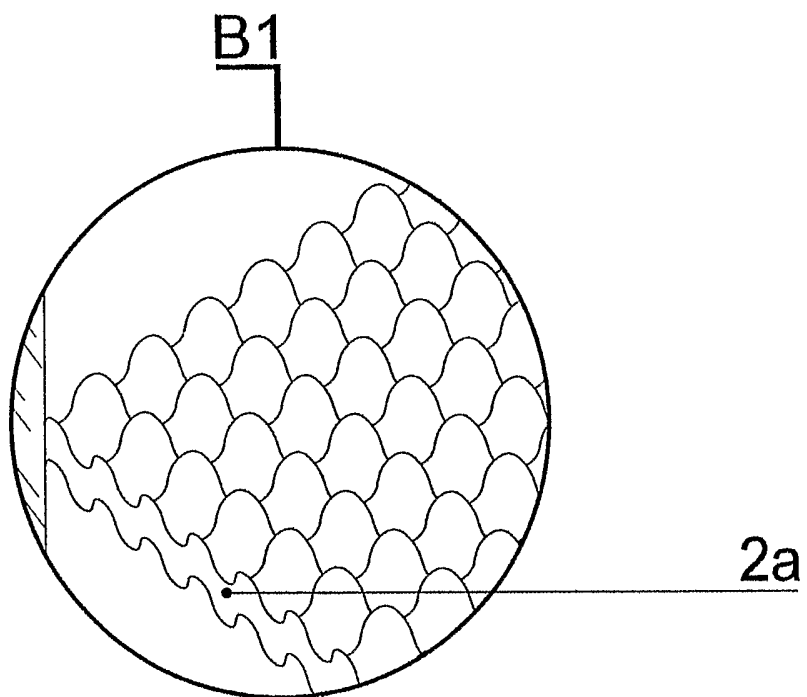


fig. 3

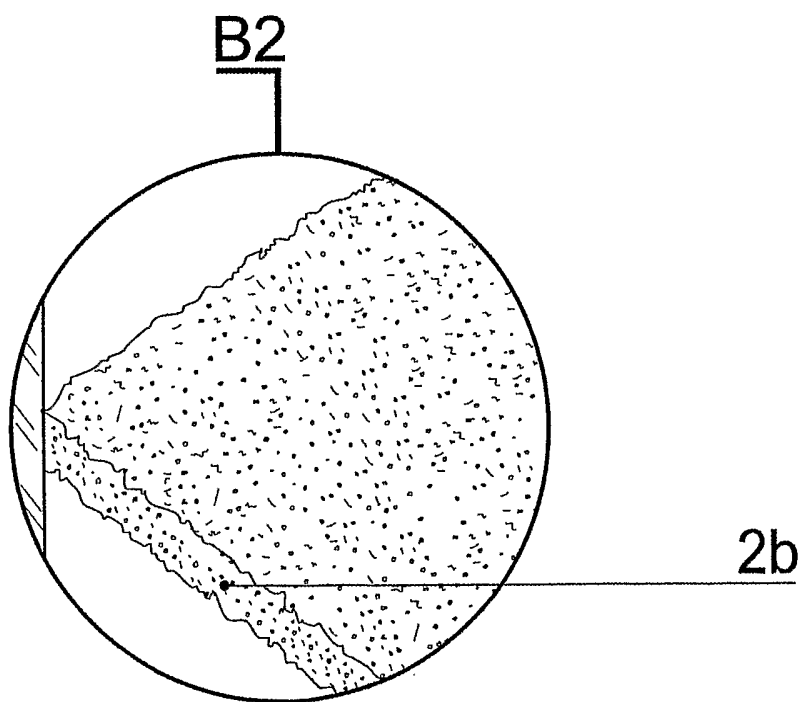


fig. 4

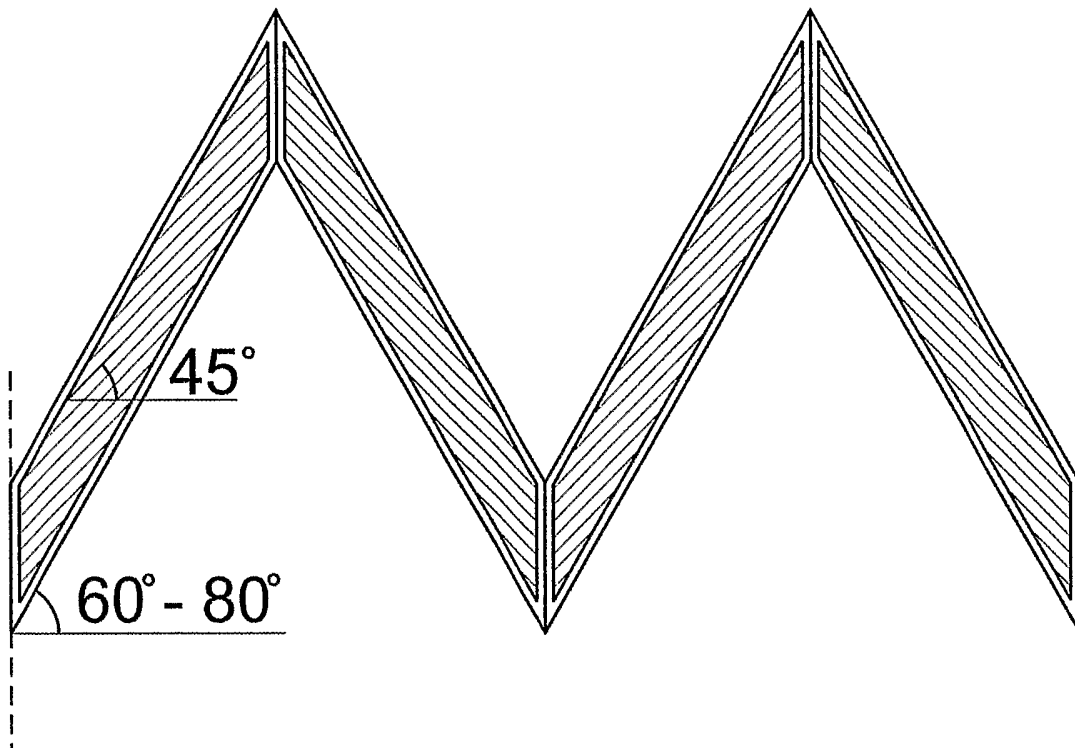


fig. 5

5/19

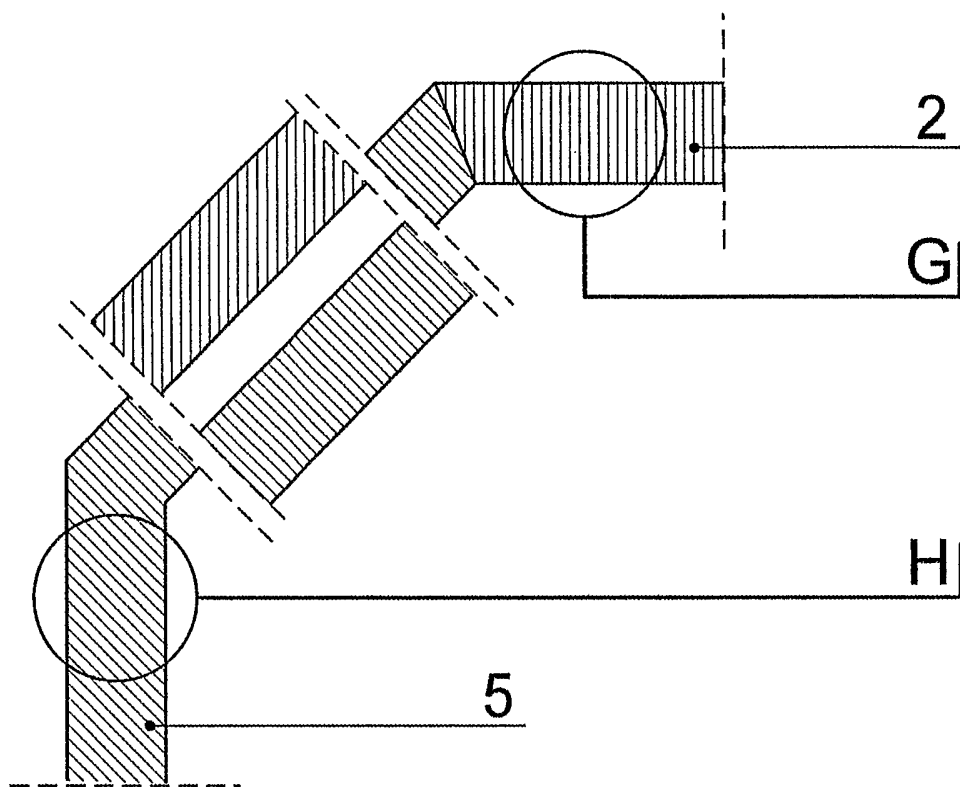


fig. 6

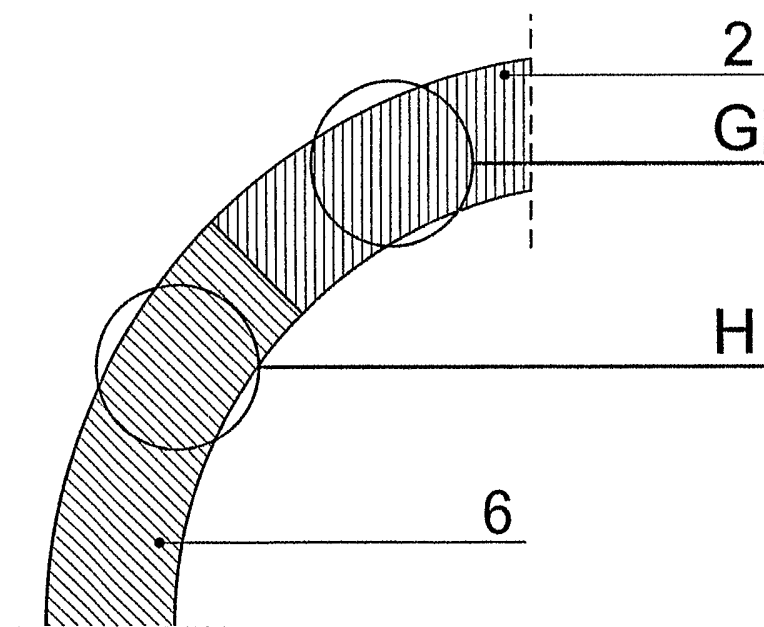


fig. 7

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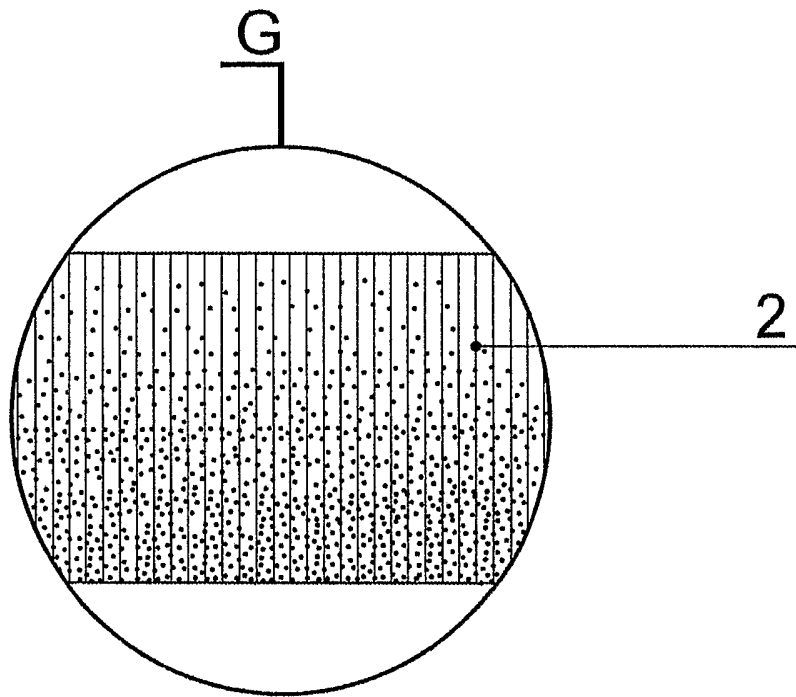


fig. 8

H

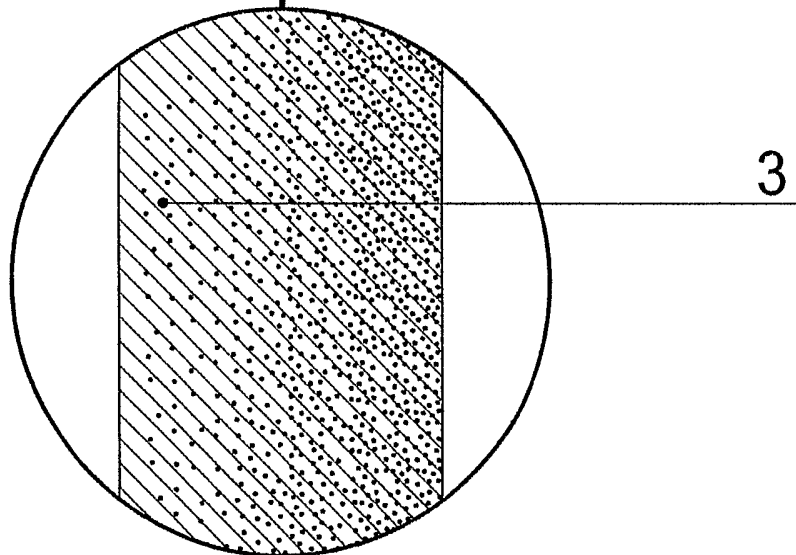


fig. 9

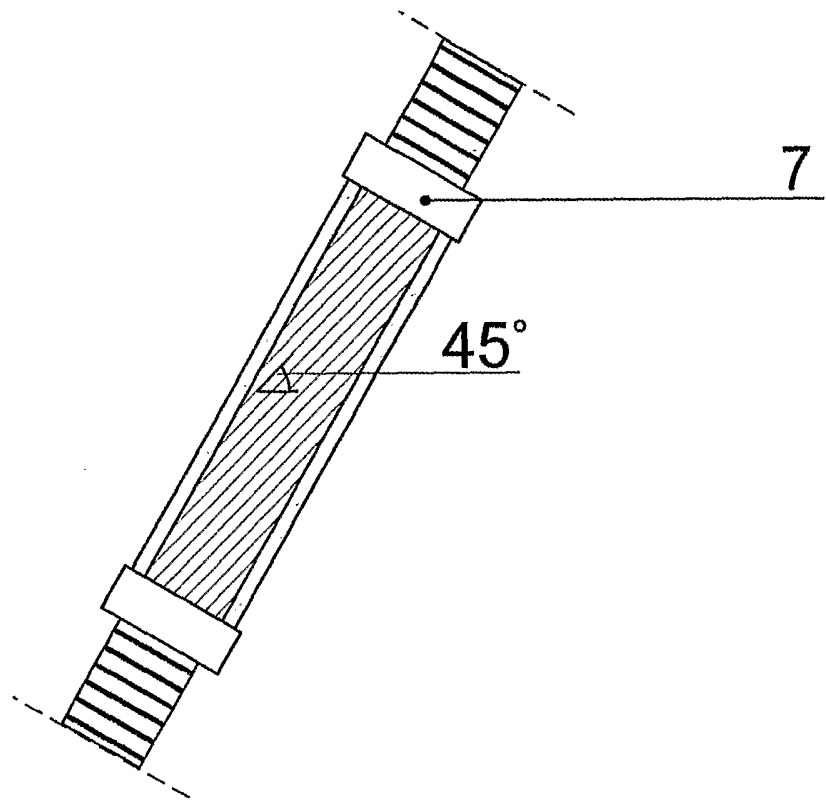


fig. 10

8/19

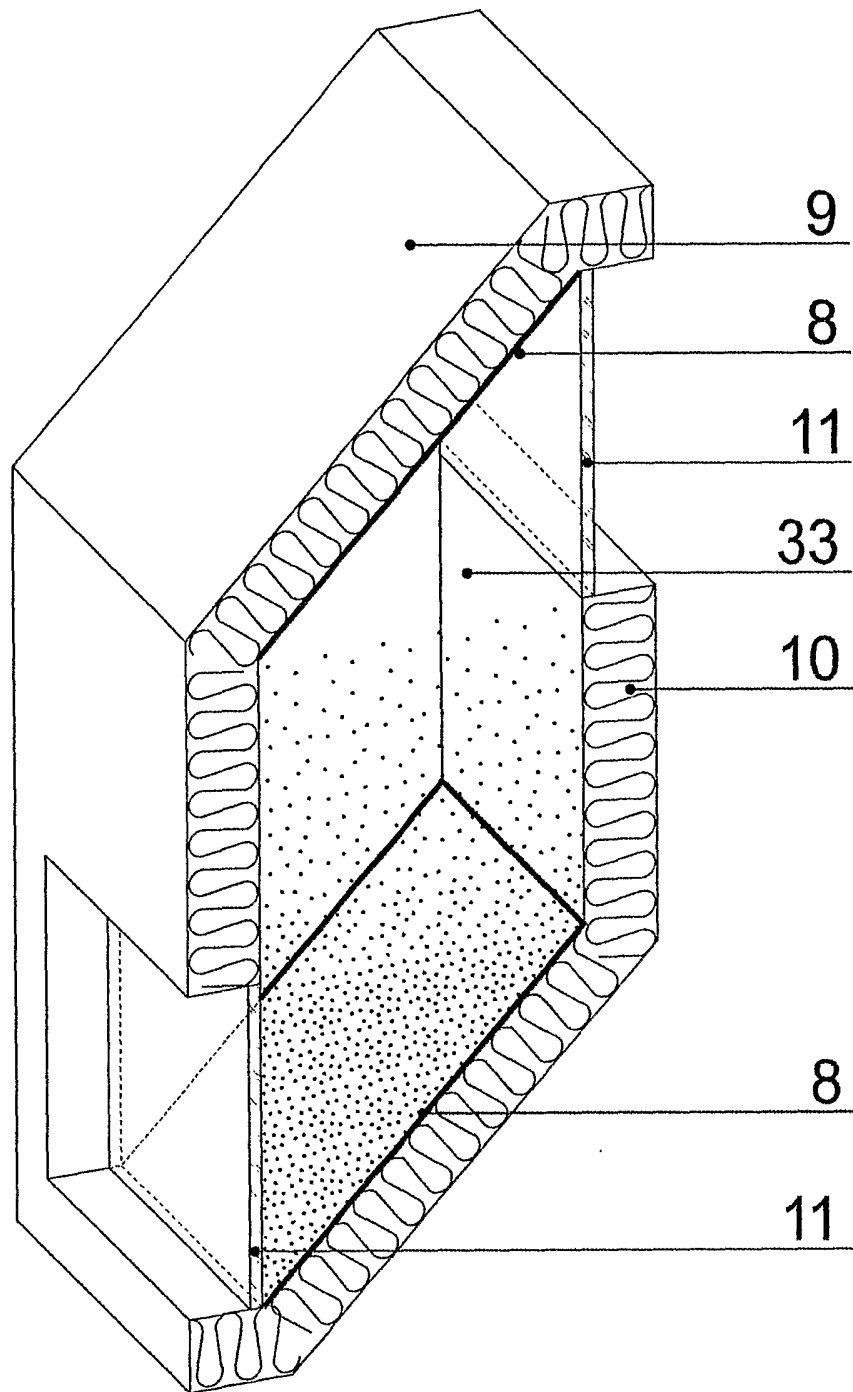


fig. 11

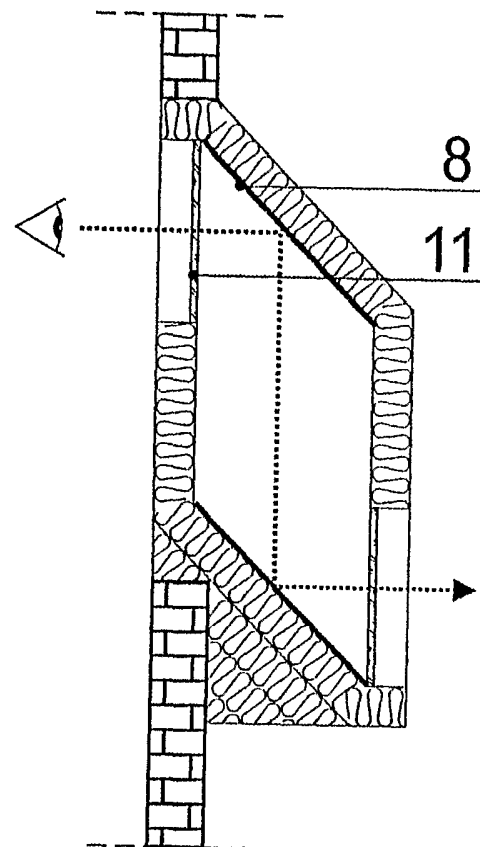
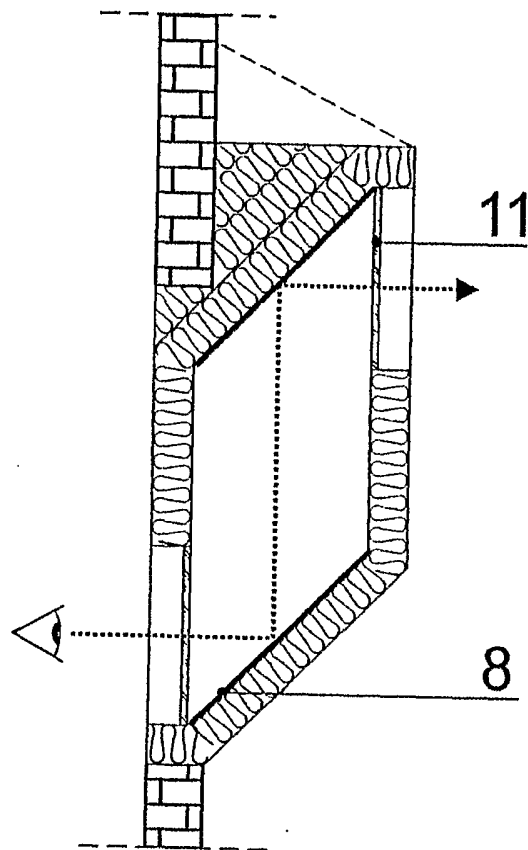


fig. 12

fig. 13

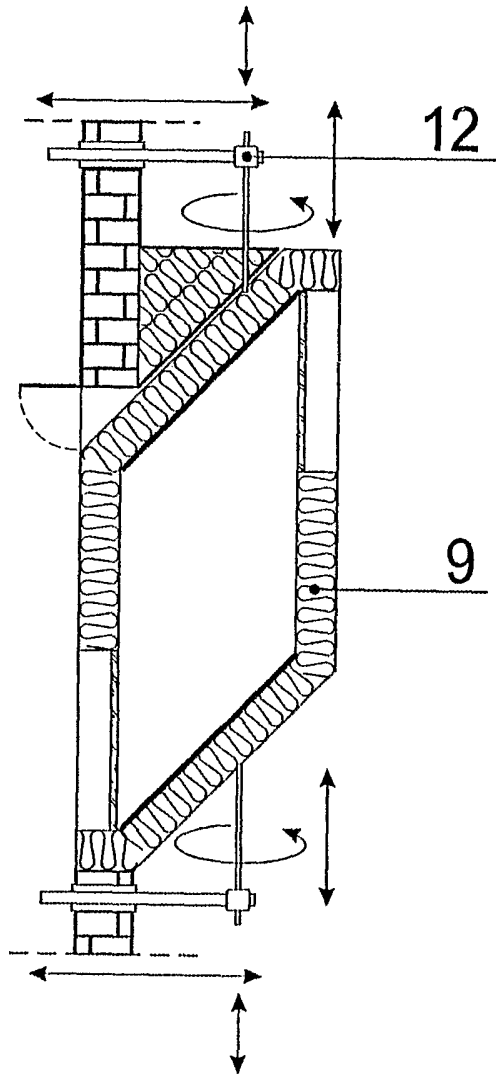


fig. 14

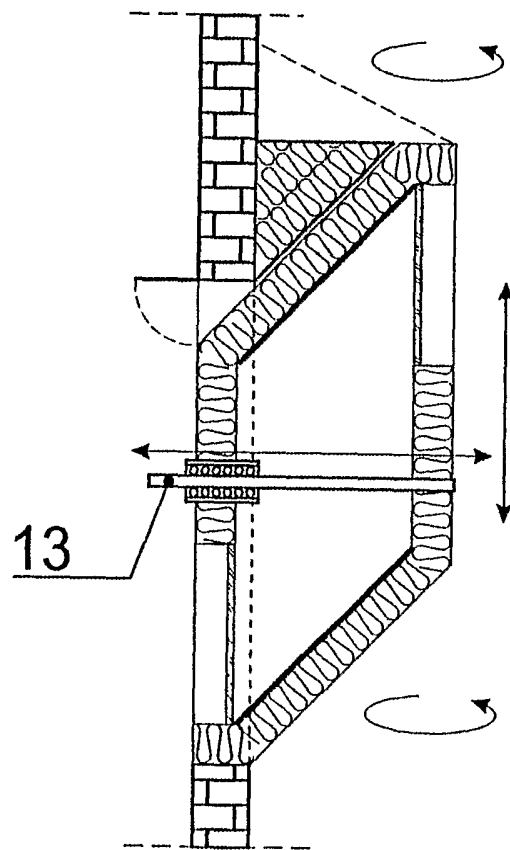


fig. 15

11/19

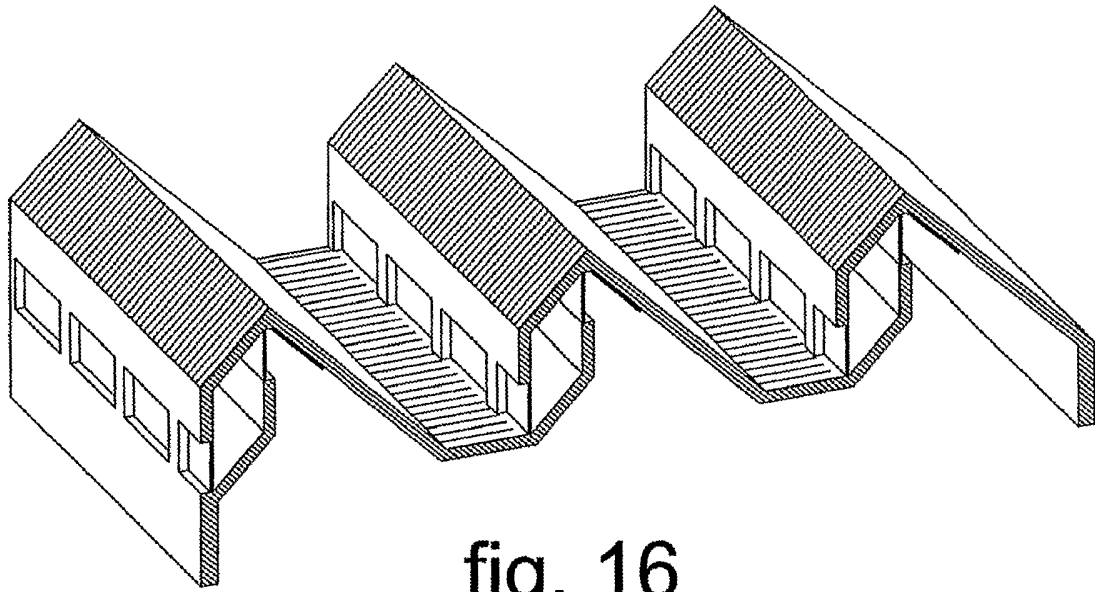


fig. 16

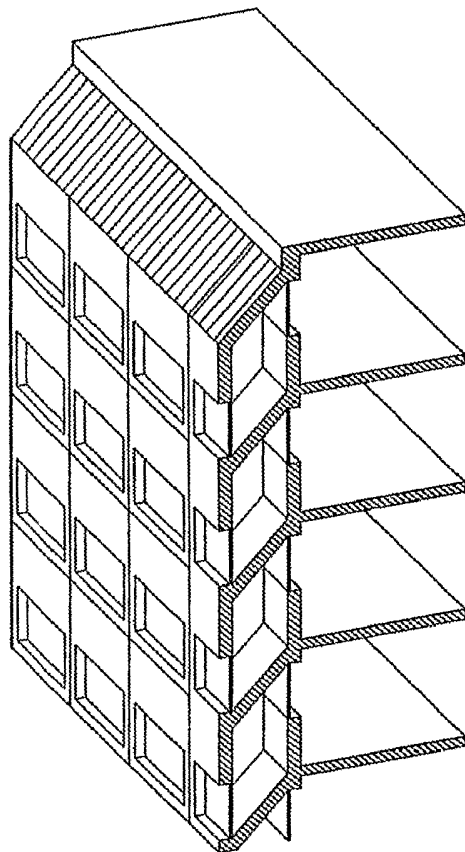


fig. 17

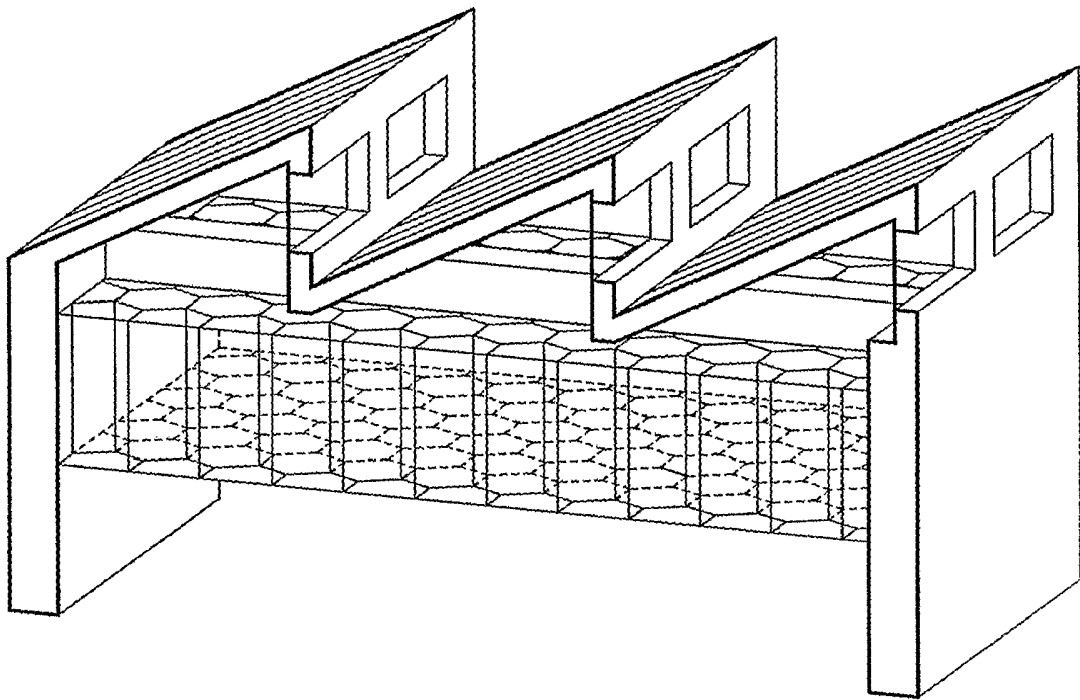


fig. 18

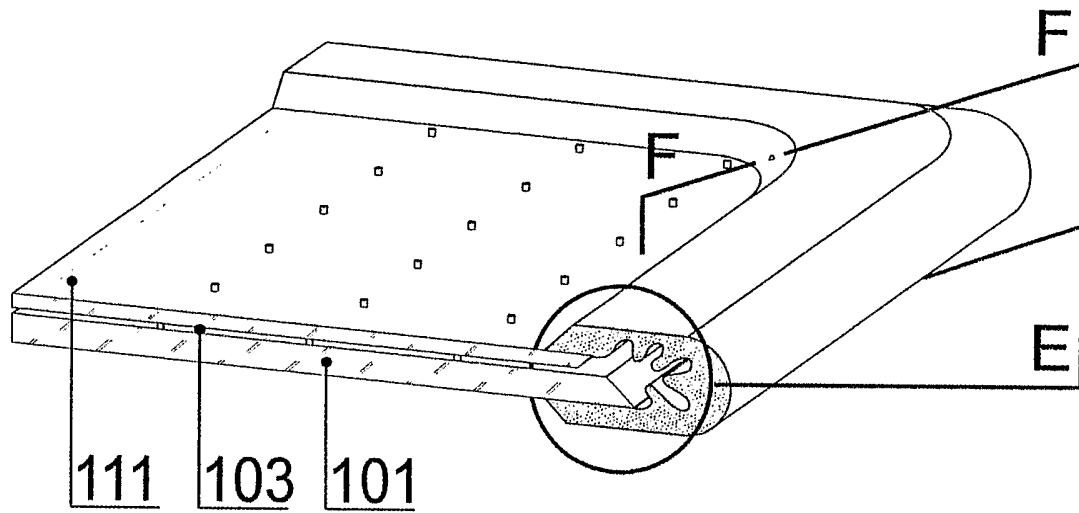


fig. 19

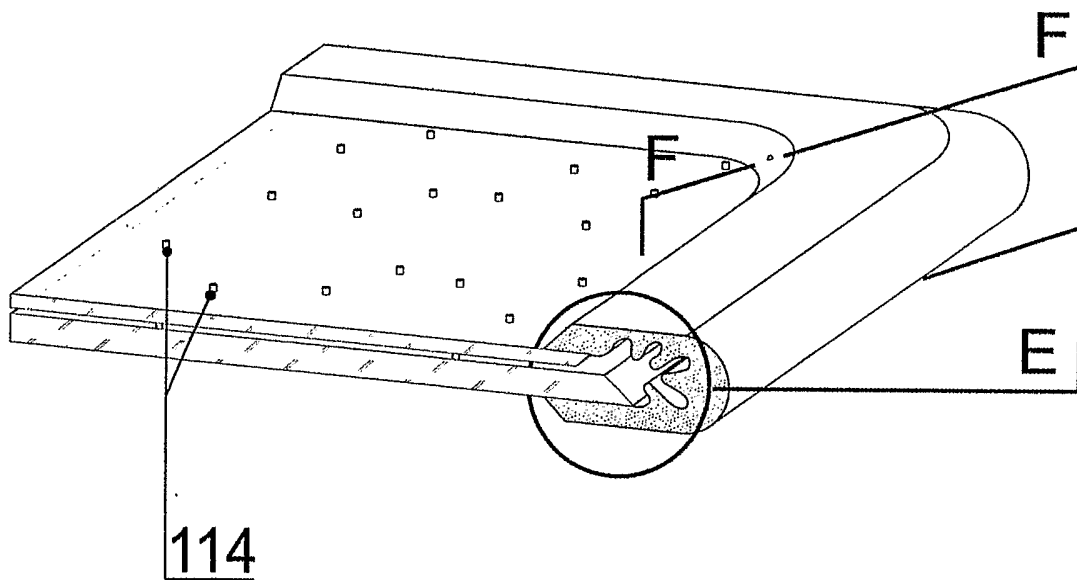


fig. 20

14/19

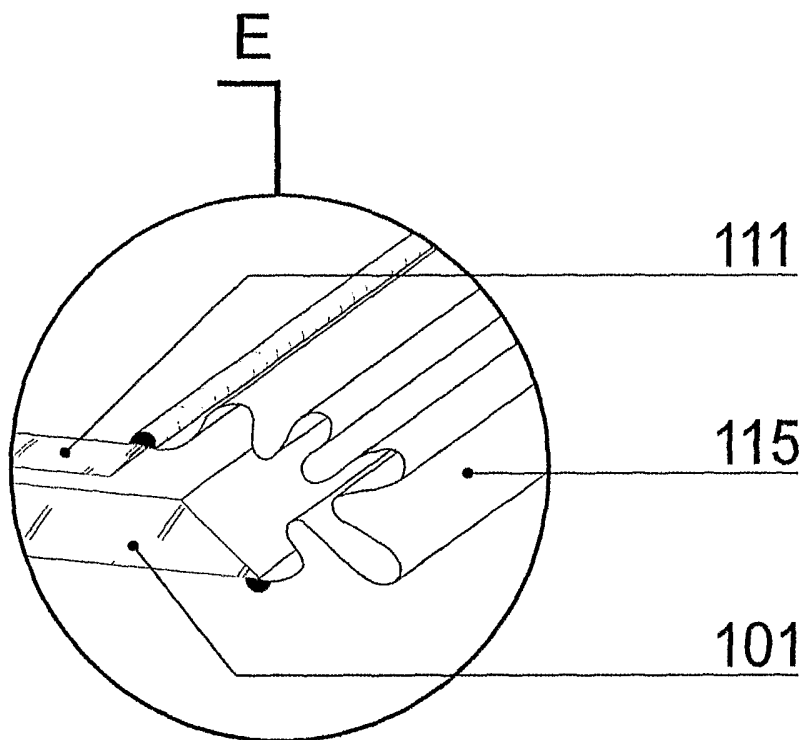


fig. 21

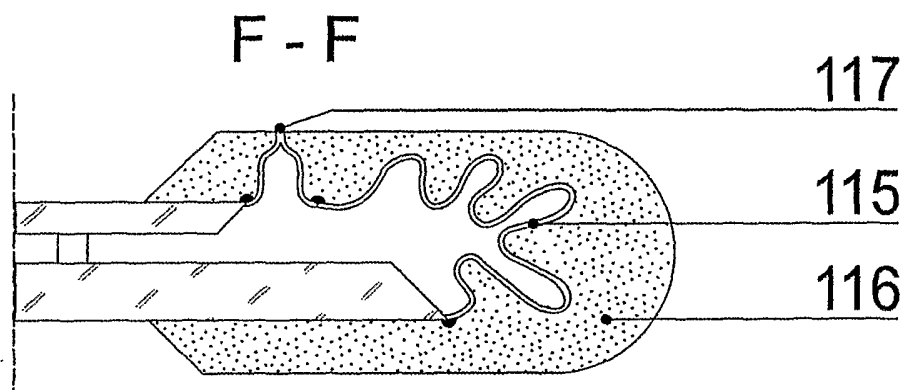


fig. 22

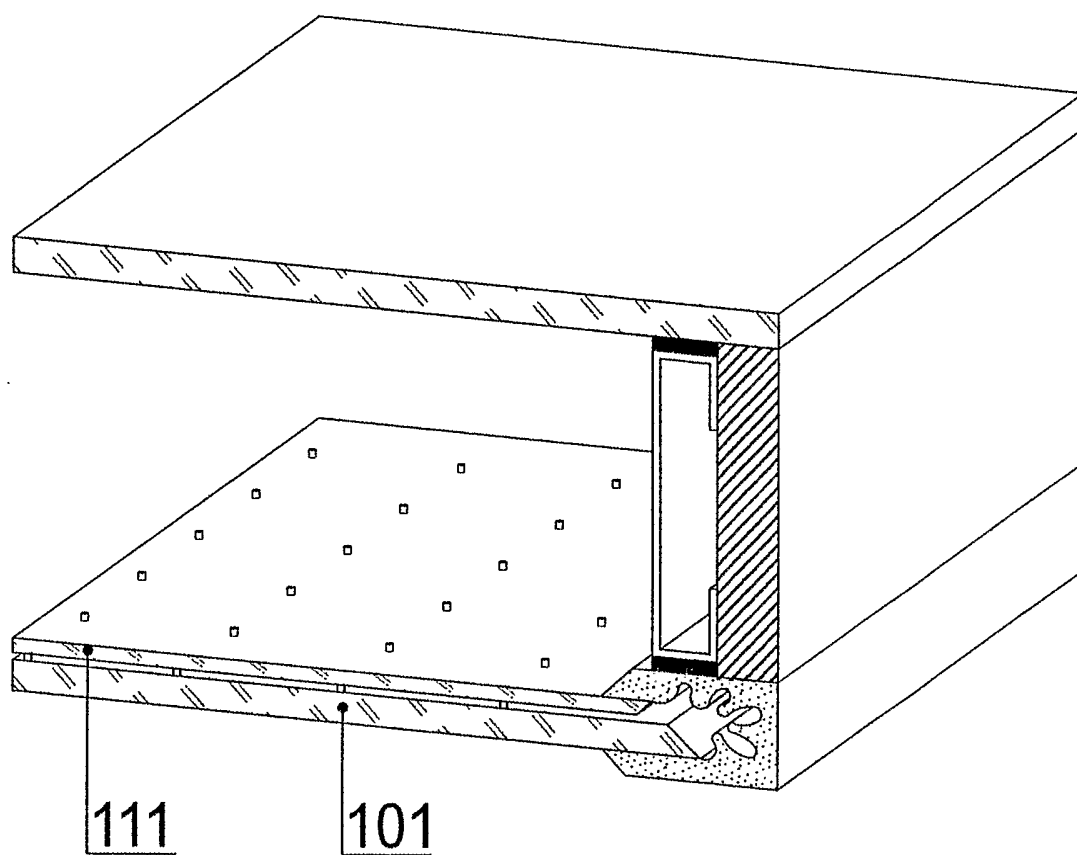


fig. 23

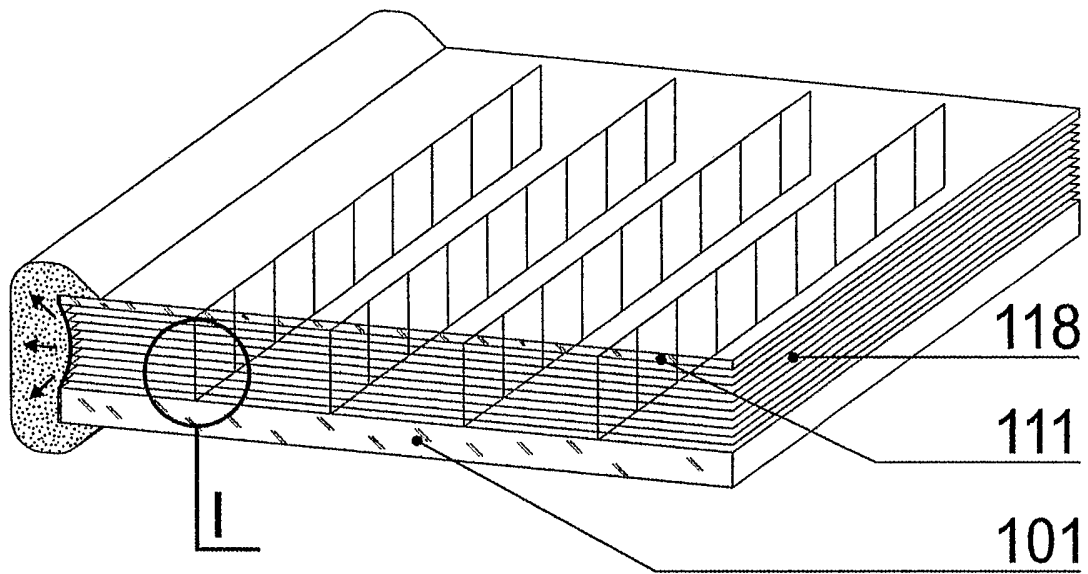


fig. 24

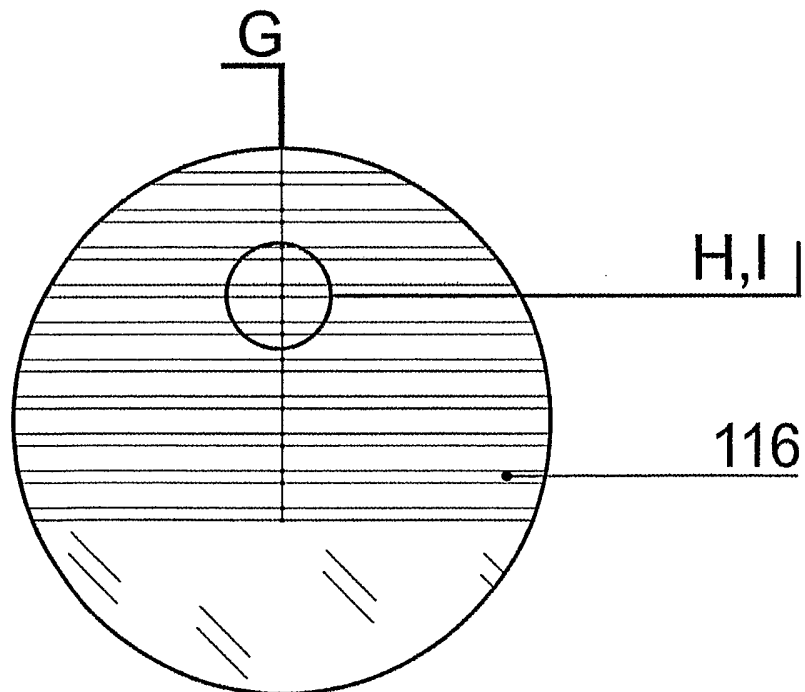
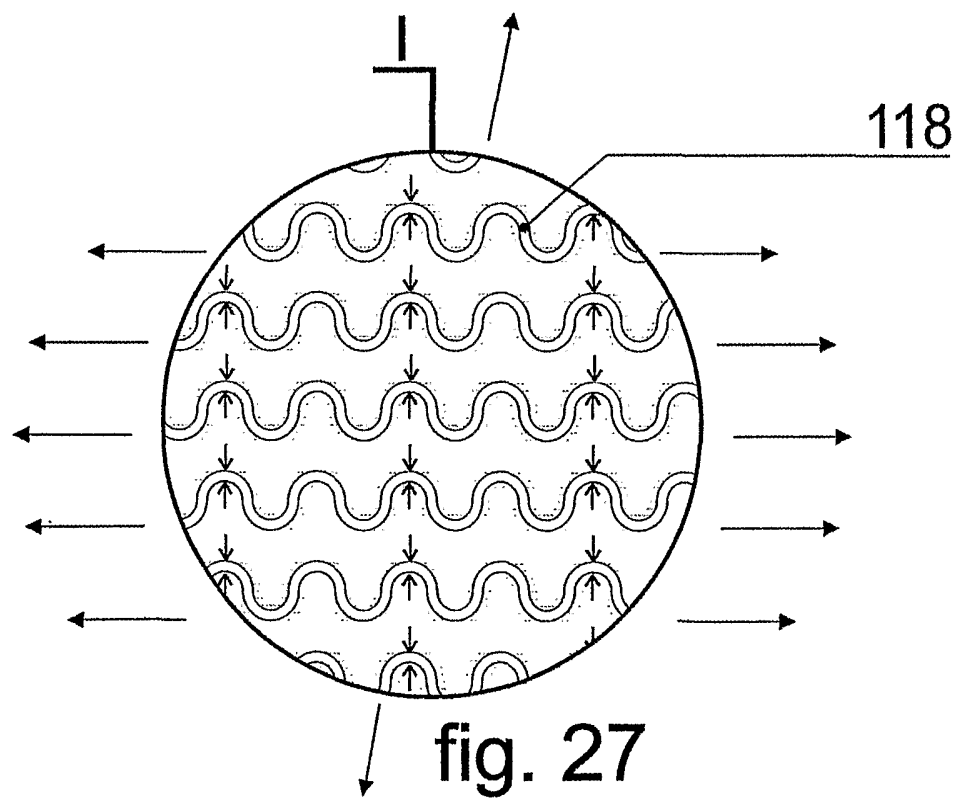
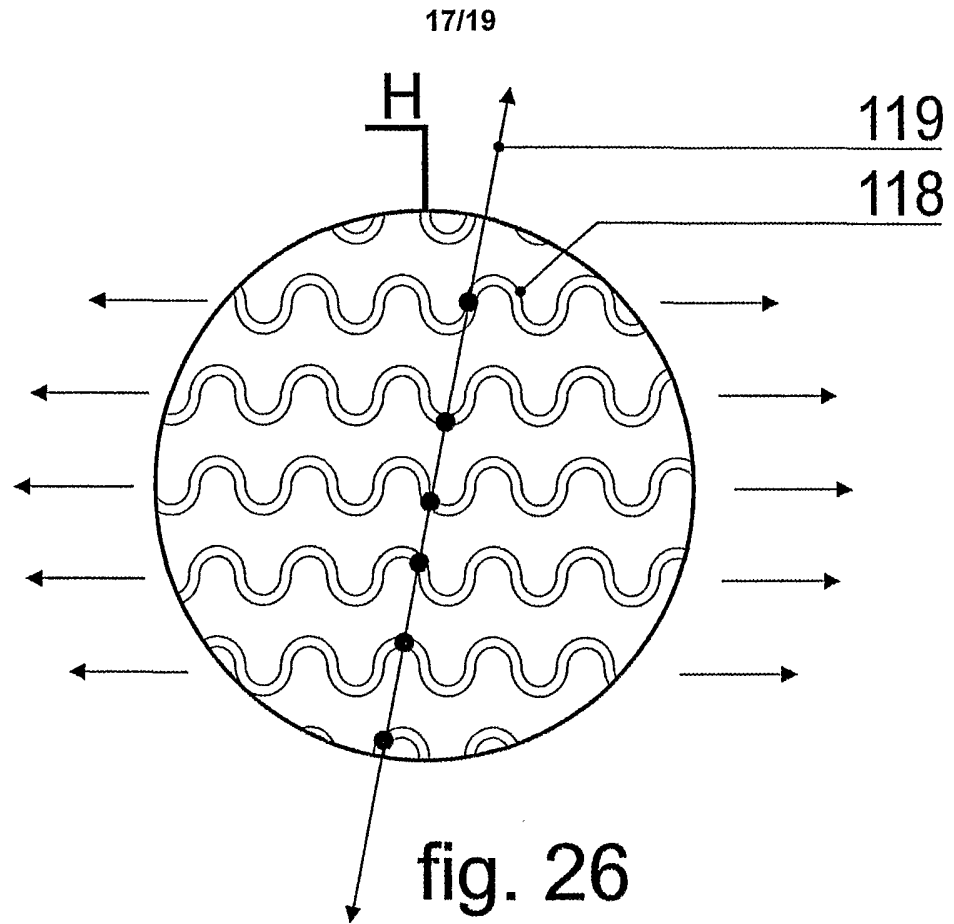


fig. 25



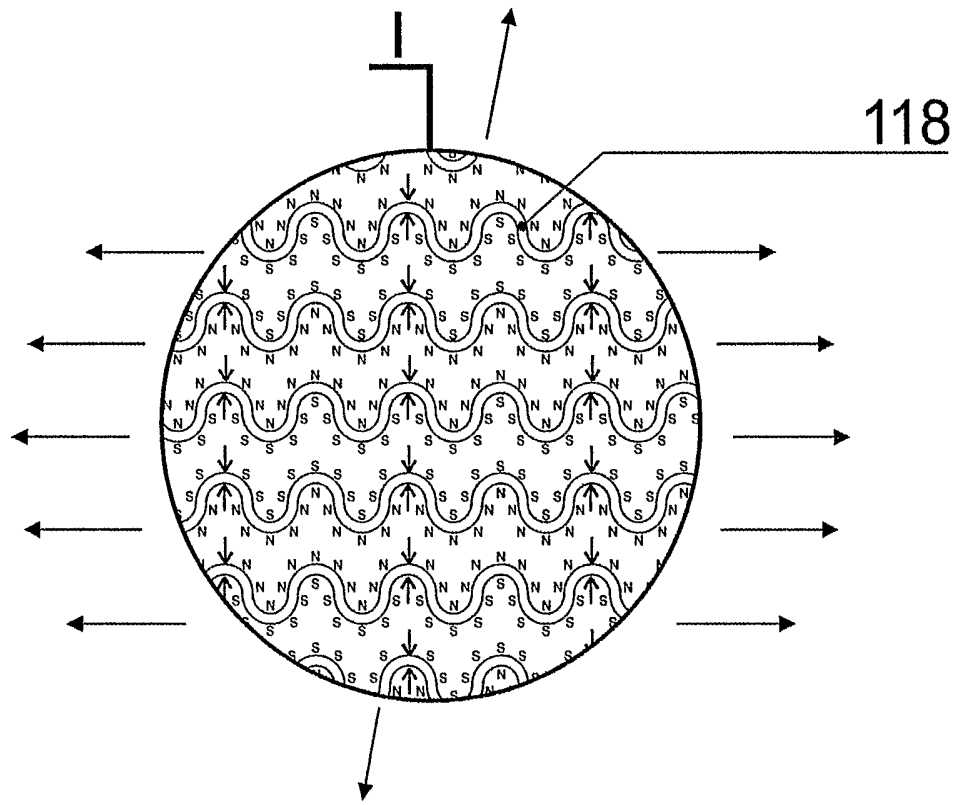


fig. 28

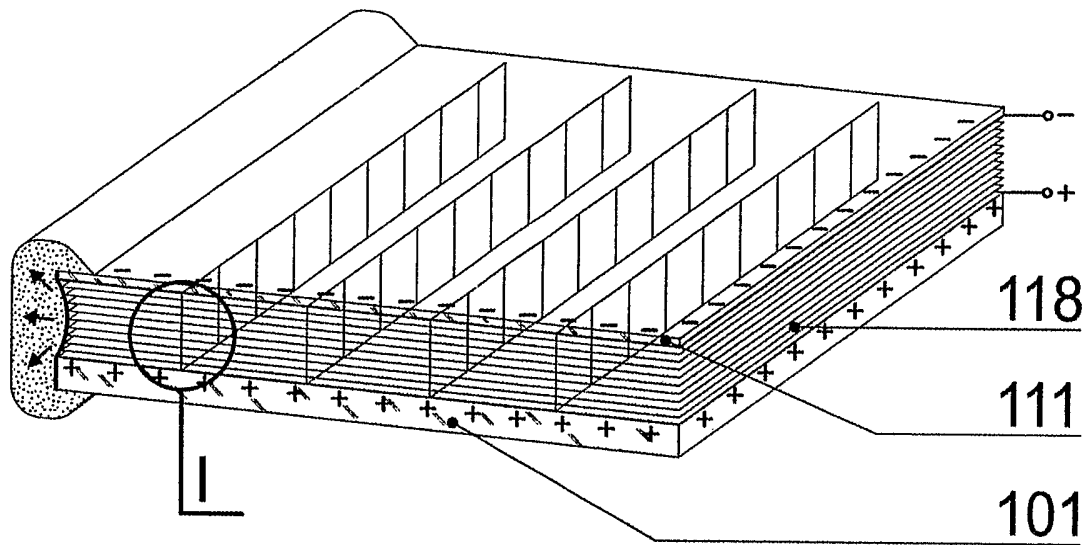


fig. 29

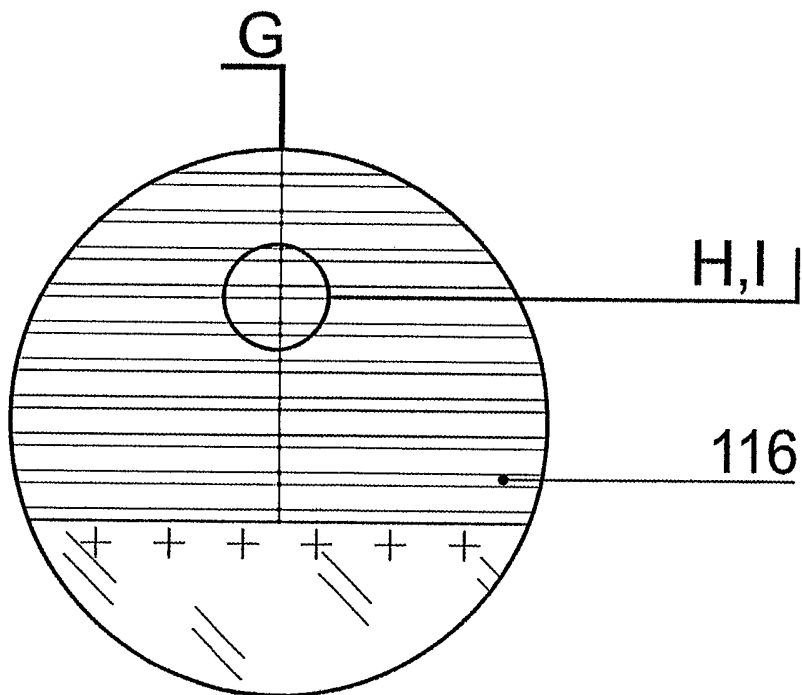


fig. 30

INTERNATIONAL SEARCH REPORT

International Application No

PCT/PL 03/00028

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 E06B3/66 E04B1/80 F16L59/06 E06B5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E06B E04B F16L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category ^o	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 195 09 545 A (FRAUNHOFER GES FORSCHUNG) 19 September 1996 (1996-09-19)	1-4
Y	page 2, line 3 -page 3, line 28 page 4, line 5 - line 23 figures	5-7, 14-26
X	DE 26 47 337 A (STANGE JOACHIM DIPL PHYS DR RE) 20 April 1978 (1978-04-20)	1-3
Y	the whole document	8-13
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Date of the actual completion of the international search

8 September 2003

Date of mailing of the international search report

16/09/2003

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/PL 03/00028

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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