(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
9 September 2011 (09.09.2011)

PCT

(10) International Publication Number
WO 2011/109335 A1

(51) International Patent Classification: *B29C 44/46* (2006.01)

(21) International Application Number: PCT/US2011/026593

(22) International Filing Date: 1 March 2011 (01.03.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/310,015 3 March 2010 (03.03.2010) US

(71) Applicant *(for all designated States except US)*: **DOW GLOBAL TECHNOLOGIES LLC** [US/US]; 2040 Dow Center, Midland, MI 48674 (US).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: **BIRCH, Adrian, J.** [GB/CH]; Weihaldenstrasse 52, CH-8645 Kempraten-jona (CH).

(74) Agent: **COHN, Gary, C.**; Gary C. Cohn PLLC, 215 E. 96th St., #191, New York, NY 10128 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) Title: PROCESS FOR INSULATING A VEHICLE CABIN

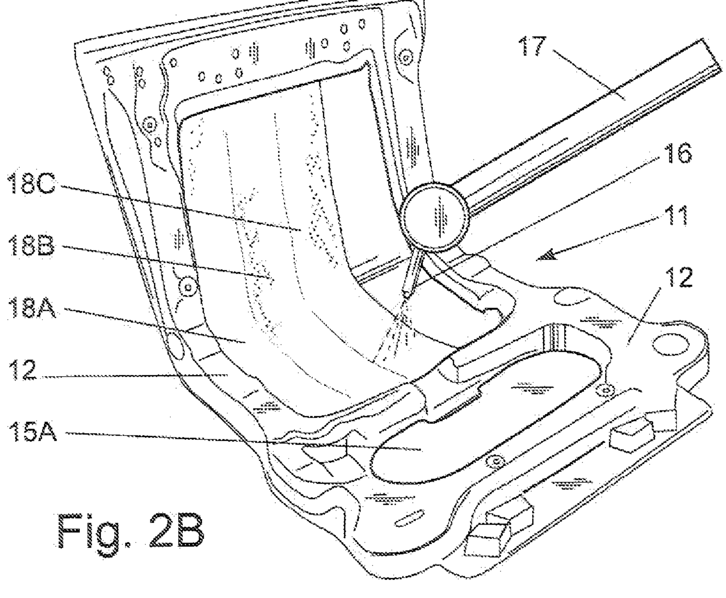


Fig. 2B

(57) Abstract: Acoustical and insulation foam is applied to the interior surfaces of a vehicle cabin by robotic spraying at controlled spray distances. A curable foam formulation is applied by spraying it through a spray head of a specific design. The foam formulation is applied as a series of two or more parallel strips, (18A, 18B, 18C).

WO 2011/109335 A1

PROCESS FOR INSULATING A VEHICLE CABIN

This application claims priority from United States Provisional Patent Application No. 61/310,015, filed 3 March 2010.

This invention relates to a process for insulating vehicle cabins.

Vehicles contain cabins or passenger compartments that enclose the operator and other passengers. For reasons of passenger comfort, portions of these cabins are often thermally and/or acoustically insulated. Large truck cabins are prominent examples. Large truck cabins often have an area behind the seats where the driver can set up a bed and store personal belongings. In the United States, truck cabins of these types are sometimes known as “sleeper cabs”. In some cases, this area can even be large enough to include a small kitchen or sitting area. Sleeper cabs allow the driver to park overnight and sleep at any convenient place along the road.

Thermal and acoustical insulation is very important in these sleeper cabs, if the driver is to be comfortable. Therefore, this insulation is routinely installed when sleeper cabs are manufactured.

This insulation is currently installed by manually applying pre-cut sections of polymeric foam and felt to the interior walls of the cabin. The foam and felt pieces must be cut in advance to fit between and around structural features such as struts, windows and doors, as well as other features. This installation process is time-consuming, as the pieces must be pre-cut to size and then manually installed. The installation process takes so much time that it is often the rate-limiting step in the trim shop assembly lines where the installation takes place. In addition, the foam and felt pieces must be inventoried, which leads to still more costs.

A faster and more economical process for applying this installation is desired.

This invention is a process for insulating a vehicle cabin, comprising robotically spraying a curable foam formulation through a flat cone airless sprayhead onto at least one interior surface of a vehicle cabin in a series of substantially non-overlapping parallel strips from a distance of from 6 to 40 cm from the interior surface, and curing the curable foam formulation to form an insulating foam adherent to the interior surface.

The process produces a good quality insulation layer on interior surfaces of the vehicle cabin. The process is rapid, thereby reducing installation time and enabling the insulation to be applied in a production line setting without creating large production delays. The process is capable of precise application of the foam insulation while virtually eliminating overspray or drift, which can mar or damage the cabin and/or a previously applied paint layer.

Figure 1A is an isometric view of a simulated roof section of a vehicle, prior to application of foam insulation in accordance with this invention.

Figure 1B is an isometric view of the simulated roof section shown in Figure 1A, after a first application of a first parallel strip of curable foam insulation.

Figure 1C is an isometric view of the simulated roof section shown in Figure 1A, during an application of a second parallel strip of curable foam insulation.

Figure 1D is an isometric view of the simulated roof section shown in Figure 1A, during application of a third parallel strip of curable foam insulation.

Figure 1E is an isometric view of the simulated roof section shown in Figure 1A, after application of a third parallel strip of curable foam insulation.

Figure 1F is an isometric view of the simulated roof section shown in Figure 1A, during application of a fourth parallel strip of curable foam insulation.

Figure 1G is an isometric view of the simulated roof section shown in Figure 1A, after application of a fourth parallel strip of curable foam insulation.

Figure 1H is an isometric view of the simulated roof section shown in Figure 1A, during application of a fifth parallel strip of curable foam insulation.

Figure 1I is an isometric view of the simulated roof section shown in Figure 1A, during application of a sixth parallel strip of curable foam insulation.

Figure 1J is an isometric view of the simulated roof section shown in Figure 1A, after application of a sixth parallel strip of curable foam insulation.

Figure 1K is an isometric view of the simulated roof section shown in Figure 1A, after application of a seventh parallel strip of curable foam insulation.

Figure 2A is an isometric view of an integrated vehicular roof and wall panel of a vehicle, prior to application of foam insulation in accordance with this invention.

Figure 2B is an isometric view of the integrated vehicular roof and wall panel shown in Figure 2A, after application of three parallel strips of curable foam insulation.

Figure 2C is an isometric view of the integrated vehicular roof and wall panel shown in Figure 2A, after application of four parallel strips of curable foam insulation in one section, and another strip of curable foam insulation in a second section.

Figure 2D is an isometric view of the integrated vehicular roof and wall panel shown in Figure 2A, after application of foam insulation in accordance with this invention.

Figures 1A through 1K illustrate sequential steps in the insulating process of the invention.

Figure 1A shows simulated roof section 1 of a vehicle cabin. Struts 2 define surfaces 5 and 5A, to which foam insulation is to be applied. As shown, simulated roof section 1 is not assembled onto other surfaces that represent other parts (sides, bottom) of a vehicle cabin. However, it is anticipated that in industrial applications, the process of the invention will typically be conducted on fully or partially assembled vehicle cabins, prior to the installation of trim and most interior components. The vehicle cabin may be painted prior to applying foam insulation in accordance with this invention, although the foam insulation may instead be applied to an uncoated surface or onto e-coated surfaces.

In Figures 1A-1K, surfaces 5 and 5A face downwardly during the spraying process, necessitating an overhead or upward spray direction (upside-down spraying). Because, in a manufacturing environment, the vehicle cabin typically will be assembled prior to applying the foam insulation, it is expected that at least one surface of the cabin often will be facing downwardly when the foam insulation is applied to it in the manner shown in Figures 1A-1K. The curable foam formulation can be applied to multiple and/or non-coplanar surfaces of a vehicle cabin, in accordance with the invention, including one or more downwardly-facing surfaces, without repositioning the vehicle cabin during the spraying process.

As shown, surface 15 is planar, but one or more surfaces of a vehicle cabin may be have non-planar surfaces. The process of the invention is easily used to apply a foam insulation layer to a three-dimensional surface of a vehicle cabin.

In Figures 1A through 1K, a curable foam formulation is applied surfaces 5 and 5A of simulated roof section 1. Mix/sprayhead 6 is affixed to robotic arm 7, which controls the movement of mix/spray head 6. Robotic arm 7 and mix/spray head 6 are operated via computerized controls (not shown) which (a) control the placement and movement of mix/spray head 6 relative to surfaces 5 and 5A and (b) control the timing of the mix/spray head operation. The computerized controls may also control other operating parameters such as pressure and/or temperatures at mix/spray head 6.

In Figure 1A, mix/spray head 6 is held in a starting position, from which it will begin the spraying process. Robotic arm 7 is controlled to move mix/spray head 6 over the surfaces 5 and 5A in a series of parallel lines. Mix/spray head 6 is operated to dispense a curable foam formulation onto surfaces 5 and 5A as it moves along those parallel lines, on each pass laying down a strip of the curable foam formulation.

Figures 1B through 1J demonstrate the movement of robotic arm 7 and mix/sprayhead 6 through the process of applying an insulating layer onto surfaces 5 and 15 of simulated roof sections 5 and 5A. Robotic arm 7 first moves upwardly and downwardly over surface 5, moving a predetermined distance to the left after each pass. During each pass, a strip of curable foam formulation is applied to surface 5. Robotic arm 7 and mix/sprayhead 6 move transversely across surface 5 in three passes to apply three strips of the curable foam formulation to surface 5.

Figure 1B shows the position of mix/spray head 6 and robotic arm 7 at the end of the first pass. During this first pass, a strip 8A of the curable foam formulation is applied to surface 5. Robotic arm 7 is operated such that mix/spray head 6 is maintained within a predetermined range of distances from surface 5 as mix/spray head 6 traverses surface 5 in this first pass (as well as all subsequent passes). Typically, this distance is maintained essentially constant throughout each pass, in order to lay down strips of uniform width and thickness.

At the conclusion of the first pass, robotic arm 7 moves mix/sprayhead 6 to the left by a predetermined distance, and applies a second strip 8B of curable foam formulation while moving back upwardly across surface 5. Figure 1C shows the position of robotic arm 7 and mix/sprayhead 6 at the beginning of this second pass. Robotic arm 7 and mix/sprayhead 6 have moved enough to the left such that the second strip 8B is applied parallel to and abuts first strip 8A, substantially without overlapping the strips. Adjacent strips abut “substantially without overlapping” if they (1) abut but do not overlap at all, (2) overlap to the extent of 10% or less of their respective widths and/or (3) are separated by a distance which becomes filled as the curable foam formulation expands. Other spraying parameters, including the distance from mix/sprayhead 6 to surface 5, the spray pattern produced by the mix/sprayhead and operating pressures, are taken into account in determining the amount of leftward movement between the application of adjacent strips 8A and 8B, so there is essentially no overlap between the first strip 8A and second strip 8B of the curable foam formulation. The distance from mix/sprayhead 6 and surfaces 5 and 5A is at least 6 cm and not more than 40 cm. A preferred distance is at least 8 cm up to 35 cm.

Figure 1D shows the position of mix/sprayhead 6 and robotic arm 7 during the application of third strip 8C of the curable foam formulation to surface 5. This third strip is again laid essentially parallel to the previously applied strip 8B, with substantially no overlap, again through robotic control of the position and path of mix/sprayhead 6. At the point in the process represented in Figure 1E, first and second strips 8A and 8B of the curable foam formulation are seen to be visibly expanding and curing, whereas third strip 8C exhibits minimal rise and cure.

Figure 1E shows the position of mix/sprayhead 6 and robotic arm 7 after the application of third strip 8C of the curable foam formulation to surface 5. At the point in the process represented in Figure 1E, first, second and third strips 8A, 8B and 8C of the curable foam formulation are seen to be visibly expanding and curing. Total elapsed time from the start of the process (Figure 1A) to the position shown in Figure 1E is on the order of about 1 to 20 secones, preferably from 2 to 10 seconds and more preferably from 4 to 5 seconds.

Figures 1F through IJ illustrate the movement of mix/sprayhead 6 and robotic arm 7 during the application of four substantially parallel, non-overlapping strips 8D, 8E, 8F and 8G to surface 5A of simulated roof section 1.

Figure 1K shows the insulated simulated roof section 1 after the application of the curable foam formulation to surfaces 5 and 5A has been completed. The applied curable foam formulation rises and cures after it is applied. As shown in Figure 1K, strips 8A-8C have merged as a result of the rising and curing process to form insulation layer 9, which adheres to surface 5 of insulated roof/sidewall 1. Strips 8D-8G, being the last to have been applied, have in Figure 1K only partially risen and cured. Upon further reaction, strips 8D-8G will merge to form an insulation layer which adheres to surface 5A of insulated roof/sidewall 1. Struts 2 remain exposed. Insulation layers 5 and 5A are of highly uniform thickness, although some thickening can be present at the junctions between adjacent strips of curable foam formulation. This thickening can be reduced or eliminated through more careful control of the movement of mix/sprayhead 6, by changing application rates (such as by adjusting operating pressures) and/or by modifying the distance from the mix/sprayhead 6 and surfaces 5 and 5A.

The process illustrated in Figures 1A-1K can of course be extended to apply a foam insulation to a fully assembled vehicle cabin body (preferably prior to installing interior components), or to sub-assemblies thereof. A fully assembled vehicle cabin body (or a sub-assembly) typically will include multiple (two or more) non-coplanar surfaces which need insulating. One or more of those surfaces is often oriented downwardly when the foam formulation is applied in accordance with the invention, so that the curable foam formulation must be sprayed upwardly onto those surfaces ("upside-down" spraying). The process of the invention is useful to apply a foam insulating layer to as few as one and as many as all of the various surfaces of the vehicle cabin body. The foam insulation can be applied to multiple surfaces using a single robotically controlled mix/sprayhead, or multiple robotically controlled mix/sprayheads.

The vehicle cabin may be a passenger compartment for an automobile, truck, boat, personal water craft, train or other land or marine vehicle. As mentioned, truck sleeper cabs are of particular interest.

The sprayhead used in this invention is a flat cone airless type. By "airless" it is mean that no propelling gas is ejected through the sprayhead as the foam formulation is sprayed onto the interior surface of the vehicle body. Gasses may be passed through the sprayhead between shots, such as for cleaning purposes. "Flat cone" refers to the spatial distribution of the sprayed foam formulation. Viewed from the side, the sprayed foam formulation forms a fan-like shape. If the sprayhead were to be held stationary with respect to the target as the foam formulation is dispensed, the sprayed foam formulation would contact the target to form a straight-line pattern or a highly elongated ellipse. The sprayhead is oriented so that the width of the spray is perpendicular to its direction of movement as the foam formulation is sprayed, so that the width of the applied strips of foam formulation is defined by the width of the spray. Flat cone sprayheads are available commercially from manufacturers such as Spraying Systems Company, Wheaton, Illinois US.

The sprayhead may be affixed to a mixhead. This will usually be the case when the curable foam formulation consists of two or more constituent components which are to be mixed immediately before spraying. In such a case, the various constituent components are brought together under pressure at the mixhead, where they are mechanically mixed together and then passed through the sprayhead for application onto the vehicle cabin. Impingement mixers are a preferred type of mixhead, but other types of mixheads, including static mixers, can be used instead of or in conjunction with an impingement mixer. Suitable mixheads are available commercially from manufacturers such as Canon and Krauss-Maffei.

The flow of materials to the mixhead, including flow rates and in some cases temperature, is preferably automated and controlled in conjunction with other operating parameters, such as the rate of movement of the sprayhead across the surface of the vehicle cabin and the distance of the sprayhead to the surface, to obtain the desired spray pattern, width of spray, and thickness of the applied layer. It is generally preferable to apply a layer which, after expansion, is from 10 to 75 mm thick, although it is possible to apply thinner or thicker layers. The output of curable foam formulation from the sprayhead may be from 1 to 200 grams/second (g/s), preferably from 5 to 100 g/s and more preferably from 10 to 50 g/s.

Traversing speeds (i.e., the relative speed of the sprayhead to the vehicle surface during a spraying step) are selected to provide the desired layer thickness. Suitable traversing speeds are typically from 100 to 2000 mm/second. A preferred range is from 200 to 1200 mm/second.

Robotic control is provided by an automated mechanical device to which the sprayhead is affixed. Movement of the mechanical device is controlled by one or more computers, by which is meant simply a programmed electronic device which generates signals that directly or indirectly produce the desired movement of the mechanical device. The program may exist in software or firmware, or some combination thereof. The mechanical device includes or is connected to various actuators, such as motors, piezoelectric or hydraulic systems, which respond to signals produced by the computer(s) to effect a predetermined movement in response to specific signals. The specific design of the robotic control system is not considered to be critical to the invention, provided that the robotic control system is capable of manipulating the sprayhead through the movements as are needed to apply the curable foam formulation. Suitable robotic control systems are available from various commercial sources, including ABB Robotics, Zurich, Switzerland.

After the curable foam formulation is applied to the interior surface(s) of the vehicle cabin, it is subjected to conditions sufficient for the formulation to expand and cure to form a foam. The preferred multipart polyurethane formulations can be formulated so that they react exothermically at temperatures ranging from slightly below room temperature to a slightly elevated (up to 50°C) temperature. In such a case, all that is required is to bring the components to the mixhead at a temperature sufficient for the components to react, and to maintain a temperature of from about 15°C to about 50°C during the spraying step and curing steps. Expansion and initial curing to a tack-free state in this case is generally completed within about 1 minute. If necessary, the components can be heated to higher temperatures or cooled to lower temperatures before performing the mixing and spraying steps, and heat can be applied to the sprayed foam to help promote expansion and curing.

Because the foam formulation can be applied rapidly and often expands and cures rapidly to a tack-free state, the process of the invention can be easily practiced in an assembly line environment, in which the vehicle cabin is mounted on a movable production line as the foam insulation is applied. In a vehicle manufacturing plant, it is common to mount the vehicle cabin on such a movable line, which may take any form, for transporting it sequentially through multiple assembly stations at which various assembly steps are performed. The movable line may be brought to a stop at one or more assembly stations at which the foam insulation layer is applied in accordance with this invention.

It is generally desirable to apply the foam insulation layer to the vehicle cabin before interior components are assembled inside of the vehicle cabin. In many vehicle manufacturing plants, these interior components are assembled onto or inside of the vehicle cabin in a “trim shop”, which is located after a preceding painting or e-coating step is completed. It is often convenient to apply the foam insulation layer to the painted vehicle cabin, in which case the foam insulation layer is applied between the paint and trim shops of an assembly plant, or in the trim shop after painting but before additional trim features are assembled onto the vehicle cabin.

However, it is also possible to apply the foam insulation layer to the vehicle cabin prior to painting, or at least prior to the application of the final paint coat. In such a case, one or more paint layers can be applied overtop the foam insulation layer. This can have benefit in at least two respects. A paint layer covering the foam insulation layer can provide stiffening and/or a non-porous surface layer. In addition, because many automotive coatings need to be thermally cured, it is possible to post-cure the foam insulation layer simultaneously with the paint curing step, to further develop the physical properties of the foam insulation layer.

The curable foam formulation can be any material which, when sprayed onto the vehicle cabin surface, (1) adheres to the surface and (2) expands and cures to form a cellular insulation. The cured insulation suitably has a foam density of from 16 to 240 kg/m^3. A preferred density is from 24 to 96 kg/m^3 and a more preferred density is from 24 to 64 kg/m^3. The insulation may be open or closed-celled, although it is preferred that at least 10%, preferably at least 25% and still more preferably at least 50% by number of the cells are open.

The curable foam formulation may be, for example, an expandable epoxy resin or an expandable polyurethane. The curable foam formulation preferably expands and cures to a tack-free state in less than one minute, preferably in less than 30 seconds, after application. A preferred type of curable foam formulation is a multi-part polyurethane, as these systems can be formulated to expand and cure very rapidly.

The multi-part polyurethane consists of at least a polyol component and a polyisocyanate component. These components are formulated separately, the polyol component containing at least one polyol and other isocyanate-reactive materials as may be present, and the polyisocyanate containing at least one polyisocyanate compound. It is possible to formulate all of the isocyanate-reactive materials into a single, formulated polyol component, and to formulate all of the polyisocyanate compounds into a single polyisocyanate component, and to bring exactly two streams into the mixhead. It is also possible to bring the ingredients to the mixhead in a greater number of streams. Auxiliary materials such as blowing agents, surfactants, catalysts, fillers, reinforcing fibers, and the like can be formulated into either or both of the polyol component or the polyisocyanate component. Reinforcing fibers can also or alternatively be brought separately into the mixhead and combined with the curable foam formulation in the mixhead, in the spray head or in the spray.

The curable foam formulation will contain at least one blowing agent. Preferred types of blowing agents are those which release carbon dioxide or react to form carbon dioxide under the conditions of the curing step. Water is a preferred blowing agent, although compounds such as certain carbamates and bicarbonate/citric acid mixtures are also useful.

The selection of particular polyols, polyisocyanates and other components of the polyurethane foam formulation are selected to provide the desired foam density, curing characteristics, insulating properties and physical properties. The cured insulation may be a highly rigid, friable material, may be a highly compressible and flexible material, or may be a so-called "viscoelastic" material which exhibits a time-delayed and rate-dependent response to an applied stress. These viscoelastic foams have low resiliency and recover slowly when compressed. Foam formulations useful for preparing these various types of insulating foams are well known and described, for example, in US

5,817,860, US 6,423,755, US 6,541,534, WO 02/079340, WO 03/037948, WO 05/069273, WO 07/040617 and WO 08/021034, all incorporated herein by reference.

The polyol component generally will contain at least one polyol that has at least three hydroxyl, primary amino and/or secondary amino groups per molecule. Two or more such polyols may be present. In addition, one or more polyol(s) having a lower (1 to 2) functionality or higher (4 to 8) functionality may be present. The polyol(s) preferably have an equivalent weight of from 31 to about 2000 per hydroxyl and/or primary or secondary amino group. When the insulation is a rigid type, the average equivalent weight of the polyols tends to be in the range of from about 50 to 200. Viscoelastic foams tend to be produced when the predominant (i.e., that present in the largest quantity by weight) polyol has an equivalent weight of 200 to 400. More flexible materials tend to be produced when the predominate polyol has an equivalent weight of greater than 400.

Suitable polyols include glycerine, trimethylolpropane, trimethylolethane, pentaerythritol, sorbitol, sucrose, diethanolamine, monoethanolamine, triethanolamine, pentaerythritol, neopentyl glycol, dipropylene glycol, tripropylene glycol, diethylene glycol, alkoxylates (especially ethoxylates and/or propoxylates) of any of the foregoing as well as other polyether polyols and triethylene glycol polyester polyols. Polyether polyols are preferred; such a polyether polyol may be a homopolymer of propylene oxide, a random copolymer of propylene oxide and optionally up to 30% by weight ethylene oxide, or an ethylene oxide-capped poly(propylene oxide).

Each polyisocyanate compound is an organic polyisocyanate or mixture. These compounds suitably have, in the aggregate, an isocyanate content of from 8 to 45 weight percent, preferably from 15 to 40 weight percent, and an average functionality of from 2.0 to 3.5 isocyanate groups per molecule. Suitable polyisocyanates include aromatic, aliphatic and cycloaliphatic polyisocyanates. Aromatic polyisocyanates are generally preferred based on cost, availability and properties imparted to the product polyurethane. Exemplary polyisocyanates include, for example, m-phenylene diisocyanate, 2,4- and/or 2,6-toluene diisocyanate (TDI), the various isomers of diphenylmethanediisocyanate (MDI), hexamethylene-1,6-diisocyanate, tetramethylene-1,4-diisocyanate, cyclohexane-1,4-diisocyanate, hexahydrotoluene diisocyanate, hydrogenated MDI (H_{12} MDI), naphthylene-1,5-diisocyanate, methoxyphenyl-2,4-diisocyanate, 4,4'-biphenylene diisocyanate, 3,3'-dimethoxy-4,4'-biphenyl diisocyanate, 3,3'-dimethyldiphenylmethane-4,4'-diisocyanate, 4,4',4"-triphenylmethane triisocyanate, polymethylene polyphenylisocyanates, hydrogenated polymethylene polyphenylisocyanates, toluene-2,4,6-triisocyanate, and 4,4'-dimethyl diphenylmethane-2,2',5,5'-tetraisocyanate. Preferred polyisocyanates include MDI and derivatives of MDI such as carbodiimide-modified or uretonimine-modified "liquid" MDI products and polymeric MDI, as well as mixtures of the 2,4- and 2,6- isomers of TDI. Any of the foregoing polyisocyanates may be modified with carbodiimide, biuret, urethane, urea or similar groups.

Either or both of the polyol and the isocyanate components may contain various optional ingredients. These include an organosilicone surfactant, one or more reaction catalysts, a diluent, a plasticizer, a flame retardant, fillers, reinforcing fibers, and the like.

The silicone surfactant, if present, is suitably an organosilicone type. A wide variety of organosilicone surfactants are useful, including those sold by Momentive Performance Materials under the Niax™ trade name or those sold by Th. Goldschmidt AG under the trade name Tegostab™, or those sold by Air Products under the Dabco™ tradename. Specific examples include Niax™ L-6900 surfactant, Tegostab™ B 1048 B-8462, B8427, B8433 and B-8404 surfactants and Dabco™ DC-193, DC-198, DC-5000, DC-5043 and DC-5098 surfactants. The surfactant suitably constitutes from 0.25 to 5 percent, preferably from 0.5 to 2.5 percent, of the total weight of the polyisocyanate component.

Suitable catalysts include tertiary amine compounds and organometallic compounds, especially tin carboxylates and tetravalent tin compounds. Representative tertiary amine catalysts include trimethylamine, triethylamine, dimethylethanolamine, N-methylmorpholine, N-ethylmorpholine, N,N-dimethylbenzylamine, N,N-dimethylethanolamine, N,N,N',N'-tetramethyl-1,4-butanediamine, N,N-dimethylpiperazine, 1,4-diazobicyclo-2,2,2-octane, bis(dimethylaminoethyl)ether, bis(2-dimethylaminoethyl) ether, morpholine,4,4'-(oxydi-2,1-ethanediyl)bis, triethylenediamine, pentamethyl diethylene triamine, dimethyl cyclohexyl amine, N-cetyl N,N-dimethyl amine, N-coco-morpholine, N,N-dimethyl aminomethyl N-methyl ethanol amine, N, N, N'-trimethyl-N'-hydroxyethyl bis(aminoethyl) ether, N,N-bis(3-dimethylaminopropyl)N-isopropanolamine, (N,N-dimethyl) amino-ethoxy ethanol, N, N, N', N'-tetramethyl hexane diamine, 1,8-diazabicyclo-5,4,0-undecene-7, N,N-dimorpholinodiethyl ether, N-methyl imidazole, dimethyl aminopropyl dipropanolamine, bis(dimethylaminopropyl)amino-2-propanol, tetramethylamino bis (propylamine), (dimethyl(aminoethoxyethyl))((dimethyl amine)ethyl)ether, tris(dimethylamino propyl) amine, dicyclohexyl methyl amine, bis(N,N-dimethyl-3-aminopropyl) amine, 1,2-ethylene piperidine and methyl-hydroxyethyl piperazine

Examples of useful tin catalysts include stannous octoate, dibutyl tin diacetate, dibutyl tin dilaurate, dibutyl tin dimercaptide, dialkyl tin dialkylmercapto acids, dibutyl tin oxide, dimethyl tin dimercaptide, dimethyl tin diisooctylmercaptoacetate, and the like.

Catalysts are typically used in small amounts. For example, the total amount of catalyst used may be 0.0015 to 10, preferably from 0.5 to 10 parts by weight per 100 parts by weight of polyol or polyol mixture. Catalyst concentrations tend to be somewhat high in this invention to promote a fast cure, so that the sprayed foam formulation does not run off of the surfaces to which it is applied, and so the vehicle cabin can be taken to downstream manufacturing processes quickly after the foam insulation layer is applied.

Diluents are materials which are added to reduce component viscosities or to balance mixing ratios. They may be of the reactive or non-reactive types. Plasticizers tend to make the cured polymer more flexible, and may also be present to balance mixing ratios. Various phthalate esters are useful for this purpose.

Flame retardants are commonly halogenated and/or phosphorus-containing compounds. A wide number of these materials are useful herein.

Fillers include particulate solids which are thermally and chemically stable at the temperatures encountered in the curing reaction. They may be inorganic materials such as various clays, ground glass, boron nitride, calcium carbonate, mica, titanium dioxide, diatomaceous earth, carbon black and the like, or may be high-melting or non-melting organic polymers. Fibers include materials such as glass fibers, carbon fibers and various types of ceramic fibers. High melting polymeric fibers also are useful.

Fibers can be introduced into the foam layer in several ways. A mat or scrim of fibers can be applied to the vehicle surface, and the curable foam formulation sprayed on top of the mat or scrim. Alternatively, fibers can be sprayed together with the curable foam formulation onto the vehicle surface. In the latter type of process, fibers can be introduced into the mixhead, where they are mixed with the curable foam formulation and transferred together to the flat cone airless sprayhead, from which they are sprayed onto the vehicle surface. It is also possible to spray the fibers and curable foam formulation separately onto the vehicle surface. The curable foam formulation in such a case should be sprayed before or simultaneously with the fiber spray, to ensure that the fibers deposit and remain on the desired vehicle surface. In these spraying processes, fibers may be supplied in the form of continuous rovings which are chopped into the desired lengths immediately before being sprayed. Krauss-Maffei manufactures spray equipment which is capable of chopping the rovings into short (6 to 30 cm) lengths and mixing the chopped fibers with a foam formulation.

A wetting agent may be present if a filler or fiber is present. Suitable wetting agents include certain acidic polyester and ammonium salts of acidic copolymers, as sold by BykUSA under the trade names BYK W985 and BYK W969.

The polyisocyanate and polyol components can be reacted at an isocyanate index of from 70 to 500 or more, although a more typical isocyanate index is from 80 to 130. Isocyanate index is calculated as the number of reactive isocyanate groups provided by the polyisocyanate component divided by the number of isocyanate-reactive groups in the foam formulation (including isocyanate-reactive blowing agents such as water) and multiplying by 100. Water is considered to have two isocyanate-reactive groups per molecule for purposes of calculating isocyanate index. A preferred isocyanate index is from 80 to 125.

Various additional coatings or other layers can be applied on top of the foam insulation layer that is applied in accordance with this invention. These include paint layers, other color layers, various show surfaces which, depending on their particular composition, can be sprayed onto the foam layer or attached thereto via various adhesives or through mechanical means, and the like. In some cases, the foam layer can also function as an adhesive layer, if a layer of another material is laid onto the foam layer before it has fully cured. Show surfaces may include woven or nonwoven fabrics, thermoplastic films, various multilayer composite materials and the like.

The following examples are provided to illustrate the invention but are not intended to limit the scope thereof. All parts and percentages are by weight unless otherwise indicated.

Example

Foam insulation is applied to a truck roof-sidewall panel in the manner generally shown in Figures 1A-1K. As shown in Figure 2A, roof-sidewall panel 11 includes peripheral members 12 which define sections 15 and 15A, to which foam insulation is applied. Section 15 is 120 cm long X 80 cm wide and bends through an angle of nearly

90°C. Section 15A is 80 cm wide and about 40 cm from top to bottom. A Krauss-Maffei Rimstar™ Compact minidose 3/3 reaction injection molding apparatus is equipped with a MK2.0-2K mixhead (reference numeral 16 in Figures 2B-2D) which feeds a Wheaton ROBTC 8003 flat cone airless spray nozzle. Mix/sprayhead 16 is manipulated with an ABB 5-joint robotic arm (reference numeral 17 in Figures 2B-2D) under computerized control.

The foam formulation is a two-part polyurethane. The components are heated to a temperature of 30-40°C and brought to the mixhead under a pressure of 160 bar (16 MPa). The weight ratio of polyol component to polyisocyanate is 1:1.18. Spray output is from 20-30 g/second. The polyol and polyisocyanate components are as follows:

<u>Polyol Component</u>	Parts by weight
Ethylene oxide-capped poly(propylene oxide)	67.1
Amine initiated polyol	3.7
Silicone Surfactant	0.8
Water	7.0
Plasticizer	2.8
Catalysts	7.7
Phosphate flame retardant	11.0
<u>Polyisocyanate Component</u>	
PMDI/MDI mixture	100

This formulation has a cream time of approximately 2 seconds under the test conditions, and expands and cures to a tack-free state in less than one minute after being dispensed.

The computer is programmed to spray the foam formulation onto section 15 in an up-and-down pattern, making four passes starting in the top left-hand corner (as shown) and finishing at the bottom right hand corner of section 15. While applying foam to section 15, mix/sprayhead 16 moves in three dimensions, maintaining a nearly constant distance from the surface of section 15 as mix/sprayhead 16 traversed the bend in section 15. Foam formulation is then sprayed into Section 15A in two left-to-right passes starting at the top left-hand corner (as shown), with mix/sprayhead 16 in this case moving first from left-to-right and then from right-to-left to apply the foam formulation. The spray distance is set at 6-10 cm, the traversing speed set at 200mm/second and the spray output is set at 25 g/second. This produces (after curing and expansion) a foam insulation layer mm thick, with minimal drift and overspray. The average time needed to fill both sections 15 and 15A with the foam formulation is less than 14 seconds.

Figure 2B illustrates roof-sidewall panel 11 after the foam formulation has been applied to part of section 15. Strips 18A, 18B and 18C of foam formulation have been applied, and are in various stages of expansion and curing. Robotic arm 17 and mix/sprayhead 16 is shown at the completion of a downward movement to apply a third strip of foam insulation to section 15.

Figure 2C illustrates roof-sidewall panel 11 after section 15 has been completely covered with the foam formulation, and a first strip 18E of the foam formulation has been applied to section 15A. As seen in Figure 2C, the foam formulation applied to section 15 has expanded and partially cured to form foam insulation layer 19. Figure 2D illustrates roof-sidewall panel 11 upon completion of the insulating process. In Figure 2D, foam insulation layer 19 covers section 15 and foam insulation layer 19A covers section 15A. The foam insulation layers 19 and 19A are generally uniformly thick, although small discrepencies are visible at the bond lines that form between adjacent strips of the foam formulation.

WHAT IS CLAIMED IS:

1. A process for insulating a vehicle cabin, comprising robotically spraying a curable foam formulation through a flat cone airless sprayhead onto at least one interior surface of a vehicle cabin in a series of at least two non-overlapping substantially parallel strips from a distance of from 6 to 40 cm from the interior surface, and curing the curable foam formulation to form an insulating foam adherent to the interior surface.

2. The process of claim 1, wherein the vehicle cabin has at least two non-coplanar interior surfaces and the curable foam formulation is sprayed onto each of said two no-coplanar interior surfaces.

3. The process of claim 2, wherein at least one of said non-coplanar interior surfaces faces downward when the curable foam formulation is sprayed onto it.

4. The process of any preceding claim, wherein the insulating foam has a thickness of from 10 to 75 mm.

5. The process of any preceding claim, wherein the insulating foam is a polyurethane or polyurethane-urea foam.

6. The process of any preceding claim, wherein the vehicle cabin is on a moving assembly line when the curable foam formulation is sprayed.

7. The process of any preceding claim, wherein the vehicle cabin is a sleeper cab.

8. The process of any of claims 1-6, wherein the vehicle cabin is an automobile passenger cabin.

9. The process of any of claims 1-8, wherein one or more paint layers are applied overtop of the foam insulation layer, and the foam insulation layer is post-cured simultaneously with a paint curing step.

Fig. 1A

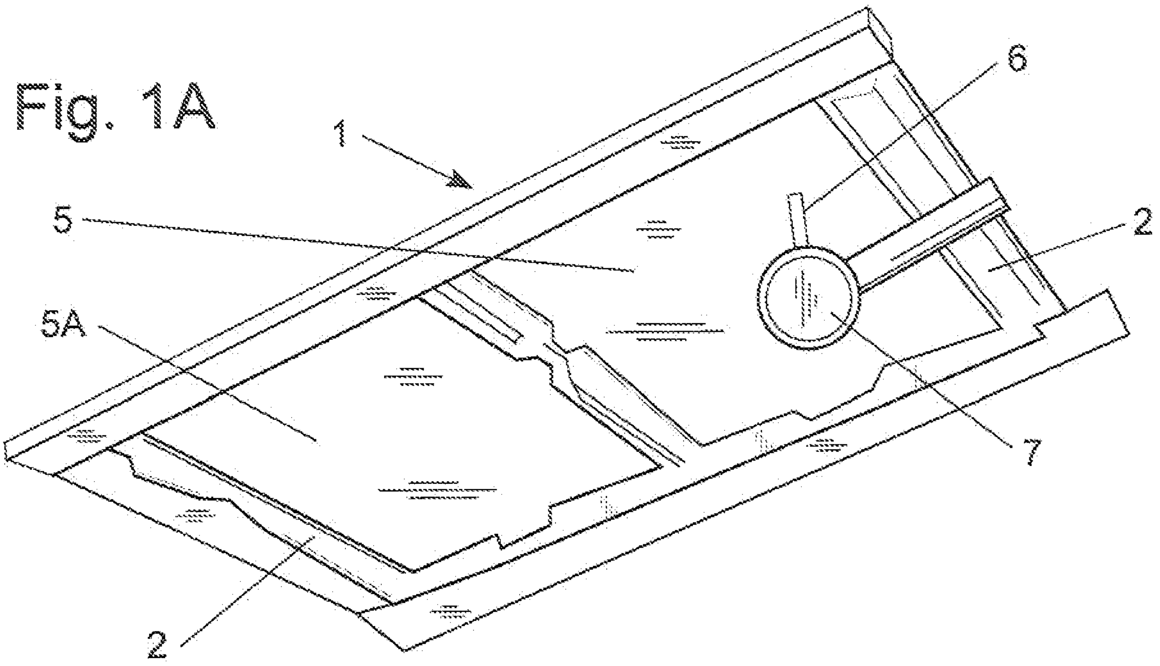


Fig. 1B

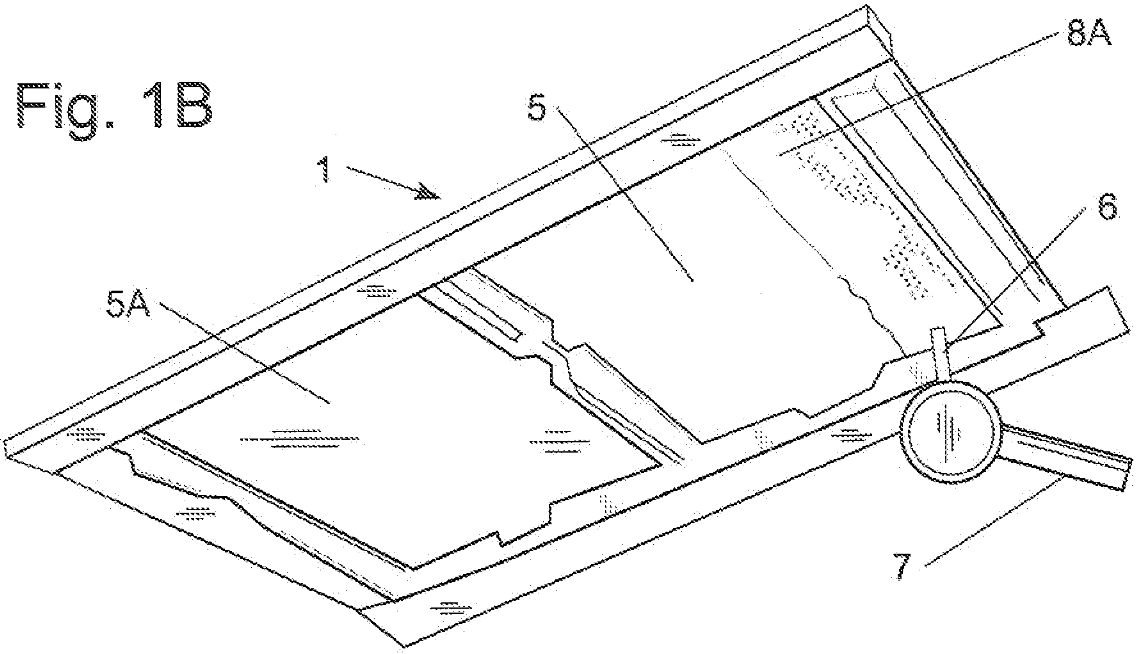


Fig. 1C

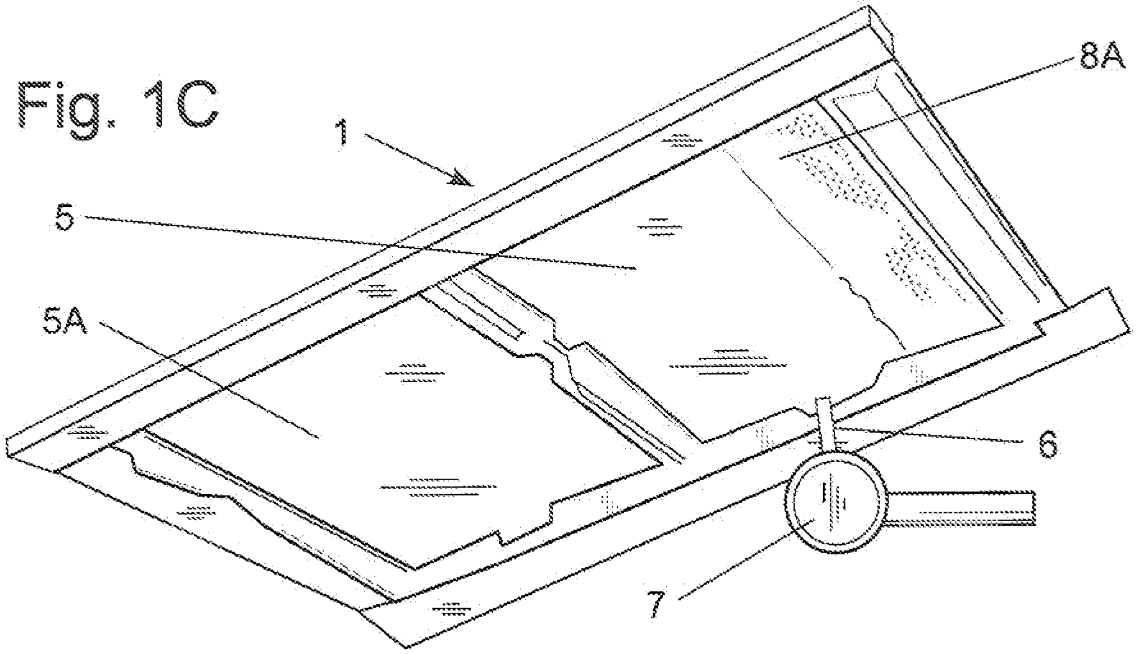


Fig. 1D

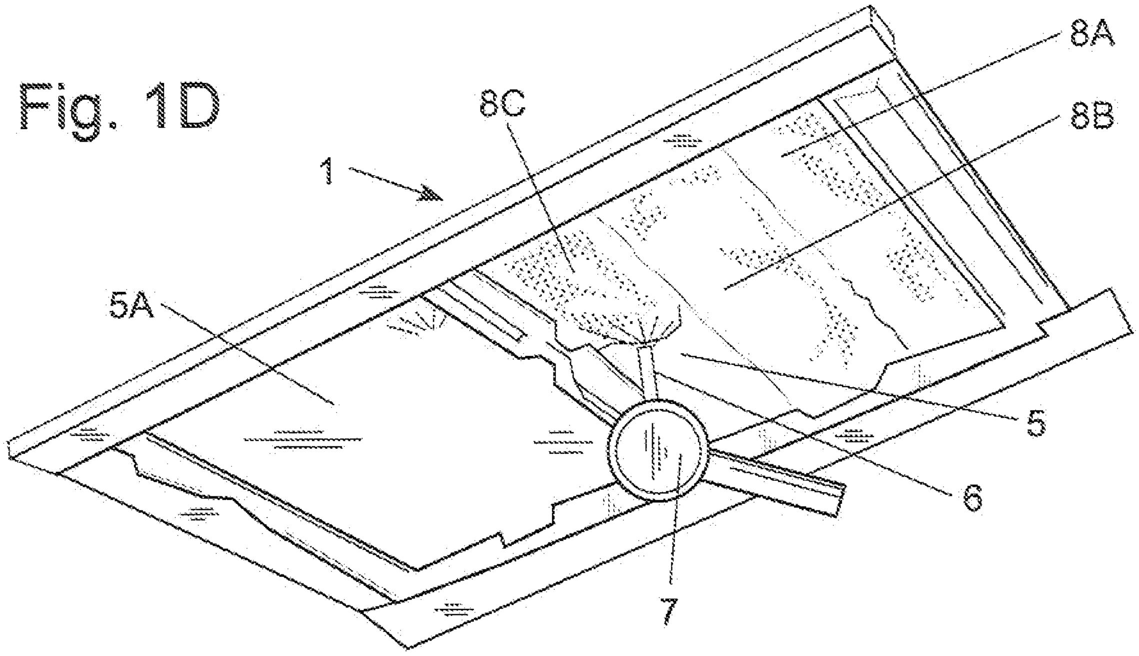


Fig. 1E

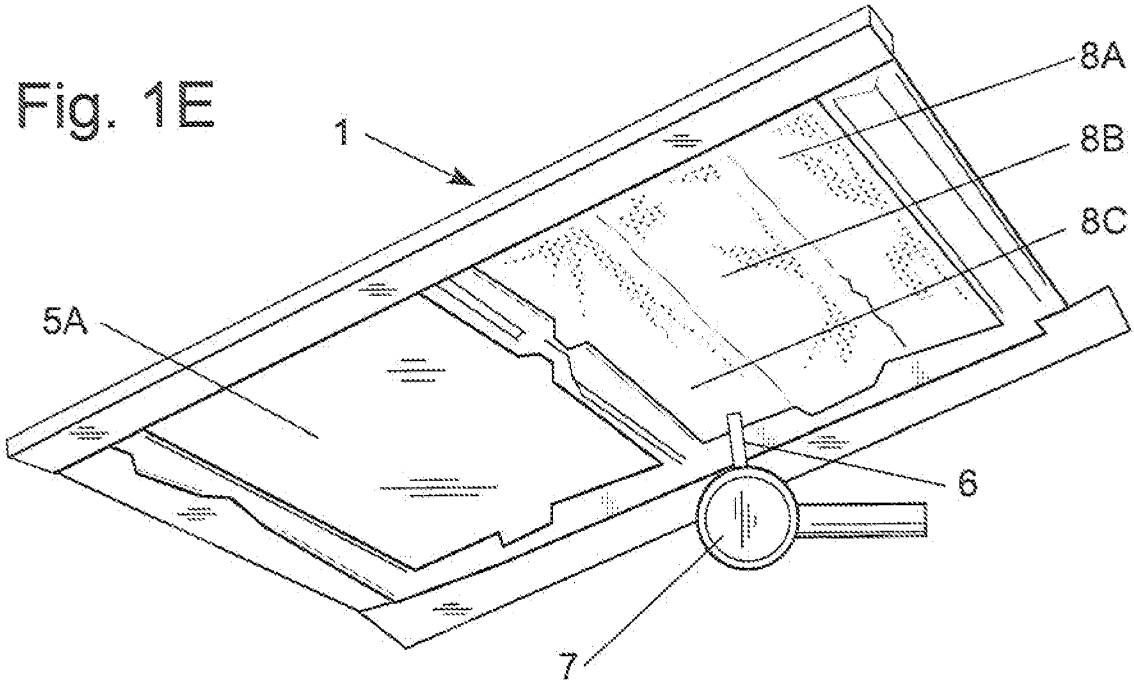


Fig. 1F

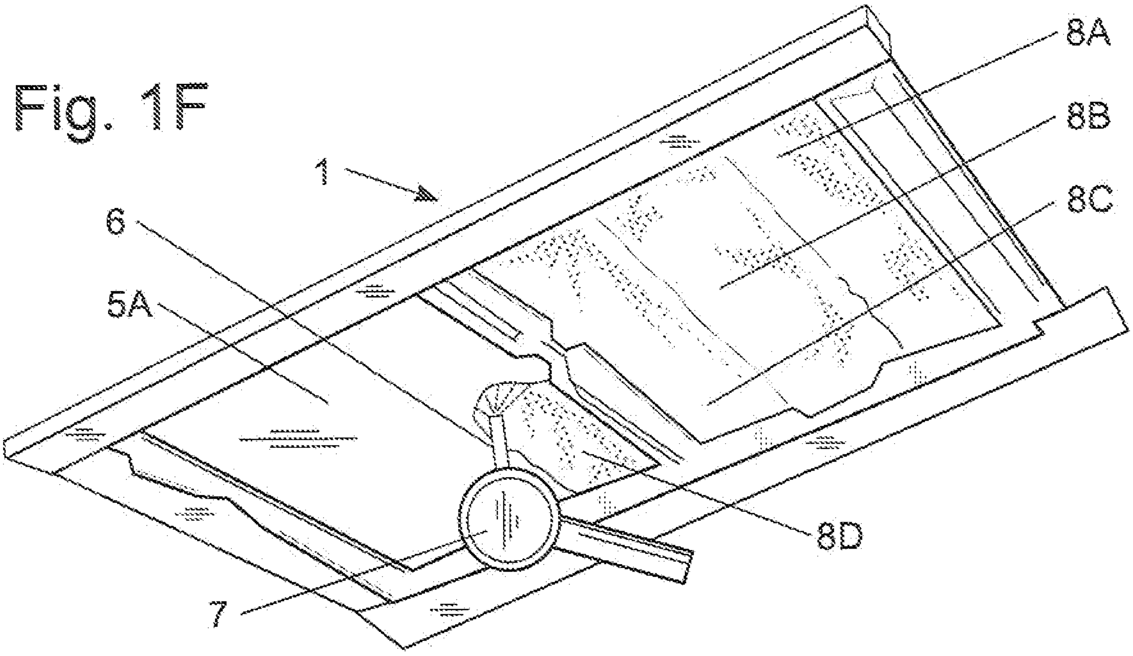


Fig. 1G

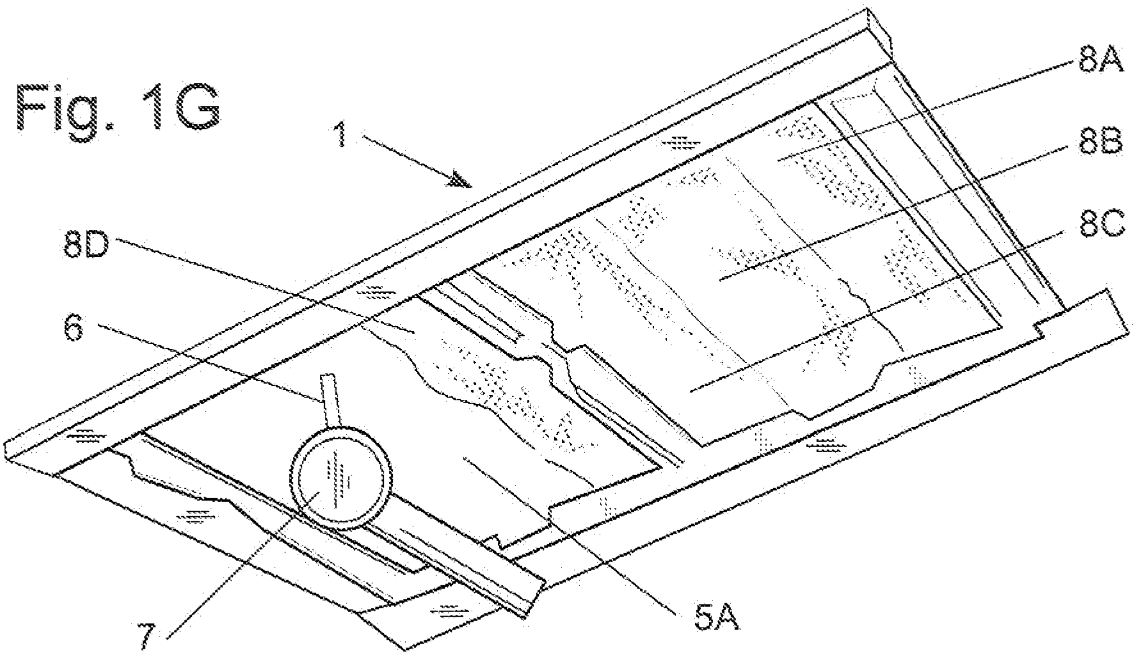


Fig. 1H

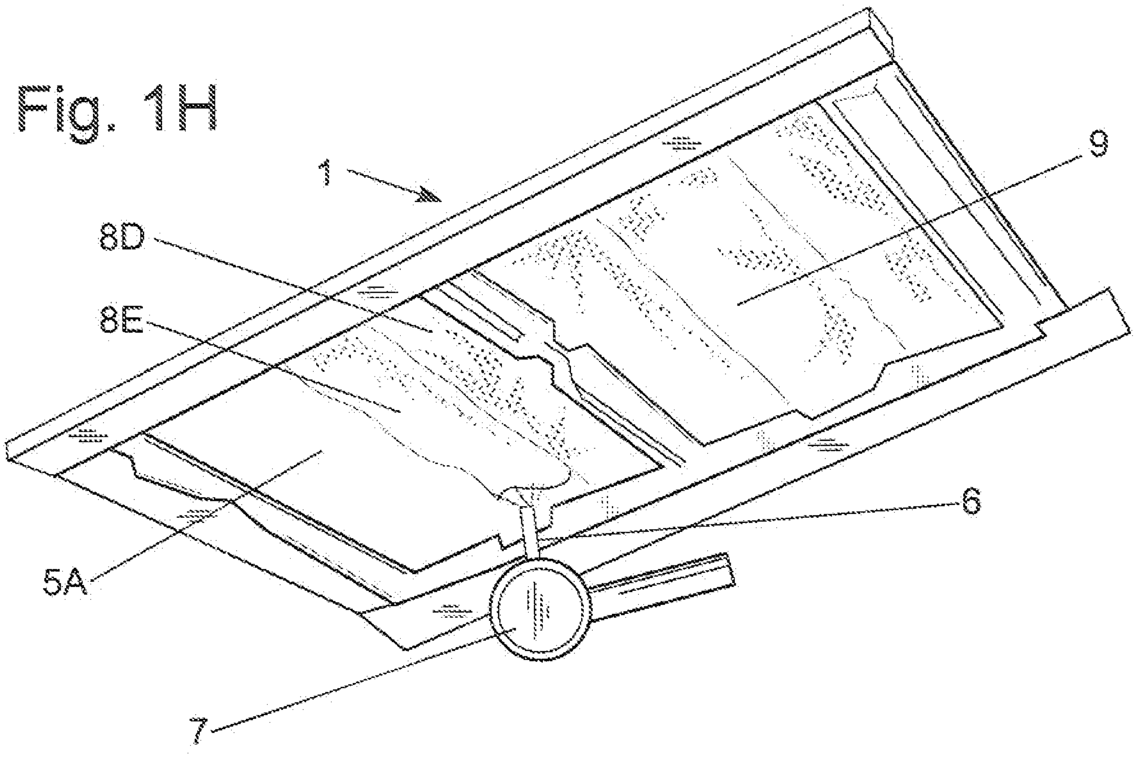


Fig. 1I

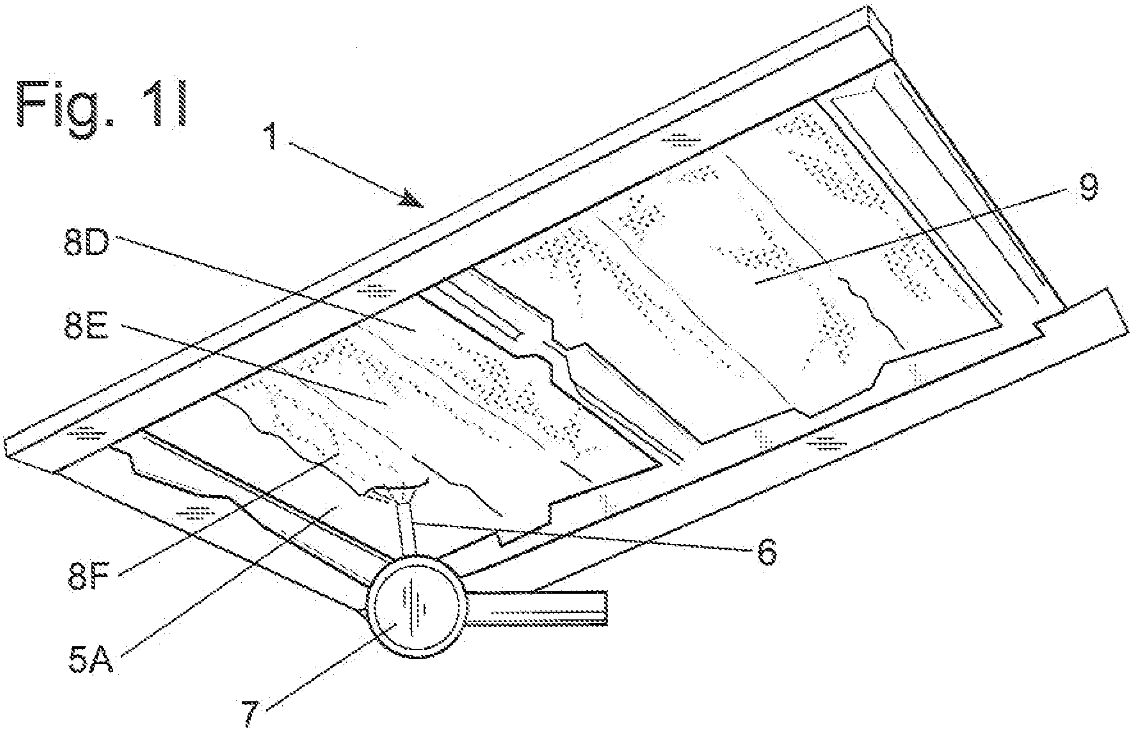


Fig. 1J

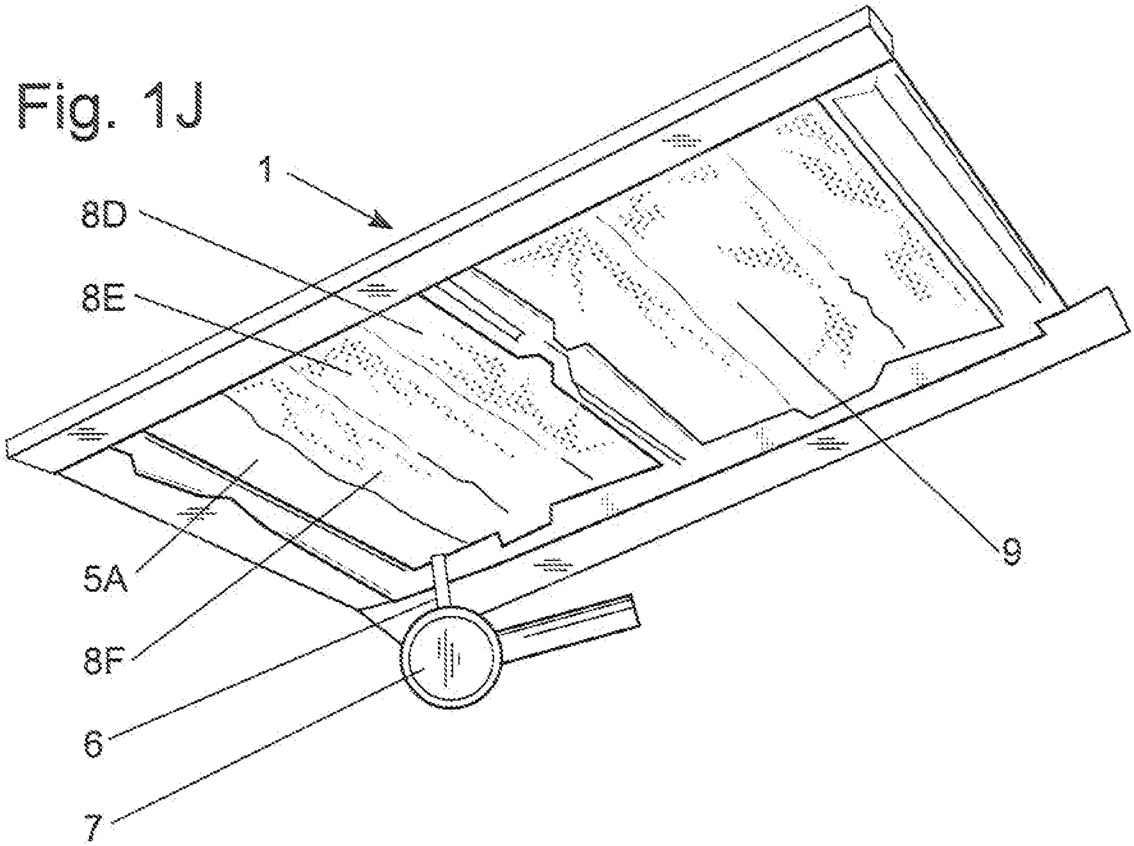
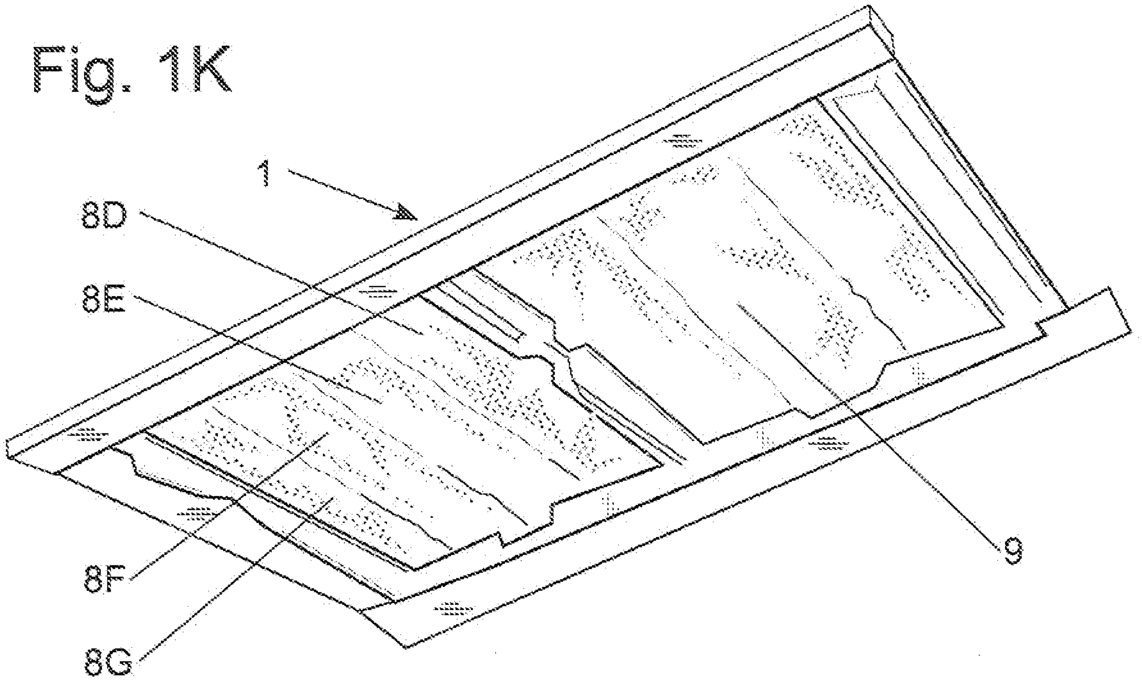


Fig. 1K



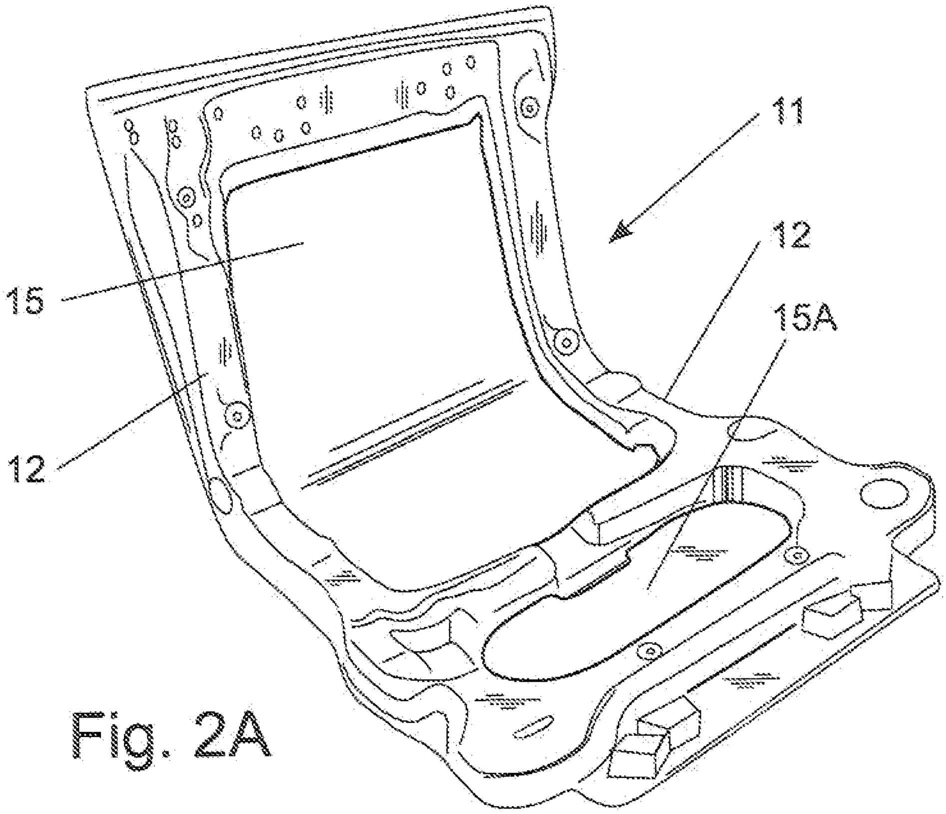


Fig. 2A

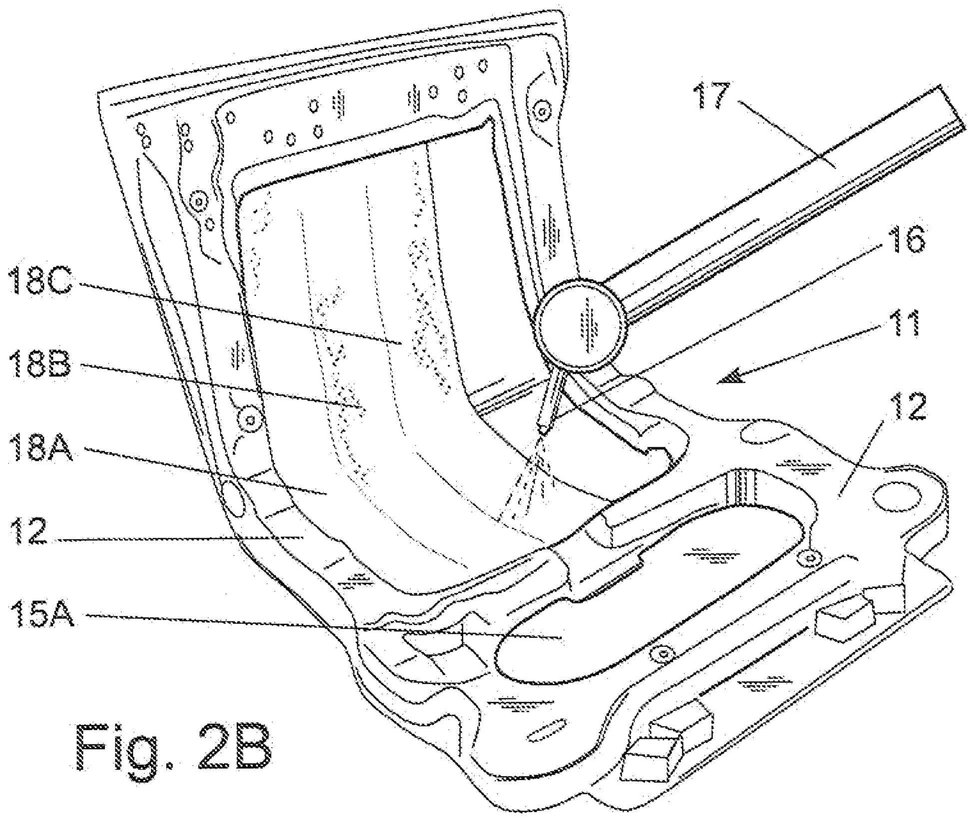


Fig. 2B

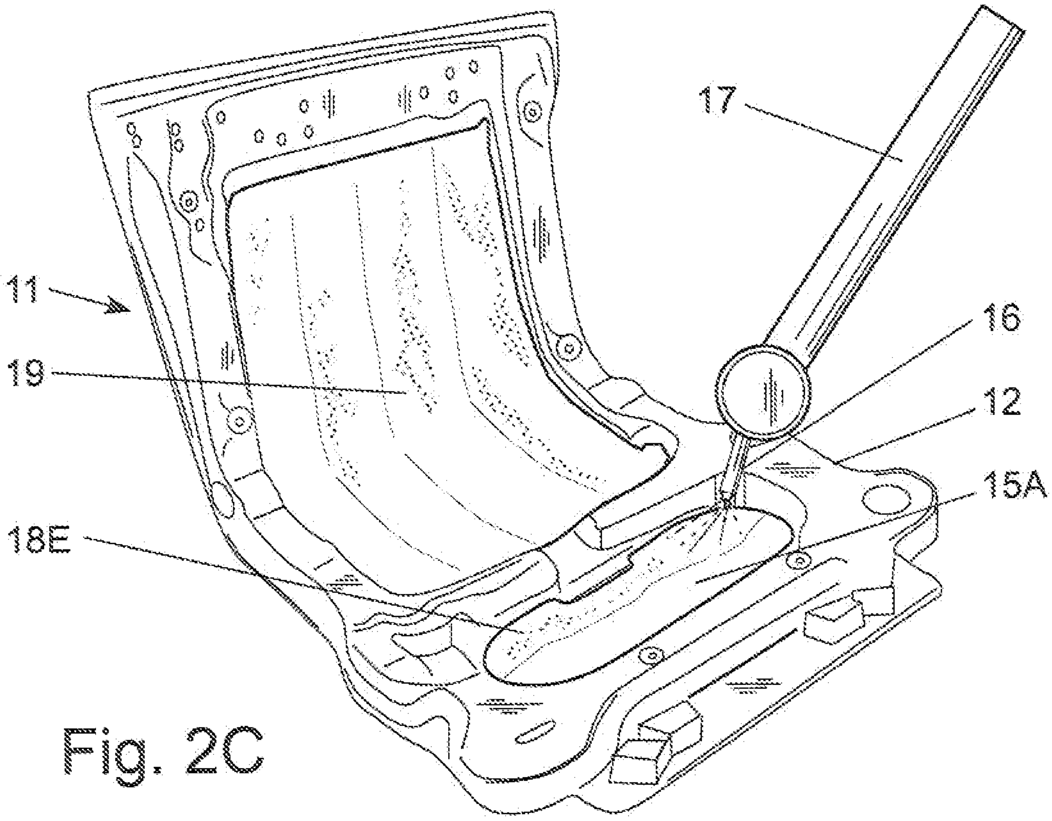


Fig. 2C

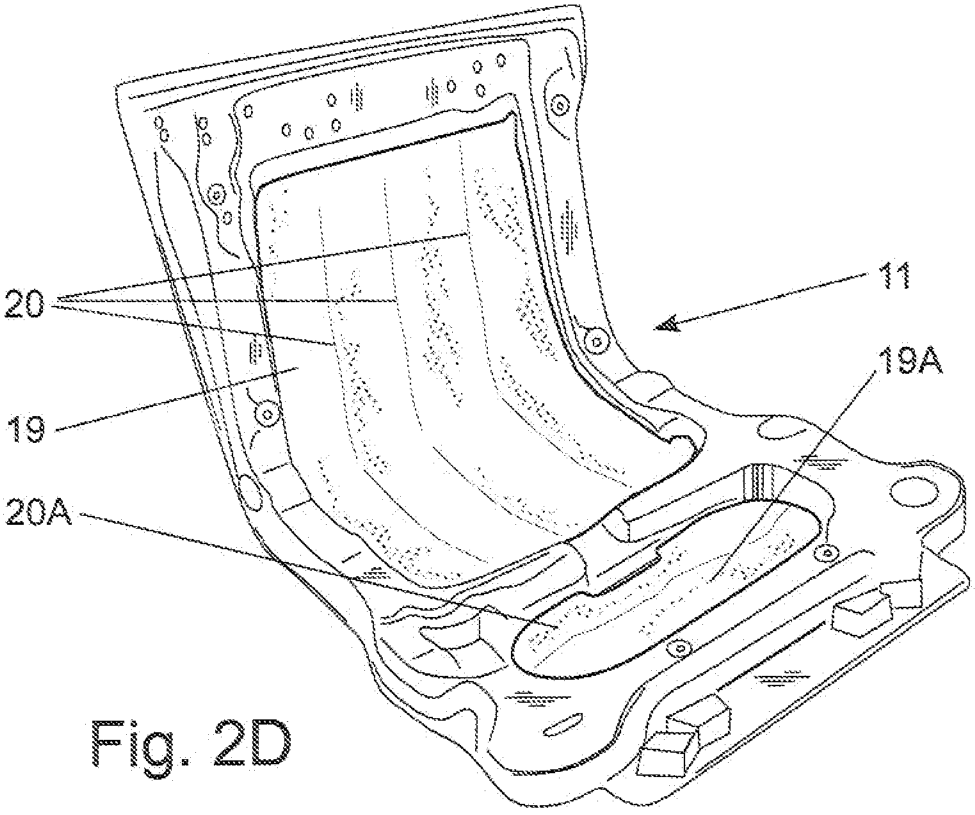


Fig. 2D

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/026593

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C44/46
ADD.

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)
B29C B60R

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*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 129 696 A (MARKUSCH PETER ET AL) 12 December 1978 (1978-12-12) column 12, lines 20-26 sentences 16-25, paragraph 13 -----	1-9
Y	US 2008/184642 A1 (SEBASTIAN LAURA [US] ET AL) 7 August 2008 (2008-08-07) paragraph [0045] -----	1-9
A	EP 1 531 116 A2 (INTIER AUTOMOTIVE INTERIORS ZI [ES]) 18 May 2005 (2005-05-18) paragraphs [0001], [0002], [0012], [0021] ----- -/--	1,2,4-8

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search 24 May 2011	Date of mailing of the international search report 01/06/2011
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Pipping, Lars

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/026593

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3 705 821 A (BREER KARL WILHELM ET AL) 12 December 1972 (1972-12-12) column 1, line 55 - column 2, line 14; claim 2	1,5,6
A	DE 10 2004 025019 A1 (BASF AG [DE]) 8 December 2005 (2005-12-08) paragraphs [0004], [0049], [0052]	1
A	EP 1 207 081 A2 (BAYERISCHE MOTOREN WERKE AG [DE]) 22 May 2002 (2002-05-22) paragraphs [0001], [0010]	1
A	EP 0 639 440 A2 (DAVIDSON TEXTRON INC [US]) 22 February 1995 (1995-02-22) column 5, lines 29-35 column 1, paragraph 1	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2011/026593

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4129696 A	12-12-1978	AT 352403 B	25-09-1979
		AU 1217776 A	22-09-1977
		BE 839710 A1	20-09-1976
		BR 7601701 A	21-09-1976
		CA 1078984 A1	03-06-1980
		CH 628655 A5	15-03-1982
		DD 125759 A5	18-05-1977
		DE 2512170 A1	23-09-1976
		DK 121076 A	21-09-1976
		ES 446182 A1	01-06-1977
		FR 2304637 A1	15-10-1976
		GB 1477623 A	22-06-1977
		HU 176469 B	28-03-1981
		IE 42661 B1	24-09-1980
		IT 1057350 B	10-03-1982
		JP 1117590 C	15-10-1982
		JP 51119095 A	19-10-1976
		JP 57009373 B	20-02-1982
		NL 7602932 A	22-09-1976
		NO 760776 A	21-09-1976
		PL 105039 B1	29-09-1979
		RO 70545 A1	30-07-1981
		SE 7602706 A	21-09-1976
		SU 850009 A3	23-07-1981
US 2008184642 A1	07-08-2008	NONE	
EP 1531116 A2	18-05-2005	ES 2203347 A1	01-04-2004
US 3705821 A	12-12-1972	NONE	
DE 102004025019 A1	08-12-2005	NONE	
EP 1207081 A2	22-05-2002	DE 10057368 A1	23-05-2002
EP 0639440 A2	22-02-1995	CA 2124641 A1	20-02-1995
		DE 69429041 D1	20-12-2001
		DE 69429041 T2	11-07-2002
		ES 2164692 T3	01-03-2002
		JP 7088856 A	04-04-1995
		US 5389317 A	14-02-1995