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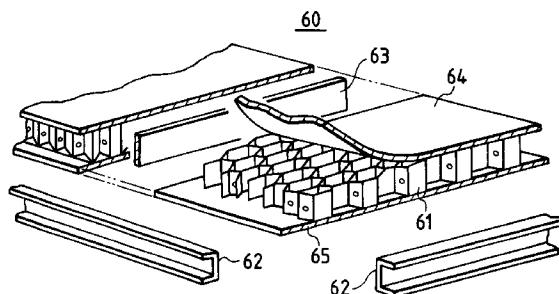
### (54) Railway cars and methods of manufacture thereof.

(57) The object of this invention is to provide a railway car body structure and a method of manufacture thereof, which maintain the strength and accuracy of the car body structure while at the same time keeping the body structure light in weight and thereby allows an efficient rigging work.

For this purpose, members (63) corresponding to the side posts and rafters, which have conventionally been arranged inside the outside sheet of the vehicle body, are incorporated between the surface sheets of the panel. Coupling members (62) are attached to the outer periphery of the panel (60). These members are brazed together to form the panel. In each of the side blocks, underframe block, roof block and end blocks, the panels are prepared, combined and, while in a restrained condition, welded together to form the respective blocks. Next, rigging base plates for mounting equipments and parts are fixed to the surface sheets of each block at specified positions. All the blocks are then assembled into an integral car body structure, with the rigging such as side panels, chairs and luggage shelves mounted on the rigging base plates.

With the construction according to this invention, it is possible to realize a block fabricating method and an assembly equipment which ensure high quality, precision and efficiency.

FIG. 4



## [BACKGROUND OF THE INVENTION]

## [FIELD OF THE INVENTION]

5 The present invention relates to a railway car body structure and a method of manufacturing the same and more particularly to a railway car body structure using panels and a method of manufacture thereof.

## [BACKGROUND ART]

10 There have been strong demands for increased speeds of railway vehicles in recent years. Higher speeds in railway cars, however, will cause problems such as destruction of railway tracks, increase of noise, as well as increase of power consumption. To solve these problems requires reduction in the weight of railway cars corresponding to the increased running speed.

15 It is known that when a railway car runs through a tunnel at high speeds, the pressure difference between the inside and outside of the vehicle changes rapidly. Particularly when vehicles pass each other inside the tunnel, a large pressure change occurs in a short period of time. For vehicles traveling at speeds higher than 200 km/h, a hermetic structure should be employed to prevent this pressure variation from being transmitted to the interior of the railway car, so as not to make the passengers feel uncomfortable.

20 Thus, the car body structure is subjected not only to the load of the passengers and the various equipment attached to it and its own weight but also to the load caused by the changes in the pressure difference between the interior and exterior of the vehicle. Therefore, the body structure needs to have an increased stiffness and an increased strength against pressure loads.

25 As the railway vehicle speed increases, the body structures are required to be light and hermetic and at the same time have higher strength and stiffness. However, improving the strength and stiffness of the body structure is generally incompatible with reducing its weight.

30 Conventionally, a railway car body structure is formed as a hexahedral structure, which comprises a roof construction, side constructions, an underframe, and end constructions and also includes frame members as reinforcing members and outside sheets that isolate the interior of the vehicle from the outside. Possible materials for the body structure may include soft steel sheets, stainless steel sheets, and aluminum alloy sheets.

35 In recent years, there are growing demands for reducing weight of railway vehicles for higher speeds. It has therefore been conceived to use hollow, extruded aluminum members or brazed aluminum honeycomb panels as members constituting the car body structure. Because the hollow extruded member or brazed aluminum honeycomb panel has high out-of-plane stiffness, a large number of these materials are being used to minimize the use of the frame members for further weight reduction. Such a car body structure is found in EP Laid-Open No. 405889. In an example shown in Figures 7 and 8 of EP Laid-Open No. 405889, force between joined panels is transferred from a surface sheet of one panel to an outer coupling member through brazed portions, and also to an outer coupling member and surface sheet of the other panel through welded portions and brazed portions. Hence the joint force between the panels is small. In an example shown in Figure 9, while the force between the panels is transmitted directly from one panel surface sheet to the other panel surface sheet, an area around the welded portion affected by welding heat has a reduced strength, particularly with aluminum alloy, so that this joint has low reliability as a means for connecting the panels.

40 A conventional car body structure fabricating method involves the following procedures. First, a frame assembled from frame members is attached with outside sheets to produce side constructions, a roof construction and end constructions. Then, the side constructions, roof construction and end constructions are positioned, assembled and welded together to form a five-plane structure. The five-plane structure is welded to an underframe, which is made beforehand by combining constituent members such as side sills, cross beams and tie beams, to form a car body structure. Such a car body structure manufacturing method is disclosed in Japanese Patent Publication No. 13860/1985.

45 In conventional steel body structures and light alloy body structures, for example, weight reduction is achieved by reducing the thickness of the outside sheet members and the frame members. But there is a limit to the reduction in weight due to the need to maintain the minimum level of strength and stiffness. There is another type of body structure in which honeycomb panels made of light alloy are used as the outside sheet members that are welded to the frame members. This structure, however, has a problem of stress concentrations that occur locally where the radius of curvature of the car body cross section changes or where the panels are joined, requiring reinforcement members, which in turn runs counter to weight reduction.

50 The conventional method of making a car body structure involves forming and welding members constituting the car body and then connecting them together. Each process is allowed certain dimensional tolerances, but as the errors accumulate, that is, manufacturing dimensional errors increase, the strength and stiffness

of the body structure may deviate from the design value. The rigging process also should consider a dimensional tolerance. The smaller the dimensional variations during manufacture, the higher the work efficiency will be and the more easily the manufacturing process can be automated.

Among the factors contributing to variations in the dimensional accuracy of the car body structure is a welding distortion during the welding process. In the conventional method of making a car body structure, welding distortions occur in each work step, such as during the welding of frame members with each other, the welding of outside sheets with each other, the welding of a frame made up of the frame members with the outside sheets, and during the welding of rigging base plates for parts. That is, the conventional method requires a total of ten work steps - the preparatory working on frame members, the assembling of the frame members, the manufacture of a frame by welding the frame member assemblies, the preparatory working on the outside sheet members, the assembling of the outside sheet members, the manufacture of the outside sheets by welding the outside sheet member assemblies, the assembling of the outside sheets and the frame, the welding of the outside sheets and the frame, the mounting of a rigging base plate, and the welding the rigging base plate. Because each of these steps cannot perfectly be carried out in an ideal way, distortions are produced. In this way, since welding distortions produced by the frame-to-frame welding, the outside sheets-to-outside sheets welding and the frame-to-outside sheets welding are accumulated, there is a limit to the accuracy with which the car body structure is manufactured.

#### [SUMMARY OF THE INVENTION]

The object of this invention is to provide a railway car with a light weight and high strength and stiffness and also a method of making the same.

Another object of the invention is to provide a method of manufacturing a car body structure which improves work efficiency while maintaining the accuracy of the car body structure.

A further object of the present invention is to provide a car body structure fabricating method, which simplifies the restraining or positioning work during the process of welding the constituent members of the body structure and thereby allows efficient manufacture of the car body structure.

This invention is characterized in that the frame members are eliminated from the car body structure so that the car body structure comprises a plurality of panels and is produced by assembling and connecting these panels. Thus, side posts and rafters, which are conventionally disposed inside the outside sheet members of the vehicle and provide the structural strength of the car body, are installed between a pair of component sheets of the panel. With a connecting member added at the peripheral portion of each panel, these members are brazed to the pair of component sheets to form the panel. Next, the peripheral portion of the panels is prepared as a welding portion. Then, the panels are combined in respective blocks such as the roof construction, the side construction, the underframe, and the end construction. With the panels held combined in each block, the welding portions are welded together to form the block, and then finally all the blocks are assembled together to form the car body structure.

According to this invention, individual panels are manufactured to a specified accuracy and these panels are combined in each block and welded together. Then, all of these blocks are assembled and welded together. With this invention, each block requires performance of the welding procedure one or two steps and the body structure one step, requiring the welding procedure at least two steps throughout the entire manufacturing process. This method greatly reduces the number of steps that the welding needs to be carried out as compared with the conventional method in which the members are successively combined, so that the distortions can easily be controlled making it possible to produce a car body structure with high precision.

Since the side posts are not employed and the peripheral portions of the panels are used as welding portions that are welded together in forming the body structure, the smoothing of the inner and outer surfaces of the body structure can easily be done. This increases the freedom of design for the painting and rigging work and also facilitates the execution of overall manufacturing process.

#### [BRIEF DESCRIPTION OF THE DRAWINGS]

Figure 1 is a schematic diagram showing an external view of the overall car body structure as one embodiment of this invention;

Figure 2 is an enlarged cross section of the car body structure taken along the line A-A in Figure 1;

Figure 3 is an example flow of steps for making the car body structure of this invention;

Figure 4 is an exploded perspective view of a honeycomb panel used in this invention;

Figure 5 is a plan view of the honeycomb panel of Figure 4;

Figure 6 is an enlarged cross section showing an essential portion of another example of the honeycomb

panel;

Figure 7 is a cross section showing an essential portion of still another example of the honeycomb panel;

Figure 8 is a schematic view showing an example step of trimming;

Figure 9 is an explanatory view showing the trimming of Figure 8;

5 Figure 10 is a schematic view showing one example of jig used in a block assembly step;

Figure 11 is a schematic view showing an example of a side block in an assembled state during the block assembly step, with Figure 11(b) being an enlarged view of B-B cross section of Figure 11(a);

Figure 12 is a schematic view showing an example of jig used in a reversing welding during the roof block welding process;

10 Figure 13 is an explanatory view showing the welding step;

Figure 14 is an explanatory view showing the welding conditions of Figure 13;

Figure 15 is an explanatory view showing the welding conditions of Figure 13;

Figure 16 is a schematic view showing a cooling structure in the panel welding portion used for block welding;

15 Figure 17 is a schematic view showing a cooling structure in the panel welding portion used for block welding;

Figure 18 is a perspective view of the panel with an example arrangement of rigging lugs;

Figure 19 is an enlarged cross section of the rigging lug portion of Figure 18;

Figure 20 is a perspective view of a rigging lug mounting equipment;

20 Figure 21 is a cross section showing another example of a rigging lug;

Figure 22 is a perspective view of an apparatus that bonds heat insulating material to a block;

Figure 23 is a vertical cross section of a structure assembly equipment;

Figure 24 is a perspective view showing the car body structure in an assembled state;

25 Figure 25 is an example flow of steps for making the car body structure as a second embodiment of this invention;

Figure 26 is a schematic view showing the process of assembling and welding the panels to form a roof block;

Figure 27 is an overall view of an apparatus for assembling a long slender block;

Figure 28 is a cross section showing the method of welding honeycomb panels together on both sides without overturning the panels;

Figure 29 is an overall view of a trimming apparatus;

Figure 30 is a schematic view showing the process of assembling and welding the panels to form a side block;

Figure 31 is an overall view of a side block assembly apparatus;

35 Figure 32 is a perspective view showing the assembled honeycomb panels being welded on one side;

Figure 33 is an overall view of a rigging base plate of a rail type;

Figure 34 is a flow of steps for making the car body structure as a third embodiment of this invention;

Figure 35 is a perspective view showing the rigging base plates installed in the car body structure of the third embodiment;

40 Figure 36 is a flow of steps for assembling the car body structure as a fourth embodiment of this invention;

Figure 37 is a perspective view of a side block assembly jig used in the fourth embodiment;

Figure 38 is a perspective view of a side block assembled by the jig of Figure 37;

Figure 39 is a front view of a side block assembled and tack-welded;

45 Figure 40 is a perspective view of an example underframe manufactured by the method of the fourth embodiment;

Figure 41 is a cross section showing a joint between a floor plate and a cross beam in the underframe of Figure 40;

Figure 42 is a perspective view of a car body structure assembly equipment used in the fourth embodiment;

Figure 43 is a front view showing the car body structure of the fourth embodiment being fully welded;

50 Figure 44 is a front view of the car body structure of the fourth embodiment equipped with rigging rails;

Figure 45 is a cross section showing the structure of the rigging rail secured to the car body structure of Figure 44; and

Figure 46 is a perspective view showing the end blocks being mounted to the car body structure of the fourth embodiment.

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#### [DETAILED DESCRIPTION]

A first embodiment of the present invention will be described by referring to Figure 1 through Figure 24.

First, the overall construction of a railway car body structure is explained with reference to Figure 1 and 2. In the figures, a railway car body structure 10 includes side blocks 20, an underframe block 30, a roof block 40 and end blocks 50, with the boundary surfaces of these blocks welded together.

The side block 20 comprises a baseboard 21, a window head board 22, grouped columns 23 and an entrance portion 24, each board consisting of a plurality of honeycomb panels combined and welded. The grouped columns 23 are so arranged as to form window portions 29 between the baseboard 21 and the window head board 22 of the side block 20. The side block 20 is formed as one piece extending upward from the upper surface of the side sill 31 of the underframe block 30 to the circumferential end surface of the roof block 40. The length of the individual honeycomb panels in the longitudinal direction of the car body is equal to the length of one of the equally divided sections of the side block 20, or preferably equal to an integer times the space of the window in the longitudinal direction of the car body. By aligning the individual honeycomb panels in the longitudinal direction of the car body and welding them together, the side block is assembled. The panel positions are adjusted so that the welding lines between the adjacent panels do not form a cross (except for a part of the side block).

As shown in Figure 2, the baseboard 21 is secured on its inner side with side panels 26 and a draft duct 27 through a rigging base plate 25. On the inner side of the window head board 22 is securely mounted a curtain retainer 28 through a rigging base plate (not shown).

The underframe block 30 has a pair of left and right side sills 31, which extend in the longitudinal direction of the car body at the transverse ends of the car body. Denoted 32 is a floor plate made of a honeycomb panel with both of its transverse ends joined to the pair of side sills 31. Insulating material 33 and floorcloth 34 are bonded to the upper side of the floor plate 32. Chairs 36 are also secured to the floor plate 32 through rigging base plates 35 for chair.

A roof block 40 consists of a central roof plate 41 and side roof plates 42 joined together as one piece, each roof plate made of a honeycomb panel. The roof block 40 is disposed between the top portions of the side blocks 20 and the end blocks 50. The length of each panel in the longitudinal direction of the car body is equal to that of equally divided sections of the roof block 40. These panels are arranged in the longitudinal and transverse directions of the car body and welded together to form the roof block 40. As shown in Figure 2, the central roof plate 41 is secured on the inner side with ceiling plates 43 through rigging base plates. A pantograph is secured at a particular position on the outer side of the central roof plate 41. On the inner side of each side roof plate 42 is mounted a luggage shelf 45 through a rigging base plate 44.

The end blocks 50 are also made of honeycomb panels with a passage opening 51. The end blocks 50 constitute the both end surfaces of the car body structure 10 and are joined to the ends of the side blocks 20, the underframe block 30 and the roof block 40 to form an integral body structure. The end blocks may be formed of a combination of the conventional aluminum alloy plate and frame members, considering that the area of the end blocks is small and that the working on the end blocks is difficult.

Next, the process of making the car body structure 10 using the honeycomb panels according to the present invention will be described. Figure 3 shows the outline of the whole manufacturing process. First, the design of the honeycomb panel is carried out (step 101). Based on this design, members constituting the honeycomb panel are prepared and then assembled in a jig (step 102). This is followed by brazing the honeycomb panel members to complete the honeycomb panels (step 103). Inspection is made of the completed honeycomb panels for correct dimensions and curvature precision and to see if there are any flaked portions (step 104). Those honeycomb panels that have passed the inspection then undergo the trimming process of forming welding portions to make the outer circumferences of the panels conform to the specified dimension according to the use, assembly position and dimensional errors during brazing (step 105). Then, one or plural sets of honeycomb panels are combined into each block (step 106) and the welding edges are welded (step 107). For larger blocks, it is desirable that the panels be welded together to form intermediate blocks of an appropriate size and combine these intermediate blocks to form a full-size block. After this, the inner and outer sides of the honeycomb panels are attached with rigging lugs at specified positions (step 108), to which heat insulating materials are mounted (step 109). All the blocks are assembled and, while being held in the assembled condition, welded together (step 110). The outer surface of the body structure is painted (step 111) and finally various equipments are installed on the inner and outer surfaces of the panel (step 112), thus completing the car body structure.

Next, each step of the manufacturing process will be explained in detail. In the first step (step 101) of designing the honeycomb panel, the shape of the honeycomb panel is determined. Although the honeycomb panels may all have the same shape, when they are applied to railway vehicle body structures, the dimensions, curvatures or strengths of the honeycomb panels are properly determined for each block. The size of the panel is preferably given some margins to allow for trimming.

Figure 4 is an exploded perspective view showing an example of honeycomb panel 20 used on the car body structure of this invention. Figure 5 is a plan view of the same. The honeycomb panel 60 includes a hon-

eycomb core 61 as a core member, outer coupling members 62, and a pair of surface sheets 64, 65. They are all made of light alloy material. For example, the honeycomb core 61 and the surface sheets 64, 65 may be formed of A6951 and the outer coupling members 62 A6NO1.

The honeycomb core 61 is made by combining wave-shaped or corrugated plates to form hexagonal cells with the contacting sides brazed together. Also built into the honeycomb panel 60 are reinforcement members 63 made of light alloy to provide necessary strength. As one example, in the embodiment of Figure 4, the core 61 of the honeycomb panel is 0.2 mm thick and 58 mm high; one of the surface plates 64, 65 is 1.2 mm thick and the other one is 0.8 mm; outer coupling member 62 is 2-3 mm thick, 58 mm high and 30 mm wide; and the reinforcement member 63 is 2 mm thick. The length of the single panels is limited by the size of the brazing furnace, and may preferably be 4 meters long by 1.2 meters wide at maximum. The thicker one of the surface plate 64 or 65 is located on the outer side of the car body structure.

After the members constituting such a panel are prepared, they are subjected to a brazing process (step 103) to combine them into a single integral panel. The brazing is accomplished by cladding a solder such as BA4045 (about 5%) to various points on the surfaces of these members, assembling the members into a panel in a jig and then heating them.

The reinforcement member 63 together with the outer coupling members 62 contributes to improving the out-of-plane bending stiffness. Because the honeycomb core 61 is placed between the surface sheets 64, 65, a sufficient space is secured between the surface sheets 64 and 65 to increase the modulus of section, thereby providing the honeycomb panel 60 with a required level of stiffness.

The reinforcement member 63, which corresponds to the side posts and rafters used in the conventional structure, is arranged between the surface sheets 64 and 65 as part of the laminated structure. Considering the pressure difference between the interior and exterior of the vehicle, the reinforcement member 63 needs to be arranged in the circumferential direction of the vertical cross section of the car body structure 10.

In the baseboard 21, the window head board 22 and the grouped columns 23, the reinforcement member 63 extends in the vertical direction of the side block 20 to connect the coupling members 62 of the adjacent panels. The reinforcement member 63 is disposed at right angles to the surface sheets 64, 65.

In the roof block 40, the reinforcement member 63 extends in the width direction of the roof block 40. That is, it is arranged in a manner corresponding to the conventional rafter. In the body structure 10, the reinforcement members 63 of the individual panels 60 are arranged to be on the same cross sectional line on the body structure (except for the grouped columns 23, which have their coupling members 62 aligned with the reinforcement members 63 of other panels). Thus, loads are shared by the reinforcement members 63, which work as ring-shaped structural members disposed between the side sills 31 located on both sides with respect to the width direction of the car body. The reinforcement members 63 therefore can resist pressure variations acting on the body structure 10.

Table 1 shows comparison between the stiffness of the brazed aluminum honeycomb panel of this invention and that of the conventional aluminum and steel plates. The honeycomb panel employed in this invention has bending stiffness and torsional stiffness, both two orders of magnitude higher than those of the conventional plates of virtually the same weight.

[Table 1]

Table 1

Item	Panel	Aluminum plate	Steel plate
Dimension (mm) (width×length×thickness)	900×1800×26.6	900×1800×2.7	900×1800×1.0
Weight (g/cm <sup>2</sup> )	0.73	0.73	0.79
Bending stiffness, EI (×10 <sup>9</sup> kgf·mm <sup>2</sup> )	1.99	0.01	0.002
Torsional stiffness, GJ (×10 <sup>9</sup> kgf·mm <sup>2</sup> /rad)	6.04	0.03	0.005

The stress occurring in the car body structure while in operation varies depending on the construction and the position. When a particularly high strength is demanded, it is necessary to locally increase the strength of the structure. To cope with this situation, an example case will be described below, in which a corner D of the honeycomb panel is locally reinforced to increase the strength of that part. An enlarged view of the corner D is illustrated in Figure 6. As shown in Figure 6, reinforcement cores 66 inserted in the honeycomb core 21 at the corner D. The reinforcement core 66 has either a cylindrical shape or a notched cylindrical shape so

that they can be installed in the gaps in the honeycomb core 61. By brazing these cores together, it is possible to increase the strength of the honeycomb panel 60 without increasing the thickness of the surface sheets.

Other types of honeycomb panel 60' may be used, like the one shown in Figure 7, which incorporates a triangular-shaped core 61' consisting of laminated plates instead of the honeycomb core 21. It is also possible to use stainless steel thin plates instead of light alloy for all members of the panel and weld them together with laser.

The car body structure 10 shown in Figure 1 comprises a total of six blocks - one roof block, two side blocks, one underframe and two end blocks. To make a body structure with high precision requires each of these blocks to be produced accurately. The adjustment of the accuracy is achieved by trimming the welding portion of the honeycomb panels 60, in other words, by trimming the outer coupling members 62 at the peripheral portions of the honeycomb panels and ends of the surface sheets 64, 65. The honeycomb panels 60 are welded together after their peripheral portions are accurately prepared and precise overall panel dimensions and shapes as well as necessary welding edge accuracy are obtained.

Figure 8 shows one example of trimming. Figure 8(a) illustrates the roof block 40 of the car body, with the rigging base plate for pantograph represented by 47. The panels are curved in the width direction to conform to the shapes of central roof plates 41, which are moderately curved, and side roof plates 42, which are sharply curved. The outer coupling members and the surface sheets of the adjacent panels are connected to each other. With respect to the longitudinal direction of each panel 60, the outer coupling members 62 are worked so as to be perpendicular to the surface sheets 64, 65, so that the block as a whole is straight. Then, these panels are assembled in a jig and, while in a restrained condition, welded together to form a desired roof block 40. For the panel to which a pantograph is to be mounted, a combination of the conventional outside sheet and frame member may be used considering the weight of the pantograph.

Figure 8(b) shows an example case of trimming the side block 20. The side block 20 has a camber, i.e. it is curved upward with the central portion slightly raised, considering deflections of the car body. Of the components constituting the side block - the baseboard 21, the window head board 22, the grouped columns 23 and entrance portion 24 - the baseboard 21 and the window head board 22 are formed trapezoidal. Take the baseboard 21 for example. The original width of the honeycomb panel 60 is  $W_0$ . Then the ends of the honeycomb panel are trimmed so that the lower side  $W_2$  is shorter than the upper side  $W_1$  by a specified amount, as shown in Figure 9. Similarly trimmed honeycomb panels are combined and, while in a restrained condition, welded together to produce a cambered side block 20. The panels may be formed as part of a fan shape instead of a trapezoid, to produce the same effect. With this technique, the assembly of honeycomb panels 60 can be curved in a plane. The honeycomb panel assembly can also be curved out of plane by differentiating the length of the outer coupling member 62 on the side of the surface sheet 64 from that on the other surface sheet 65. The welding portions of the honeycomb panels 60 therefore constitute a factor that determines the overall length as well as the structure of the assembly.

After the honeycomb panels are each worked into the required shapes, they are set at specified positions in a dedicated assembly jig during the next assembly procedure (step 106) and held in the assembled state.

Figure 10 shows an example of a block assembly jig. In this example, the panels 60 that form the central roof plate 41 of the roof block 40 are placed at specified positions and are clamped between a pair of upper and lower jigs 72. Denoted 73 is an escape for welding. It is important that the welding portions on both front and back sides of the panel be welded in the same restrained state. Hence, the jig 72 has a clamp 74 and a rotating shaft 75 to permit assembling, holding and reversing of the block.

Figure 11(a) is a perspective view of the side block 20 in an assembled state. The welding portions may be provided with fitting portions 62A, 62B, as shown enlarged in Figure 11(b), to prevent the assembled panels from moving in the longitudinal and lateral directions.

In this restrained condition, the panels are welded together for each block (step 107). Figure 12 shows an example of a welding equipment, which detects, by a sensor 77, the welding portions of the central roof plate 41 restrained by the pair of upper and lower jigs 72 and the clamp 74 and then connects the panels together by the welder 76. First, the joint of each panel on one side is welded successively. Next, the assembly is lifted and overturned while keeping the welded portions from being deformed, and then is lowered to the original position for welding on the back side. In this way all the welding portions are welded. Smaller blocks may be welded without being restrained by the jig. For larger blocks, the panels may first be assembled and welded into intermediate blocks, which are then welded into a final large block.

When interconnecting a plurality of honeycomb panels 60, their welding edges are welded. The detail of the welding edge is shown in Figure 13. The welding portions, i.e. the outer coupling member 62 and the surface sheets 64, 65 at the periphery of the honeycomb panel have a width L. The contacting ends (at weld line 67) of the two honeycomb panels are joined by the weld bead 67W. Because the surface sheets of the adjoining panels are welded together, any external force acting on one panel is smoothly transmitted through the welded

portions to the surface sheet of the next panel. In other words, when an external force is applied, that force is received by all panels, preventing undue force from acting on a particular brazed portion, allowing the panel assembly to resist large external forces.

Figure 14 shows the distribution of hardness at the central portions of surface sheets 64 and 65 attached on both sides of a honeycomb panel 60 when the outer coupling member 62 3 mm thick and the surface sheets 64, 65 1 mm thick are MIG-welded with an input heat amount of 3 kJ/cm. An area softened by welding heat spreads in width  $L_1$ , beyond which no hardness changes are observed. In the softened area the tensile strength also deteriorates. If  $L > L_1$ , then it is possible to secure the strength required for the joint of the honeycomb panel because the outer coupling member and the surface sheets are brazed together. When  $L < L_1$ , however, the joint strength is smaller than other portions of the honeycomb panel since the strength of the thin surface sheets deteriorates.

An input heat amount of 2 kJ/cm is required for MIG welding to produce a sound welded portion in a butt joint of aluminum alloy material 1-5 mm thick. Even welding methods with good energy concentration, such as electron beam welding and laser welding, requires at least about 1 kJ/cm. Providing a welding portion with an appropriate width  $L$  for the welding method employed is necessary to secure a sound joint strength.

Figure 15 shows the relationship between the input heat amount for welding and the width of a softened area affected by the heat when the above-mentioned aluminum alloy is MIG-welded. The softened area falls in a range between the solid line and the dashed line. As the welding input heat is reduced, the width of the softened area also decreases. However, if the material of the welding portion has a property such that the strength of the welding portion, after being softened by the welding heat, will be recovered to nearly the original level with passage of time at normal temperatures, the joint strength of the welding portion is easily secured. In other words, it is possible to reduce the thickness of the welding portion.

Table 2 shows comparison of strength when 6NO1 alloy and 7NO1 alloy are used for the outer coupling member 62 of Figure 13, with the honeycomb core 61 and the surface sheets 64, 65 made of 6951 alloy of JIS standard. It is seen that the 6NO1 alloy requires a thickness of 3 mm while the 7NO1 alloy needs only 2 mm thickness because of its capability to recover the strength after natural ageing. The 7NO1 alloy thus contributes to weight reduction.

[Table 2]

Table 2

	Material	Tensile strength (N/mm <sup>2</sup> )			Thickness (mm)
		Base material	Portion affected by heat		
Conventional	6NO1	257		190	3
Invention	7NO1	333	245 (Immediately after welding)	314 (after natural ageing)	2

The residual strains and residual stresses in the honeycomb panel caused by welding should be minimal. Cooling areas near the welding portion of the honeycomb panel during the welding process is effective for minimizing the residual strains and stresses. This is accomplished by providing portions close to the welding edges with passages for cooling mediums to pass without interfering with the welding procedure, as shown in Figure 16. Figure 16 shows two honeycomb panels 60 assembled so that they can be welded along the welding line 67. The outer coupling member 62 is formed with upper and lower passages 68 isolated from each other by reinforcement sections 69. These passages run through the circumference of the honeycomb panel and have an inlet and an outlet. Water, gas, liquid nitrogen or other appropriate cooling mediums are supplied into these passages while the edges along the welding line 67 are welded. The cooling medium absorbs heat that would otherwise be transferred to the honeycomb core 61, minimizing the effect the welding heat has on the honeycomb core 61 and the surface sheets 64, 65. This offers welding that produces only small strains.

The reinforcement sections 69 not only form the passages 68 but also reduce the thickness and weight of the coupling members of the honeycomb panel and increase their stiffness. Since the coupling members and other associated members are heated to near the melting point during the brazing process in the manufacture of the panels, there is a possibility of the peripheral end portions of the coupling member drooping down by its own weight. But because the peripheral end portions of the coupling member are supported by the reinforcement sections 69 on the upper and lower sides, the drooping can be prevented. Further, in the

example of Figure 16, since the welding portion is cooled, the width  $L$  can be reduced as compared with the construction shown in Figure 13.

Another method of absorbing welding heat consists, as shown in Figure 17, in holding the welding line 67 between cooling restraining plates 78 and the equipment body 79 and performing the welding procedure. This produces the same effect as the previous method.

The cooling restraining plates 78 may interfere with a torch during the conventional MIG welding and TIG welding. However, if welding is done by radiating a laser beam, which offers the highest energy concentrations in the atmosphere, in the direction of arrow W, a welded joint with small strains can be obtained because the laser welding requires only a small amount of input heat and because the welding portion is cooled during welding. The laser welding therefore does not require the cooling restraining plates and still produces the results similar to the previous example.

In the conventional process, the welding of the frame members are carried out separately from the welding of the outside sheets, and these two groups of members are welded together through joint members. This process increases the amount of welding and the number of times the welding is required to be performed, and the resulting increase in the amount of input heat causes large welding strains. Because the individual frame members and outside sheets have differing thicknesses depending on the locations where they are installed, the strength varies greatly according to locations. This means that the amount of deformation caused by various kinds of load will vary according to locations, producing extreme strains at the boundary portions.

With this invention, however, it is possible to perform joining of members equivalent to the conventional joining between the frame members, between the outside sheets, and between the frame members and the outside sheets, simply by welding the surface sheets and the outer coupling members at the periphery of the honeycomb panel once. Thus, the method of this invention can reduce the amount of welding, the number of times the welding is carried out and therefore the amount of input heat, which in turn helps reduce the welding strains. Moreover, because the members are joined without using special joint members, the welding strains are further reduced.

Since the widthwise cross section of the coupling member is symmetrical with respect to the panel thickness direction, the shrinkages of the beads on both sides of the panels welded together balance each other, minimizing deformation, such as warping, of the panels as well as strains therein. Therefore, there is no need to increase the thickness of the coupling members and the surface sheets to secure their strength, allowing an extreme design whereby each member is reduced in thickness to the minimum level.

The coupling member of the previous example is made of 6NO1 alloy. When a material 7NO1 alloy is used, which has the property of recovering the original stiffness and strength by natural ageing after welding, the coupling member can be made thinner than the aforementioned construction for weight reduction. Furthermore, since the coupling member has reinforcement sections 69, which make its cross section box-shaped, the strength is improved.

After the block welding is complete, the interior of the vehicle needs to be equipped with heat insulator 33 and floorcloth 34, which prevent the flow of heat into and out of the vehicle, and with other rigging. Mounting of rigging is done through the surface sheets of the honeycomb panel (surface sheet on the interior side of the vehicle). Because the surface sheets are formed of aluminum alloy thin plates (0.5-3 mm) for weight reduction, simply fixing rigging to the thin sheets with screws and rivets may not provide sufficient mounting strength. As a solution to this problem, a rigging base plate, i.e. a rigging lug, is secured to specified positions on the surface sheet (step 108).

Figures 18 and 19 show such rigging lugs. The rigging base plates 80 are securely mounted to the surface sheet 64 of the honeycomb panel by rivets 82 with adhesive 81 interposed therebetween.

Figure 20 shows a rigging lug mounting equipment 83, which includes a jig 84, an NC positioning mechanism 85, a clamping head 86, and a rivet head 87. The equipment presses the positioned rigging base plate against the surface sheet and fixes it with a specified number of rivets and screws. The rigging base plate 80 is applied with an adhesive beforehand. The rigging base plate 80 is made of light alloy about 5 mm thick, for example, and has an area such that the stress will be 1 kg/cm<sup>2</sup>. When for example the rigging base plate receives a load of 10 kg, the area will be 10 cm<sup>2</sup>. In this way, the load of equipment mounted thereon is received by the entire surface of the rigging base plate.

The rigging base plate 80 may be brazed to the surface sheet simultaneously with the brazing of the honeycomb panel 60, to achieve the same result. Figure 21 shows the simultaneous welding, in which the rigging base plate 80 is bonded to the face of the surface sheet 64 by a solder 88, as with the honeycomb core, 61 during the brazing of the honeycomb panel (step 103).

Since the interior of the body structure, i.e. the surface sheet of the honeycomb panel is smooth, the heat insulator may be installed (step 109) either before or after the mounting of the rigging base plates. If installed before the rigging base plates are mounted, the insulator is installed as is. If installed after the mounting of

the rigging base plates, the insulator is cut and removed of the portions corresponding to the base plates. Then the heat insulator 33 in a sheet form is bonded by an adhesive applied between it and the inner surface of the car body.

Figure 22 shows how the insulator sheet is bonded to the side block 20. The sheet insulator 33 is cut and removed of the portions corresponding to windows 29 and rigging base plates 80 by a cutting device 89. While being fed by a feeding device 90, the sheet insulator 33 is pressed against the side block 20 by a roller (not shown). The fact that the inner surface of the body structure is smooth allows uniform bonding of the heat insulator in this way.

After the rigging lug and the insulator have been mounted, the blocks are assembled and welded into a car body structure (step 110). Figure 23 shows a front cross-sectional view of a block assembling equipment 92. With the contacting end surfaces of each block, i.e. the welding edges along the peripheries of the adjoining honeycomb panels taken as the welding line 67, the blocks are MIG-welded by a torch welding head 93. The assembling equipment 92 has a first station 94 and a second station 95 and performs the body assembly by welding the blocks in the following order.

On the first station 94, the side blocks 20, the roof block 40 and the end blocks 50 are welded together to form a five-plane structure. That is, the roof block 40 is placed on the side blocks 20 and the end blocks 50, and these blocks are correctly positioned relative to each other. While in a restrained condition, the blocks are welded together along the welding lines 67 on both the inner and outer sides simultaneously.

Next, the five-plane structure is placed on the underframe block 30 on the second station 95, with the side blocks 20 positioned on the side sills 31 of the underframe block 30 and the end blocks 50 positioned on the longitudinal ends of the underframe block 30. The underframe block 30 has its underside curved in the longitudinal direction along the camber provided by the jig by its own weight so that the camber of the underframe block matches that of the side block. Then, the welding is done between the underframe block 30 and the side blocks 20 and between the underframe block 30 and the end blocks 50 to complete a hexahedral structure. The car body structure 10 is assembled in this way. In the first station 94, the structure is open at the bottom so that positioning and welding equipments can be put inside the structure for welding and assembly process, which means that the work procedure can easily be automated in the first station. In the second station 95, the equipments are taken into or out of the structure through the passage opening in the end blocks.

Figure 24 shows a perspective view of an assembled car body structure.

The use of the honeycomb panels 60 makes the inner surface of the assembled car body structure 10 smooth. The interior material mounting fittings, interior materials, and interior structures, whose mounting positions have conventionally been restricted by the side posts and rafters, can be standardized in this invention. This invention also eliminates the need for making dimensional or positional adjustment in the process of mounting the rigging, facilitating the work. Since the blocks constituting the car body structure have high strengths despite the fact that there are no side posts or rafters, their thickness can be reduced, increasing the interior space of the vehicle.

Next, the outer surface of the car body structure is painted (step 111). First, the surface is degreased and roughened by sand-blasting. Then, the treated surface is applied with rust-prevention paint, anti-vibration paint and decorative coating.

Finally, rigging is mounted on the interior and exterior of the vehicle (step 112) to complete the car body structure as shown in Figure 2. In this rigging process, equipments have conventionally been mounted directly to the car body or through the rigging base plate either by screws or welding. When equipments are to be directly screwed or riveted to the car body made of light alloy honeycomb panels, there is a limit to the fixing strength. Welding may cause strains and may also provide insufficient strength. With this invention, the car body is provided with the rigging base plates on which to mount rigging, so that the honeycomb panels of the car body can be prevented from being strained.

Considering the difficulty in controlling the in-furnace temperatures during the brazing process, each block in the above embodiment is divided before brazing and then combined after brazing. If the in-furnace temperature control technique is improved, each block may be formed of a single continuous honeycomb panel rather than using divided panels. Instead of dividing the body structure into multiple blocks and welding them together, the structure may be divided crosswise and then welded together.

While the embodiment described above offers an example case where the present invention has been applied to the method of fabricating a car body structure, it is easily understood that this invention is also applicable to fields where the light-weight, large strength and high precision are demanded: for example, vehicles such as ships and automobiles, high-rise buildings, or building structures such as walls of an overhanging room and roofs.

This invention minimizes variations of dimensional accuracy of the car body structure and maintains a sufficient strength and a hermetic structure while keeping the structure light in weight, thus improving the reli-

ability of the structure. During the process of mounting rigging, there is no need for making dimensional or positional adjustment, making the work easy and simple.

Next, a second embodiment of this invention will be explained in detail with reference to Figure 25 through Figure 33. This embodiment makes each block in a way different from that of the first embodiment. That is, the step 105 to step 107 of Figure 3 are replaced with steps 114-119 of Figure 25. Figure 26 shows the method of manufacturing the side block of the car body structure using the honeycomb panels. As shown in Figure 26(a), the curved honeycomb panels 60 are precisely trimmed at curved sides, i.e. side weld portions 62 by a trimming machine to form welding edges. The panels 62 formed with welding edges are then welded in a circumferential direction of the panels to form a long, slender blocks 41, 42 as shown in Figure 26(b). For such a circumferential welding, a laser beam welding that has a very small input welding heat and thus can minimize strains or deformations, is preferably used.

Figure 27 shows an overall view of a long, slender block assembly apparatus 200. A long block 41, assembled from trimmed aluminum honeycomb panels 60, is placed on one of reference plates 220. The panels are precisely positioned by positioning pins 221. Then, another reference plate 220 is put on the positioned panels and these reference plates are fastened together by connecting pins 222 and reference plate connecting holes 224 to firmly restrain the long block 41. Because the panels 60 are held between the two reference plates 220, the panel surface which easily yields to a locally concentrated force can be protected. Welding is carried out through welding openings 223 formed in the upper reference plate 220. The welding openings are formed so as not to block the welding line. After the welding on the front surface is finished, the restrained panels are overturned for welding on the back side. In this way, the long blocks 41, 42 are formed. Because there are no obstructions blocking the welding lines, the welding accuracy and efficiency can be improved.

There is another method of welding the front and back side of the panels, as shown in Figure 28. A laser beam is passed through an MIG or TIG route gap 64G provided in the surface sheet 64 on the upper side to weld the welding edge 67 on the lower side. This is followed by the welding of the surface sheet 64 on the upper side. This method permits welding on both sides of the panel from only one side, eliminating the process of reversing the panel, improving the work efficiency and accuracy.

Next, as shown in Figure 26(c), a few long blocks 41 (42) are combined to form a roof block 40 as shown in Figure 26(d). First, as shown in Figure 29, the straight side 41a of each long block 41 is trimmed in a straight line by a trimming machine 96. The trimming machine 96 has a base 96A on which to mount the long block 41, a working head for trimming 96B and a control unit 96C. A fast MIG or TIG welding is used for the longitudinal welding because the MIG or TIG welding has a wide adjustment margin large enough to compensate for errors in the welding edge formed in the long block 41 (42) that may be caused by distortion. By welding the long block in the circumferential direction first, the remaining longitudinal welding is continuous and straight and its welding can be easily automated.

Next, the process of making a side block 20 from the honeycomb panels 60 is shown in Figure 30. As in the case of the roof block, a plurality of long blocks 21, 22 are first fabricated as shown in Figure 30(a) and 30(b). Then, the long blocks and single blocks 23, 24 are welded together in the longitudinal as well as circumferential direction to form a side block 20.

Figure 31 shows an overall view of a side block assembly apparatus 300. Designated 310 is a reference plate, 311 positioning pins, 312 connecting pins, 313 openings for welding, and 314 reference plate connecting holes. The welding openings 313 are formed so as not to interfere with the welding work. Using this apparatus, it is possible to perform all welding works without removing the panels 60 from the side block assembly apparatus 300. This in turn improves precision and quality of the side block 20.

Figure 32 shows an example of MIG or TIG welding apparatus, which welds, through openings 323 in a jig 321, the welding edges of the honeycomb panels 60 clamped between a pair of upper and lower jigs 321, 322. Then, with the panels restrained by the jigs, the entire assembly is lifted and rotated about a shaft 328 to be overturned. The reversed assembly is lowered to the original position for welding on the back side, thus completing the side block 20.

After the blocks constituting the car body structure are completed, rigging base plates 44 are installed. Examples of the rigging base plates include that of a rail type 44A shown in Figure 33. The rail type rigging base plate 44A allows longitudinal positional adjustment of the mounted rigging, making it possible to absorb welding distortions and deformations in the final assembly of the car body.

Next, a third embodiment of this invention will be described by referring to Figures 34 and 35.

The work steps shown in Figure 3 allow the rigging base plates or rigging lugs and heat insulating materials to be precisely and efficiently installed after the blocks are completed before the car body structure is assembled and welded. However, the accuracy of relative positions of the rigging lugs on different blocks, e.g. on the side block 20 and the underframe block 30, is affected by the assembly accuracy of the blocks. Particularly when large rigging is to be mounted on the rigging lugs on two or more blocks, high assembly precision is needed.

ed. The work steps shown in Figure 34 offers a solution to this problem.

The steps (101-107) from the panel design to the block welding are the same as those of Figure 3, so their description is not given here. Immediately after the blocks are completed, they are assembled and welded (step 120) and, with the blocks firmly connected together, the rigging lugs are installed (step 121). Thus, the rigging lugs on different blocks can be installed while maintaining their relative positions within a required accuracy. This allows rigging to be easily mounted on these lugs in a later process of rigging 124. After the structure is painted (step 122), a rolled insulator material is installed on the interior of the car body structure (step 123).

The procedure of mounting the rigging lugs will be explained with reference to Figure 35. In the figure, the rigging lugs 404 are to be installed on the floor of the underframe 30 of the car body 405. First, portable rails 401 are installed inside the car body and the lug mounting apparatus 402 is set on the rails. The mounting apparatus 402 has mounting heads 403 that have functions of positioning and riveting, screwing or bonding with adhesives the rigging lugs with good precision in the longitudinal and width direction of the car body. First, the rigging lugs 404 are installed successively on the floor and then those 406 on the sides are also secured in the same manner. In this way, the rigging lugs on the floor and the sides can be installed with high relative-position precision.

Next, a fourth embodiment of this invention will be detailed with reference to Figure 36 through Figure 46.

Prior to making the body structure 10 using the honeycomb panels 60, the structural blocks are fabricated. Let us take the side block 20 for example. Figure 37 shows a jig 460 for making the side block. The jig 460 consists of a plurality of cross-section shaped plates 461, each of which has its support surface formed in conformity to the cross-sectional shape of the interior of the side block 20. The cross-section shaped plates 461 are arranged in their width direction and connected together by a plurality of longitudinally disposed connecting plates 462. The assembly of the shaped plates 461 is set in a base frame to form the jig 460. The ends of the connecting plates 462 also form support surfaces that receive the honeycomb panel 60. The cross-section shaped plates 461 and the connecting plates 462 are so arranged that their support surfaces align with the joining positions of the honeycomb panels 60, i.e. welding lines 67. The jig 460 has a detachable restraining jig 463 that restrains portions of adjacent honeycomb panels 60 close to the welding line 67 during the tack welding.

The procedure for making the side block 20 will be explained. The honeycomb panels 60 whose peripheral ends are worked are positioned and arranged on the upper surface of the jig 460. Positioning of the honeycomb panels are done by putting the peripheral portions of the honeycomb panels in contact with ends of the jig 460 or with positioning projections, which are located at the openings such as windows and entrances in the side block. With the honeycomb panels 60 positioned, the restraining jig 463 is used to hold immovable the adjacent honeycomb panels 60 to be welded, and the joint surfaces or welding lines 67 are tack-welded as shown in Figure 39. Portions to be tack-welded 423 are preferably about 50 mm in length and provided at at least two locations for the two adjacent honeycomb panels 60. After the tack welding is finished for all welding lines 67 shown in Figure 39, the side block 20 or structural block is completed.

The roof block 40, like the side block 20, is made by positioning the honeycomb panels 60 on the jig and tack-welding the panels while restraining them with the restraining jig. The positioning of the honeycomb panels 60 on the jig is achieved by taking a positioning projection located at the end of the jig as the reference and arranging the panels with respect to the reference projection.

The underframe 30, as shown in Figure 40, has cross beams 37 and tie beams (not shown) arranged between side sills 31 located on both sides with respect to the width direction of the car body. End beams (not shown) are provided at the ends of the side sills 31. Between the cross beams 37 and between the cross beams 37 and the tie beams are arranged floor plates 32 made of honeycomb panels. The side sills 31, the cross beams 37 and the end beams are extruded shaped members of aluminum alloy. The joint between the floor plate 32 and the cross beam 37 is formed, as shown in Figure 41, by fitting the honeycomb panel floor plate 32 between the cross beams 37 and then welding a hermetic weld portion 38 on the front and a fillet weld portion 39 on the back. In this way the underframe 30 is formed. In welding the cross beams 37 and the honeycomb panel floor plates 32, it is desired that the welding of the hermetic weld portion 38 on the interior of the vehicle be carried out prior to the welding of the fillet weld portion 39 on the exterior side.

Now, the procedure for assembling the side blocks 20, roof block 40 and underframe block 30 - all of which were assembled from the honeycomb panels 60 by tack welding - into a cylindrical structure, as well as the facility used for this procedure will be explained with reference to Figure 42 and Figure 43. Figure 42 shows a cylindrical structure 10 rotatably supported on a rotating equipment 500 through a rotary structure assembly jig 502. The rotary structure assembly jig 502 can be divided into two sections, a lower section covering the underframe and the side blocks and an upper section covering the side blocks and the roof block. The lower section of the rotary structure assembly jig 502 is not joined with the upper section and supports the under-

frame 30 and the side blocks 20. The lower section also serves as a jig used in tack-welding the roof block 40 to the top of the side blocks 20 to assemble them into the cylindrical structure 10. Then, the upper section of the rotary structure assembly jig 502 is placed over the structure 10 - which was assembled and supported on the lower section of the jig 81 - and is joined to the lower section so that the structure 10 can be rotated.

5 The rotary structure assembly jig 502 has its outer circumferential surface formed in nearly a true circle and its inner circumferential surface conform in shape to the outer circumferential surface in the widthwise cross section of the cylindrical structure 10. In this way, the jig 502 has both functions of retaining and restraining the cross-sectional shape of the structure.

10 Next, by referring to Figure 43, the procedure of welding the cylindrical structure 10, i.e. the procedure of fully welding the joints between the honeycomb panels 60 and between the structural blocks will be explained. A welding equipment is of a gate type for welding the joints on the outer surface of the structure 10. The welding equipment includes a carrier structure 503 that can travel in the longitudinal direction of the car body and a welding device 505 that can be moved along the carrier structure 503 in the width direction of the car body. The operation of the carrier structure 503 and the welding device 505 are automatically performed by numerical control. The welding on the interior side of the structure 10 between the honeycomb panels 60 and between the structural blocks is done by means of a rail 504 laid inside the car body along the longitudinal direction of the car body and a welding device 506 which is mounted on and movable along the rail 504 in the longitudinal direction of the car body and which can be adjusted in the vertical and lateral directions and also in the welding angle. The welding device 506 performs the full and final welding along the joints and its control is done automatically by numerical control. The first welding device 503 and the second welding device 506 can use any of the welding methods - MIG welding, automatic TIG welding and laser welding.

15 The welding work is done as follows. In the case of welding the structure 10 in the longitudinal direction of the car body, the rotating equipment 500 turns the cylindrical structure 10 supported on the rotary structure assembly jig 502 until the welding edges along the welding lines face up. With the structure 10 held immovable in this state by the rotating equipment 500, the welding device 505 is moved facedown in the longitudinal direction of the car body to carry out welding. Similarly, in the case of welding the inner surface of the structure, the welding device 505 is operated facedown with the welding edges along the welding lines at the joints facing up. For the welding in the cross-sectional direction of the structure 10, the welding device 505 is operated in the vertical directions while at the same time controlling the rotating equipment 500 to rotate the structure in synchronism with the vertical control of the welding device. For the welding on the inner surface of the structure 10, the welding device 506 is similarly controlled in the vertical direction and in the welding angle and at the same time the rotating equipment 500 is controlled in synchronism with the control of the welding device 506 to perform welding on the structure while in rotation. Performing the welding on the outer circumferential surface and on the inner surface simultaneously improves the work efficiency. In this case, the welding of the welding line extending in the longitudinal direction of the car body should be done prior to other welding lines extending in the width direction, i.e. the circumferential direction of the car body. For the welding on the outer circumferential surface and the inner surface, the outer circumferential surface is given priority because this is advantageous in minimizing the strains occurring in the outer circumferential surface of the structure 10.

20 For the cylindrical structure 10 fabricated as described above, a rigging structure for efficiently mounting rigging will be explained by referring to Figures 44 and 45. Figure 44 shows the cylindrical structure 10 attached with rigging rails 600, which are used for supporting interior equipment. Figure 45 shows the structure of the rigging rail 600. In the figure, the rigging rail 600 is located at a specified position in the cross-sectional direction of the car body, i.e. in the circumferential direction and extends in the longitudinal direction of the car body, as shown in Figure 44. The rigging rail 600 is almost C-shaped in cross section and accepts in its groove heads of movable bolts, through which the rigging is supported on the rail. Thus, the rigging can be adjusted in dimension in the longitudinal direction of the car body. The rigging rails 600 are provided for the purpose of mounting interior rigging such as ceiling plates, fluorescent lamps, ducts, inner linings, partitions, and compartments. The mounting positions of the rails are determined considering the fact that these interior equipments formed as individual units are supported astride two or more rails. Separate supporting and fixing fittings may be provided so as to straddle two or more rigging rails 600 in the circumferential direction of the car body, if required, for mounting large rigging such as partition wall members.

25 The rigging is mounted to the rails 600 by means of bolts, or by hooking one end of the modular rigging and fixing the other end through the bolt means. The rigging rails 600 themselves are secured to the structure 10 by a rivet-bonding method, a combined fastening method which uses a bonding agent 602 at a location of the frame member 603 brazed inside the honeycomb panel 60 and also a fastening means 601 capable fastening works from the one surface side of the honeycomb panel 60 utilizing bolts or rivets. This provides secure fastening strong enough to allow connection of even rigging members. The frame members 603 are brazed

between the surface sheets beforehand at locations where the rigging rails are to be installed on the panels. They are installed where large strength is required for mounting the rigging. Installation of the rigging rails 600 is done automatically, after the cylindrical structure 10 is completed, by using an automatic rigging rail mounting apparatus which runs on the rail 401 (Figure 35) laid inside the structure 10. That is, the rigging rail 600 with its connecting surface applied with the bonding agent 602 is positioned at a specified location on the inner surface of the structure 10; holes are drilled in the structure; and the fastening means 601 are tightened. These works are done automatically. This rigging rail mounting may be done when each structural block is completed. It is noted, however, that the welding lines perpendicular to the rigging rails 600 need be fully welded before rail installation.

The cylindrical structure 10 fabricated thus far is attached with the end blocks 50, as shown in Figure 46. That is, at the final assembly process the end blocks 50 are mounted by performing positioning and then arc welding. While in this embodiment the end blocks 50 are so formed as to completely cover the longitudinal end faces of the cylindrical structure 10, they may be formed otherwise. To secure sufficient strength for the welding procedure that is done while rotating the structure, the end block may be divided into a ring-shaped outer circumferential portion and an intermediate portion that is formed with an opening such as a passage, and the ring outer circumferential portion of the end block may be installed when the cylindrical structure is assembled with tack welding.

Since the honeycomb panels 60 are assembled by tack welding to form structural blocks and a cylindrical structure, deformation due to welding heat is very small, making it possible to perform positioning and restraining of the honeycomb panels or structural blocks relatively easily, which in turn enhances work efficiency. Further, because the welding edge accuracy is secured and because the structural blocks are not bonded by full welding, an overall assembly error due to shrinkage and deformation does not occur. The structural blocks do not require to be overturned for bothside welding, thereby improving the precision of the structural blocks themselves. In fully welding the cylindrical structure 10, deformations are canceled out by the adjacent honeycomb panels being welded together or by the adjacent structural blocks being welded together, thereby minimizing strains in the structure 10.

Since the cylindrical structure 10 is rotated by the rotating equipment 500 through the rotary structure assembly jig 502 so that the weld portions can be welded with the welding device facedown automatically and continuously. This ensures sufficient strength at the welded portions. The rigging rails 600 are secured to the cylindrical structure 10, so that the rail-installed areas are free from influences of heat deformation due to welding, allowing the modular rigging to be mounted easily and accurately. Since the welding and the rigging rail mounting are carried out after the structure 10 is formed cylindrical, these works can easily be automated by simply installing the rail 401. Because the rigging rail 600 can be installed at a precise position, there is little error in the positional relationship between the modular rigging installed and the structure 10. This eliminates the need to make adjustment between the adjacent rigging installed on the interior of the structure, enhancing the rigging mounting efficiency. It is therefore possible to eliminate the tapping work that has conventionally been performed to install interior rigging after the structure is completed.

With the rigging rails 600 installed, the replacement of rigging can easily be done. That is, when the interior rigging becomes old and worn after many years of service of the railway cars, the rigging rails facilitate the work of interior remodeling or repair, especially such works as removing old rigging, taking them out of the entrance, carrying new equipments through the entrance into the car and then mounting them on the inside of the car. New equipments to be installed have means to allow their mounting to the rigging rails 600.

The rigging rails 600 offers the similar effects also in other railway car body structures whose underframe block, side blocks and roof block are formed of hollow, extruded shape materials or members. That is, the hollow, extruded shape members are so formed as to conform to the lateral cross-sectional shapes of the car body at the locations where those shape members are to be installed. The extruded shape members are arranged and assembled so that their longitudinal directions match that of the car body. A plurality of these longitudinally assembled units of extruded shape members are placed side-by-side in the circumferential direction of the car body and then welded together to form the car body structure. The railway car body structure made up of such hollow, extruded shape members also have a smooth surface on the interior side. The rigging rails therefore can be installed on the inside of the car body for the mounting of interior equipments, thus achieving the same effect of the previous embodiment.

It is also possible to integrally form the rigging rails with the hollow, extruded shape members. In this case, because the work for installing the rigging rails is eliminated, the overall car body structure fabrication process becomes simpler. The repair is done in the same way as in the previous embodiment.

**Claims**

1. A railway car having a car body structure made up of a plurality of blocks, characterized in that each of said block comprises:
  - 5 a plurality of panels, each of said panel having a pair of surface sheets and core and end members held between the pair of surface sheets, all brazed together; each of said panels bonded together by metal-to-metal bonding at the peripheral portions of the surface sheets and at the end members to form the blocks; the blocks being welded together to form the car body structure.
- 10 2. A railway car body according to claim 1, wherein the surface sheets of the panels are made of light alloy and the panels are honeycomb panels, each of which has light alloy honeycomb cores and end members for use in welding, both secured between the pair of surface sheets.
- 15 3. A railway car body according to claim 1, wherein the panels have a plurality of riggings mounted to the surface sheets of the panels through rigging base plates.
4. A railway car body according to claim 3, wherein the rigging base plates are rigging rails that extend in the longitudinal direction of the car body.
- 20 5. A railway car body according to claim 3, wherein the rigging base plates are fastened to reinforcement members of the panels.
6. A railway car body according to claim 1, wherein the car body structure comprises a roof block, side blocks, an underframe block and end blocks.
- 25 7. A railway car body according to claim 6, wherein the inner surfaces of the side blocks and the roof block are smooth.
8. A railway car body according to claim 7, wherein the car body structure is formed by joining the panels whose end members and the peripheral portions of the surface sheets are trimmed.
- 30 9. A method of manufacturing a railway car made up of a plurality of blocks, characterized by the steps of:
  - 35 preparing a plurality of panels, each panel being made up of a pair of surface sheets, at least one core between the inner portions of the surface sheets and end members arranged at the peripheral portions of the surface sheets, all brazed together;
  - performing metal-to-metal bonding between the surface sheets of the panels and between the end members of the panels to form each block; and
  - 40 trimming metal-to-metal bonding between the peripheral portions of the adjacent blocks to integrate the blocks into the car body structure.
10. A method of manufacturing a railway car according to claim 9, the method further comprising the steps of:
  - 45 trimming the panels, which constitute the side blocks, in an inverted trapezoid;
  - arranging the panels, which constitute each block, in specified positions and restraining them;
  - perforating the panels, which constitute each block, in specified positions and restraining them;
  - assembling the blocks and performing metal-to-metal bonding between the welding portions of the adjacent blocks to integrate the blocks into the car body structure.
- 50 11. A method of manufacturing a railway car according to claim 9, further including the steps of:
  - 55 after the plurality of panels are integrated into each of the blocks, fixing rigging base plates on the surface sheets at specified positions; and
  - after the adjacent blocks are joined into the car body structure, mounting rigging on the rigging base plates.
- 55 12. A method of manufacturing a railway car according to claim 11, further including the steps of:
  - welding the peripheral portions of the panels to form each of the blocks;
  - bonding a sheet of heat insulating material to each block by removing portions of the insulator sheet

that will interfere with the rigging base plates;  
 integrating all the blocks into the car body structure by metal-to-metal bonding; and  
 mounting rigging on the rigging base plates.

5        13. A method of manufacturing a railway car according to claim 9, wherein each of the panels comprises a pair of surface plates, thin-plate cores and end members having a cooling passage therein, the method further comprising the steps of:  
       arranging and restraining the panels at specified positions and welding the welding portions of the panels to form each of the blocks while flowing a cooling medium through the cooling passage; and  
 10        welding the blocks together to form the car body structure while flowing a cooling medium through the cooling passage located at the welding edge of each block.

14. A method of manufacturing a railway car according to claim 9, wherein the car body structure comprises side blocks, a roof block, end blocks and an underframe block, the method comprising the steps of:  
 15        trimming the peripheral portions of the honeycomb panels by necessary amounts to form welding portions so that each honeycomb panel conforms to the shape of a specified position in each block;  
       arranging said honeycomb panels, which constitute each block, in specified positions and restraining them;  
       performing metal-to-metal bonding between the welding portions of the adjacent blocks to integrate the blocks into the car body structure.  
 20

15. A method of manufacturing a railway car according to claim 9, wherein in the welding of the peripheral portions of the honeycomb panels, portions of the honeycomb panels near a welding line between the adjacent panels are held by cooling plates that absorb heat.

25        16. A method of manufacturing a railway car according to claim 9, wherein rigging base plates are secured to the surface of the honeycomb panels that constitute each block by a combination of a bonding means and a mechanical connecting means, and rigging is mounted on the interior and exterior of the car body by means of the rigging base plates.

30        17. A method of manufacturing a railway car according to claim 9, wherein the welding of the peripheral portions of the honeycomb panels comprises the steps of:  
       restraining and welding the plurality of honeycomb panels, which constitute each block, along the peripheral portions on one side;  
       with the honeycomb panels kept restrained, reversing the block;  
 35        and welding the peripheral portions of the honeycomb panels on the other side.

18. A method of manufacturing a railway car according to claim 9, wherein the panels are curved honeycomb panels having a curved edge and a straight edge, the method further comprising the steps of:  
       welding the curved edges of the honeycomb panels to form a small block;  
 40        welding the straight edges of the honeycomb panels of the small blocks to form a structural block;  
       and  
       welding the structural blocks to form the car body structure.

45        19. A method of manufacturing a railway car according to claim 9, further comprising the steps of:  
       preparing a plurality of panels for each block, each of the panels comprising a pair of surface sheets, honeycomb cores and end members, all brazed together;  
       inspecting whether each of the panels agrees with design values;  
       trimming by necessary amounts the peripheral portions of the panels that have passed the inspection to form welding portions so that these panels conform to the shapes of specified positions in each block;  
 50        arranging and restraining the panels at specified positions by using a jig prepared for each block;  
       bonding together the welding portions of the restrained panels by metal-to-metal bonding to form each block;  
       fixing rigging base plates on the face of the surface plates;  
 55        bonding a sheet of heat insulating material to the inner surface of the panels by removing portions of the insulator sheet that will interfere with the rigging base plates;  
       welding the welding portions of the side blocks, the roof block and the end blocks to each other by metal-to-metal bonding to form a five-plane structure;

welding the five-plane structure to the underframe block by metal-to-metal bonding to form a car body structure;  
 painting the external surface of the car body structure; and  
 mounting rigging on the rigging base plates.

5       **20.** A method of manufacturing a railway car according to claim 9, further comprising the steps of:  
 10      positioning and arranging a plurality of panels on jigs, the jigs having support surfaces conforming to the shape of the car body;  
           tack-welding the plurality of panels to form a plurality of structural blocks;  
           assembling and tack-welding the plurality of structural blocks to form a cylindrical structure;  
           successively full-welding joints of the panels in the cylindrical structure; and  
           joining end blocks to the cylindrical structure.

15       **21.** A method of manufacturing a railway car according to claim 20, wherein in making the blocks of the car body structure from the honeycomb panels, the panels in each block are welded in the circumferential direction first and then the welded panels are assembled and welded in the longitudinal direction to form each block.

20       **22.** A honeycomb panel comprising:  
 25      a plurality of honeycomb cores;  
           a reinforcement member disposed between the adjacent honeycomb cores;  
           a pair of surface sheets between which to hold the honeycomb cores, the reinforcement member, and outer coupling members for welding; and  
           rigging base plates secured to the surface of the surface sheets.

30       **23.** A honeycomb panels according to claim 22, further comprising reinforcement cores inserted into the honeycomb cores at the corner of the honeycomb panel.

35       **24.** In a method of manufacturing a honeycomb panel having a plurality of honeycomb cores, a reinforcement member disposed between the honeycomb cores and a pair of surface sheets between which to hold the honeycomb cores and the reinforcement member, the honeycomb panel manufacturing method comprising the steps of:  
 40      holding the honeycomb cores and the end members for welding between the pair of surface sheets and brazing them together to form a honeycomb panel; and  
           fixing the rigging base plates to the surface of the surface sheets.

45       **25.** A method of manufacturing a honeycomb panel according to claim 24, further comprising the steps of:  
 50      holding between the pair of surface sheets the cores and the end members for welding and then brazing them together; and  
           brazing the rigging base plates to the surface of the surface sheets.

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FIG. 1

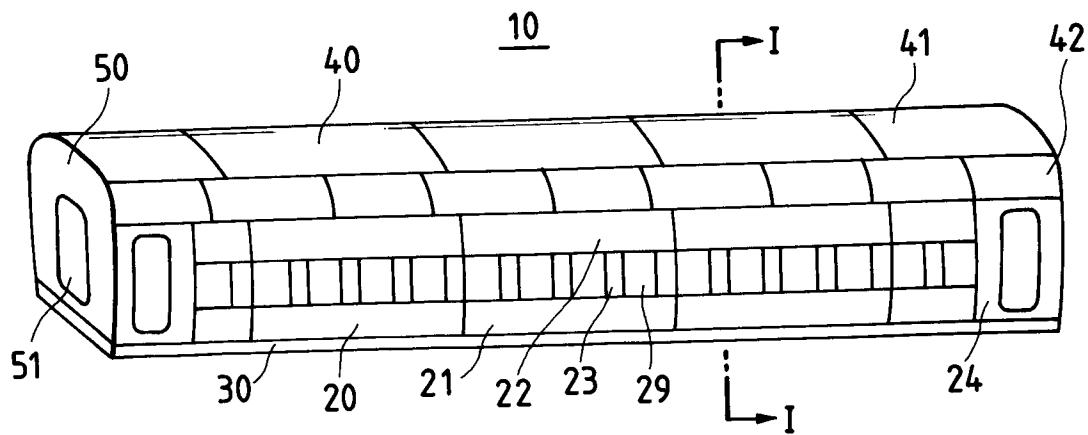


FIG. 2

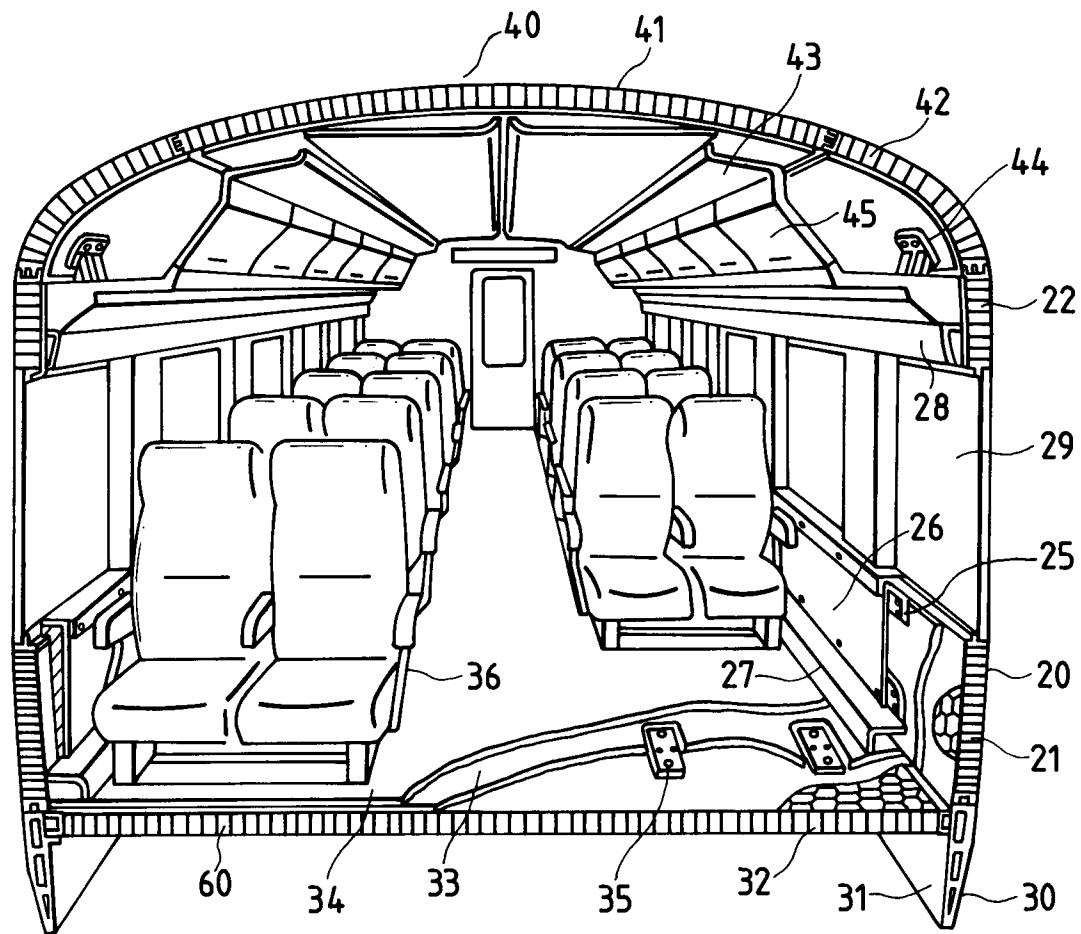
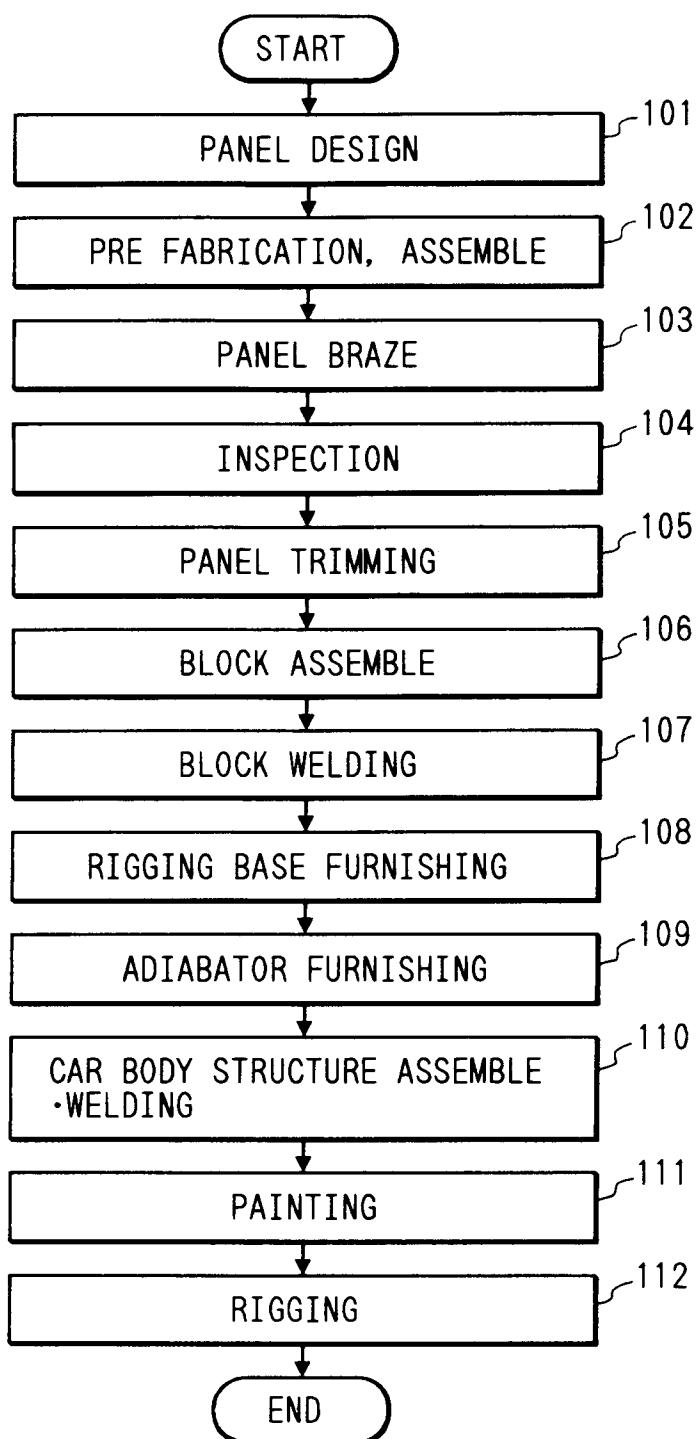
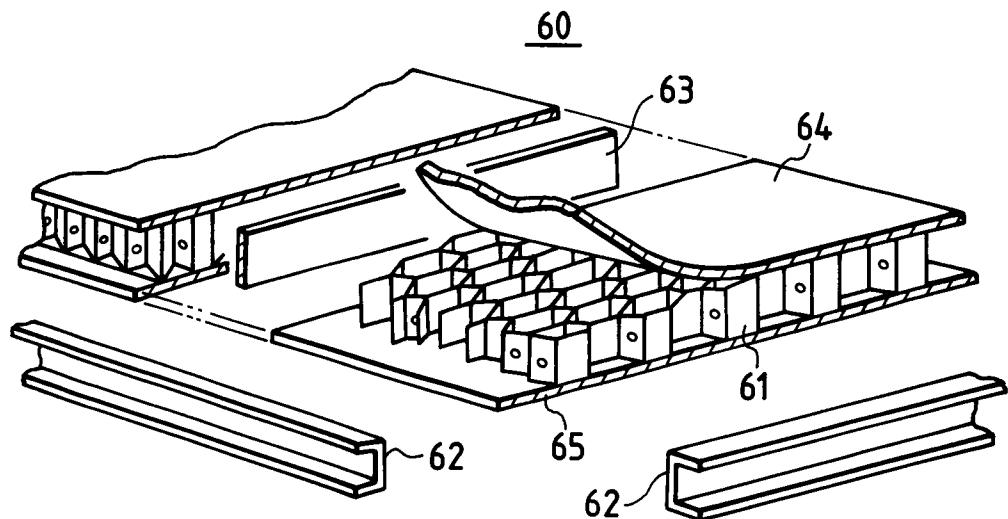


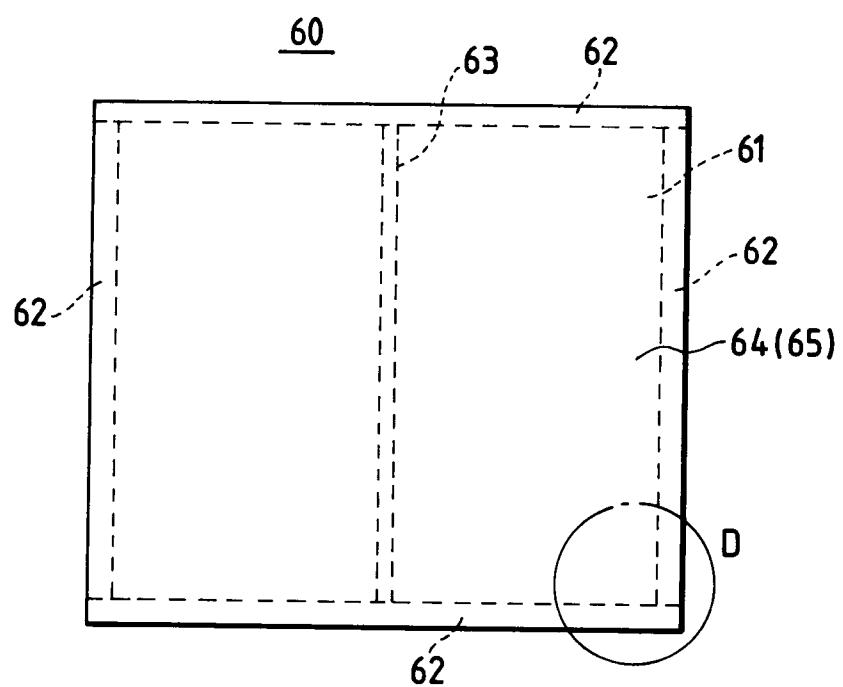
FIG. 3



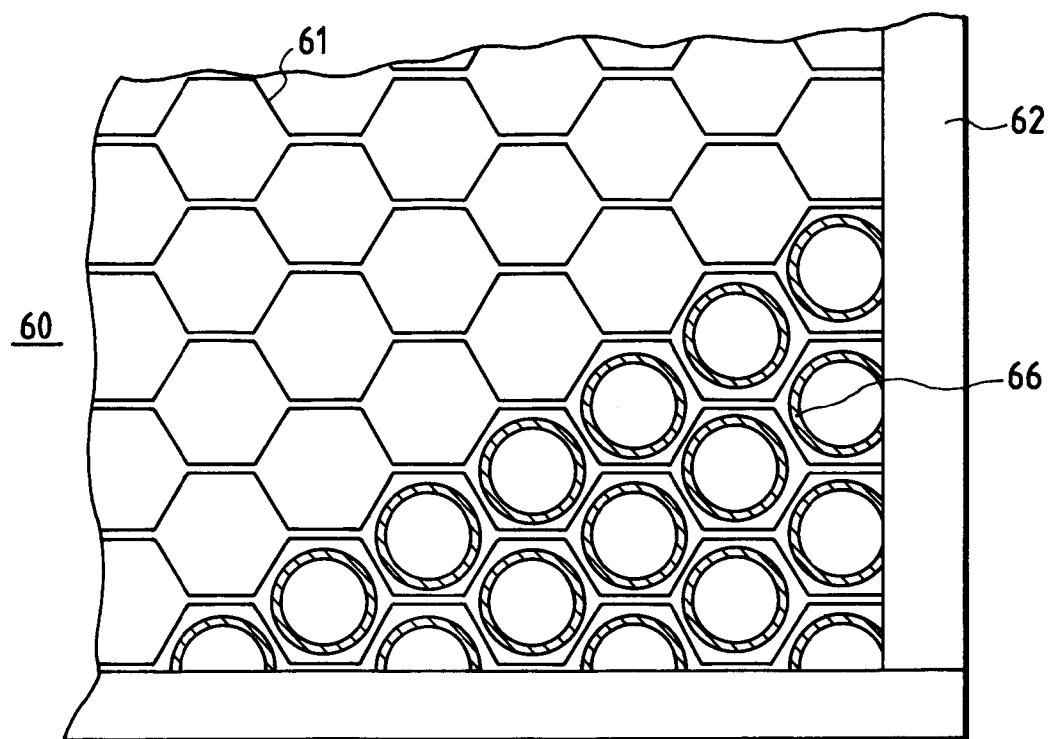
*FIG. 4*



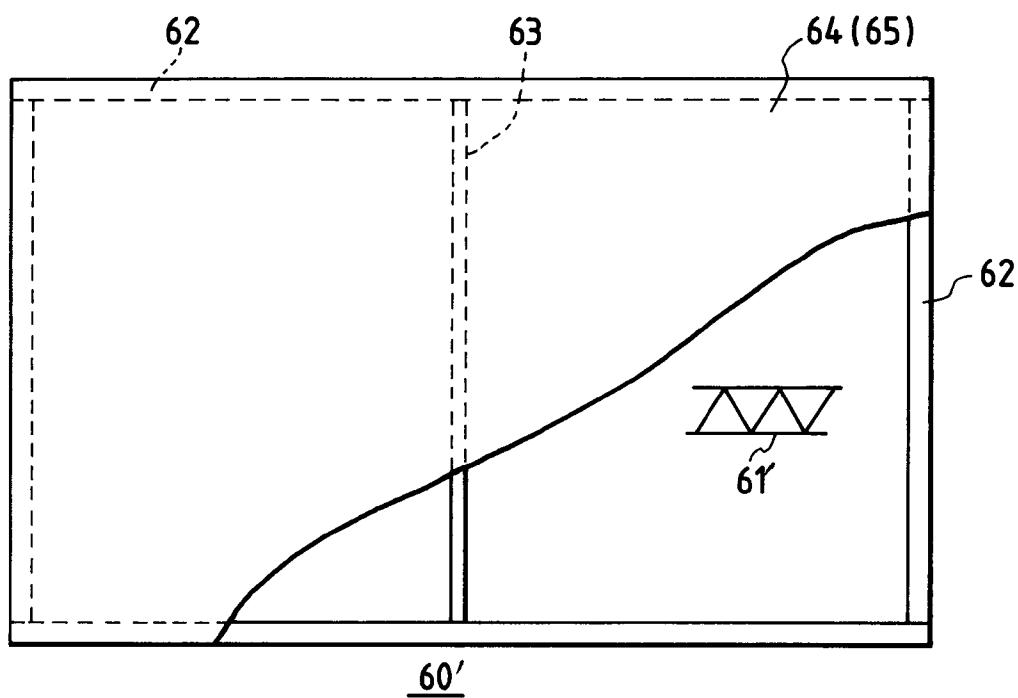
*FIG. 5*



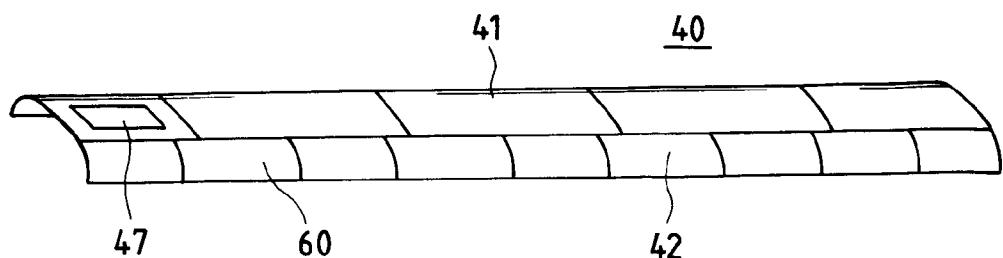
*FIG. 6*



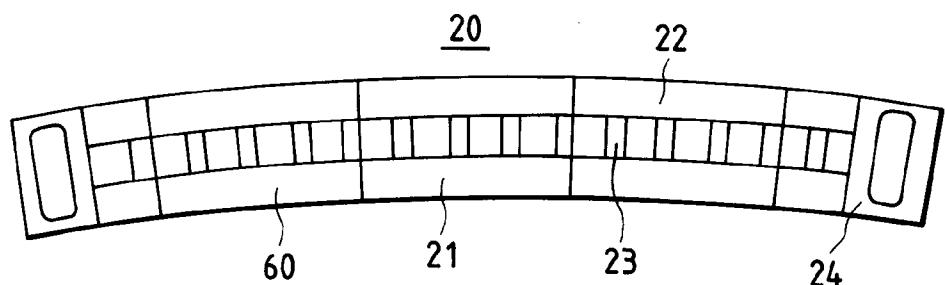
*FIG. 7*



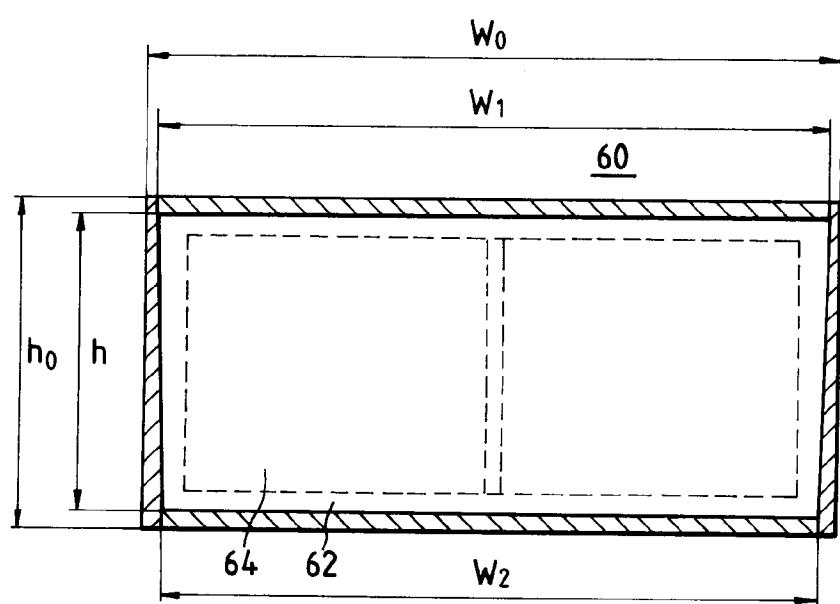
*FIG. 8 (a)*



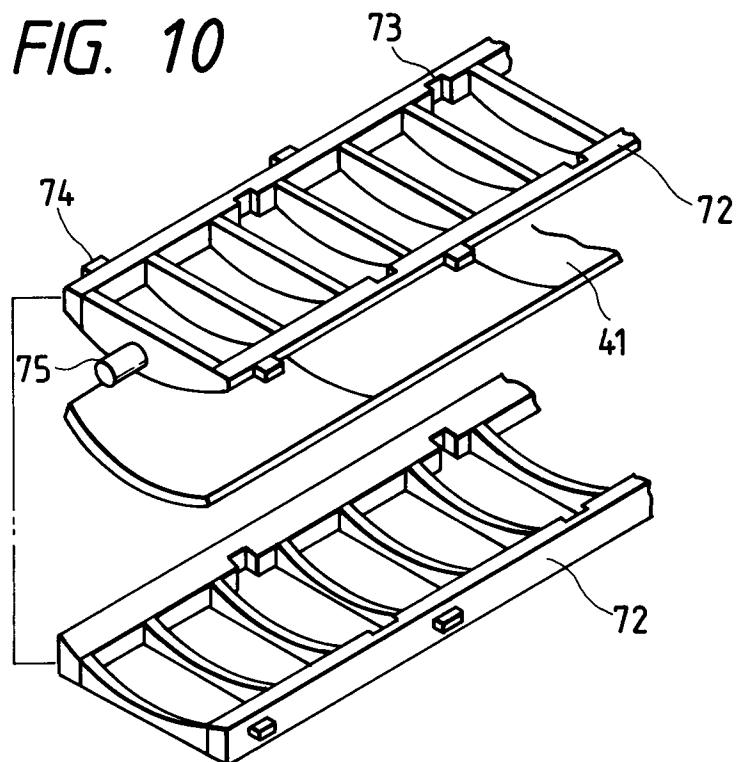
*FIG. 8 (b)*



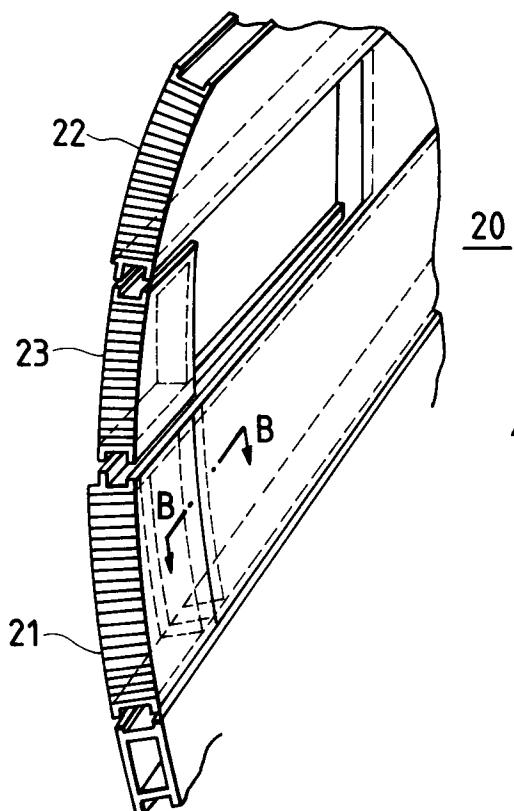
*FIG. 9*



*FIG. 10*



*FIG. 11(a)*



*FIG. 11(b)*

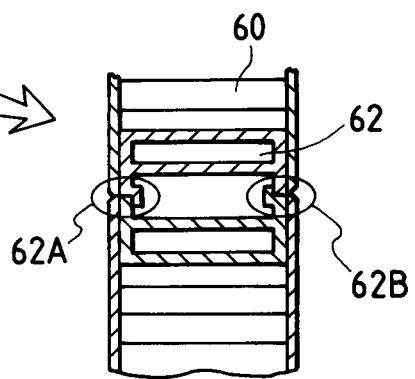


FIG. 12

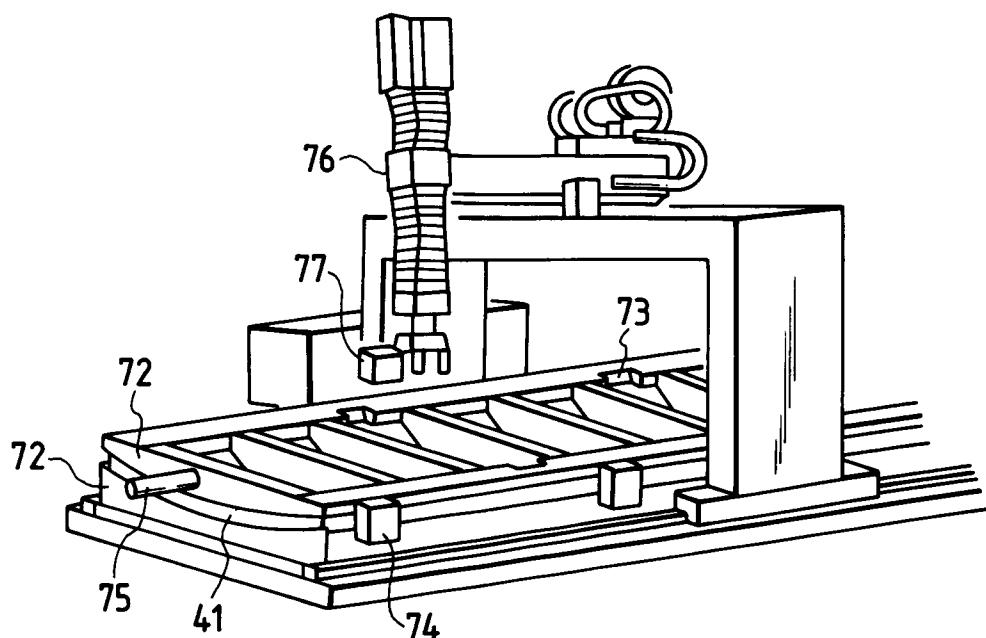


FIG. 13

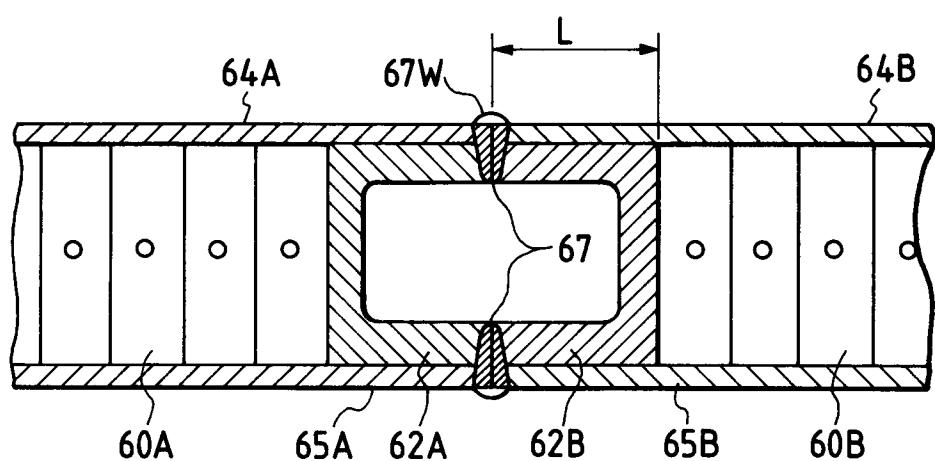


FIG. 14

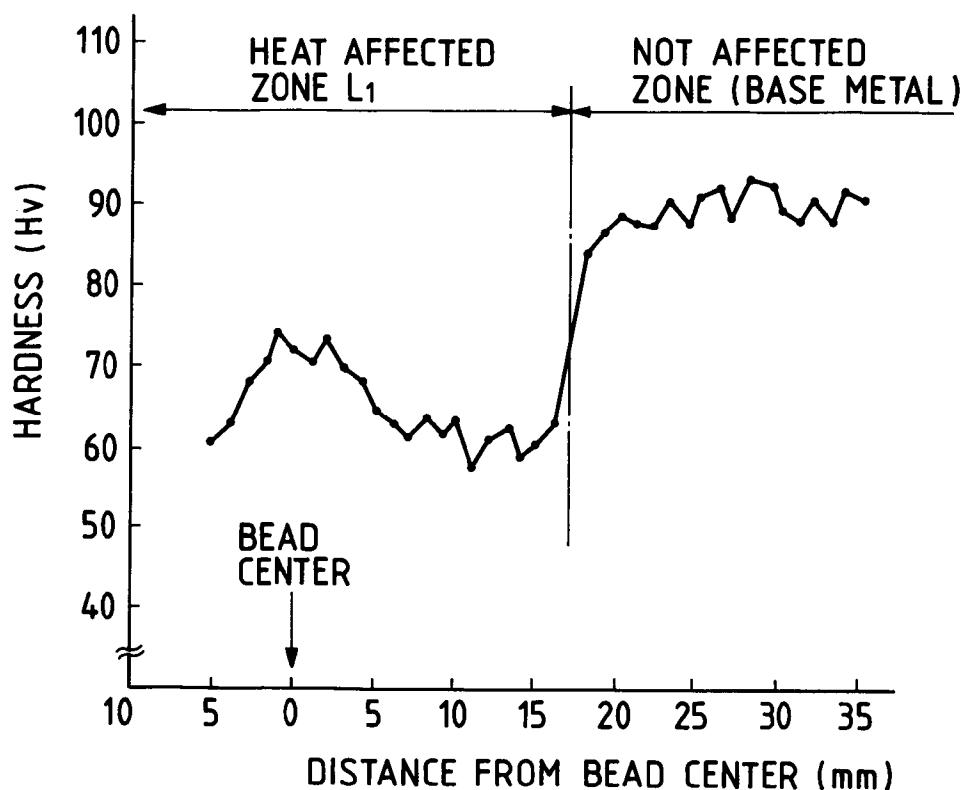
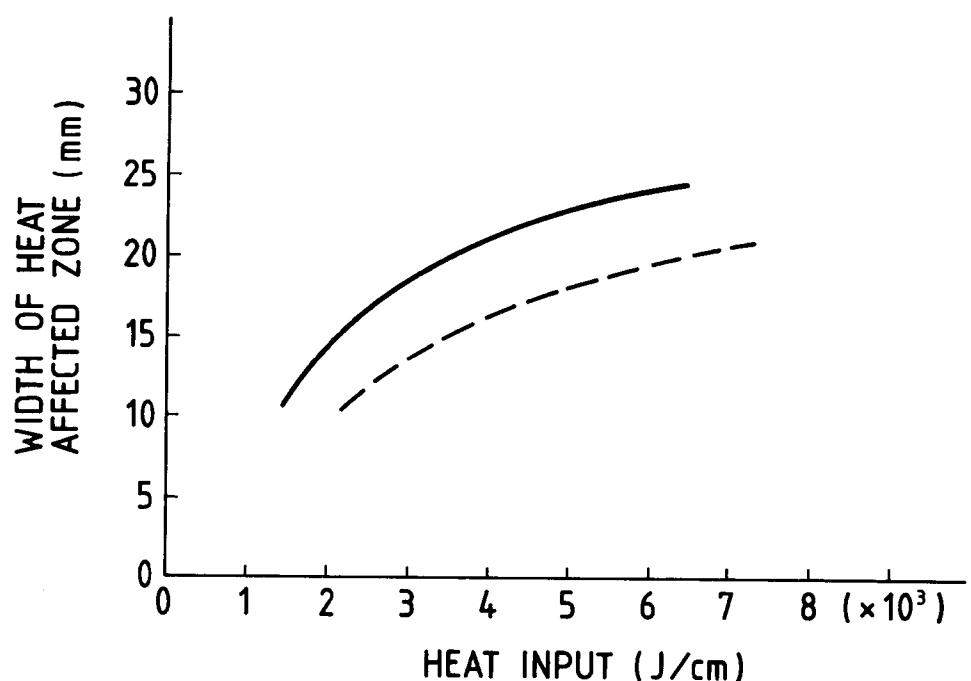
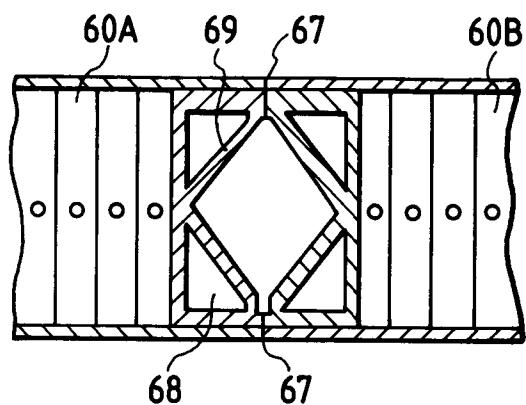


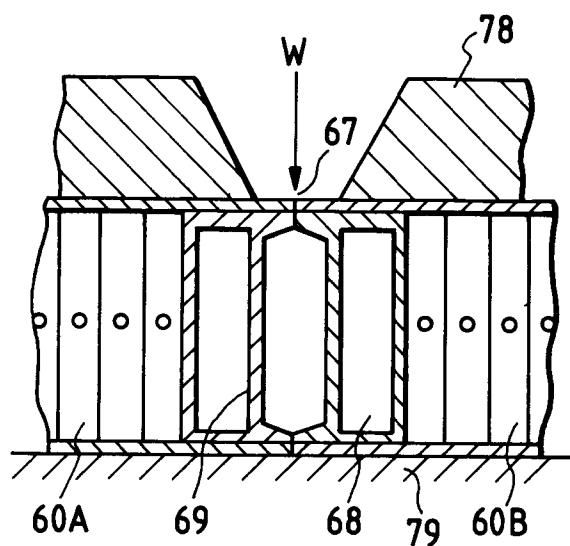
FIG. 15



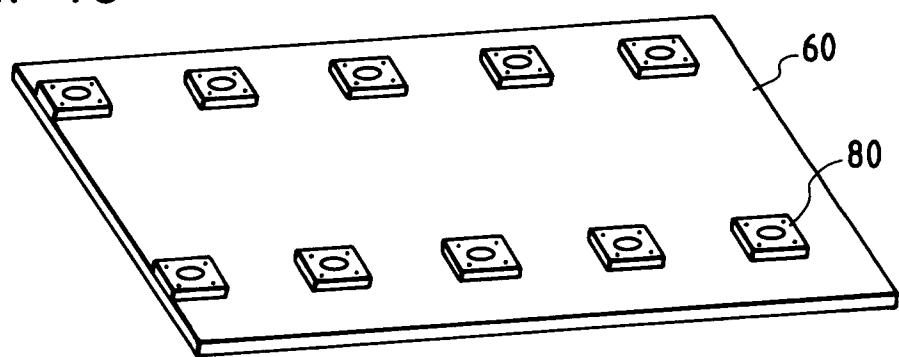
*FIG. 16*



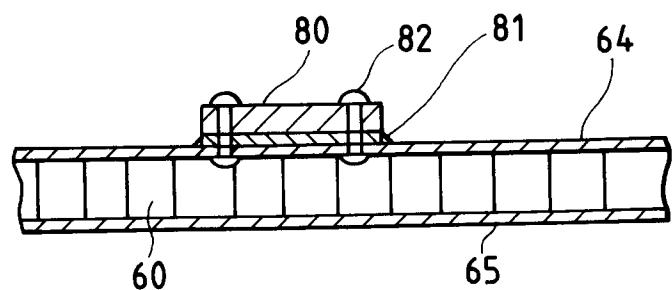
*FIG. 17*



*FIG. 18*



*FIG. 19*



*FIG. 20*

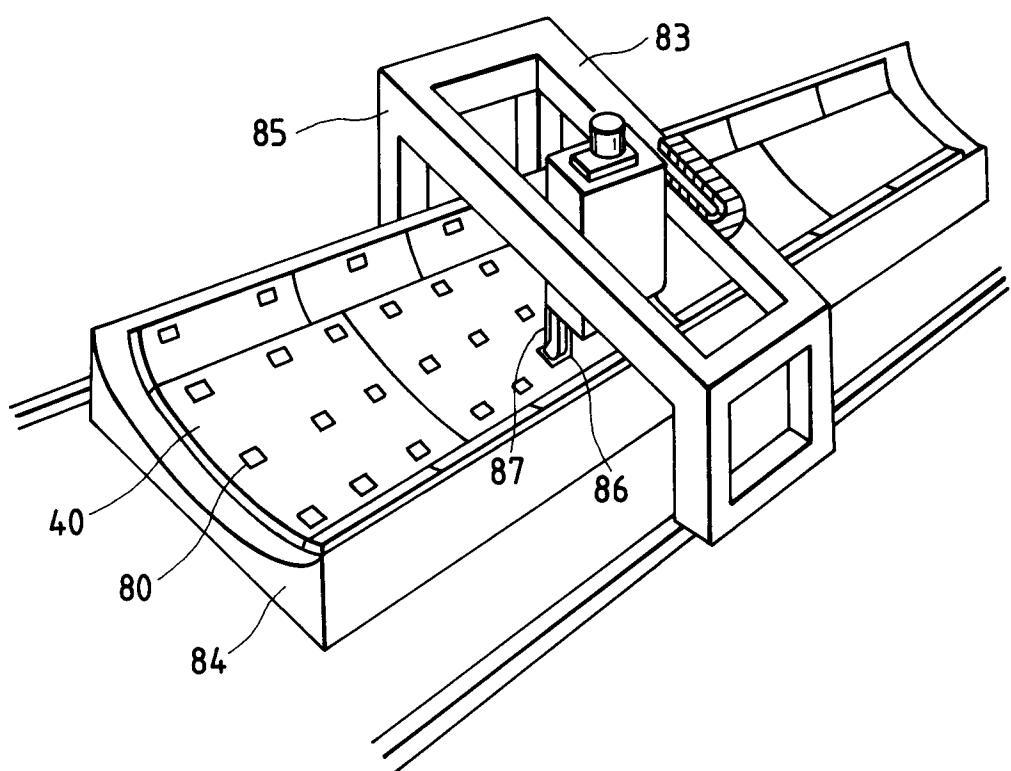


FIG. 21

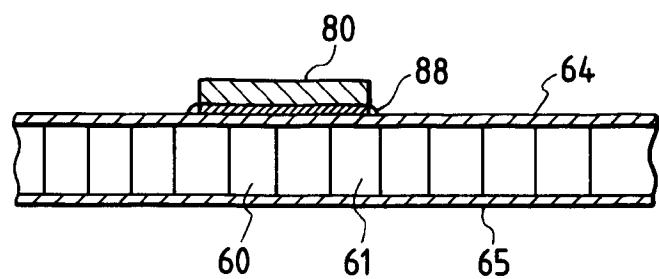


FIG. 22

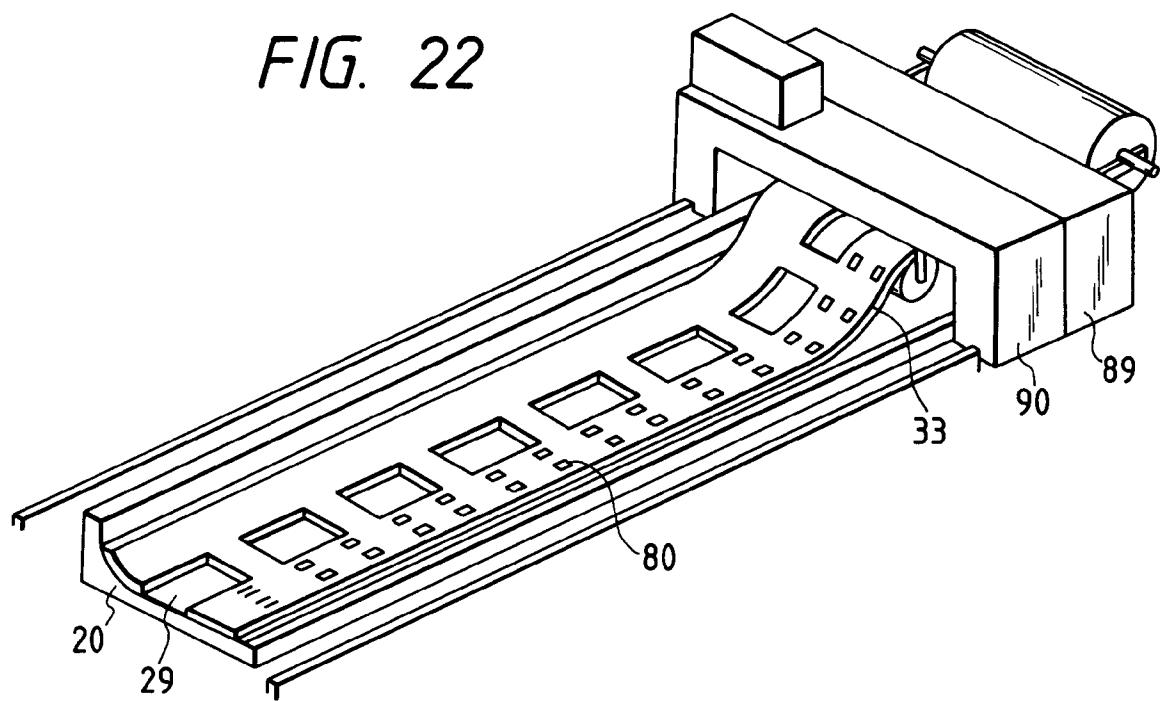


FIG. 23

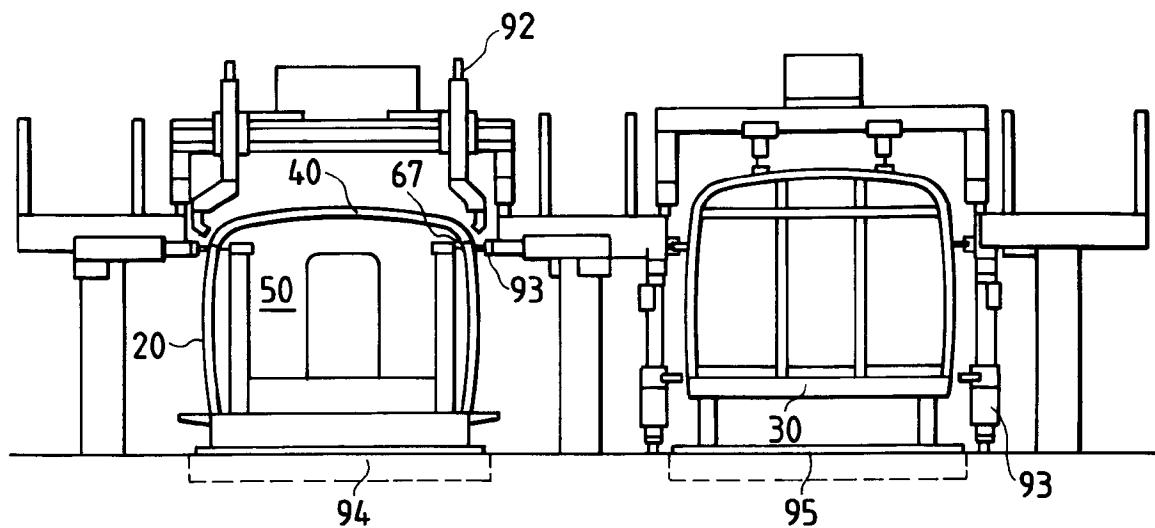


FIG. 24

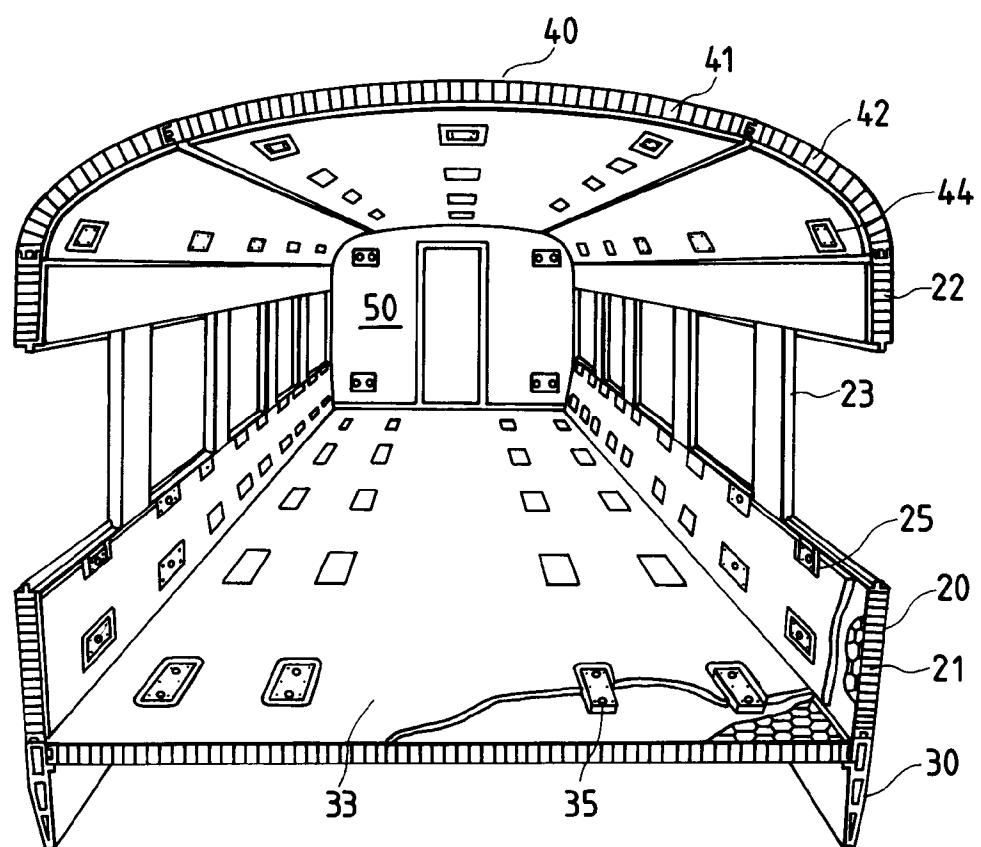
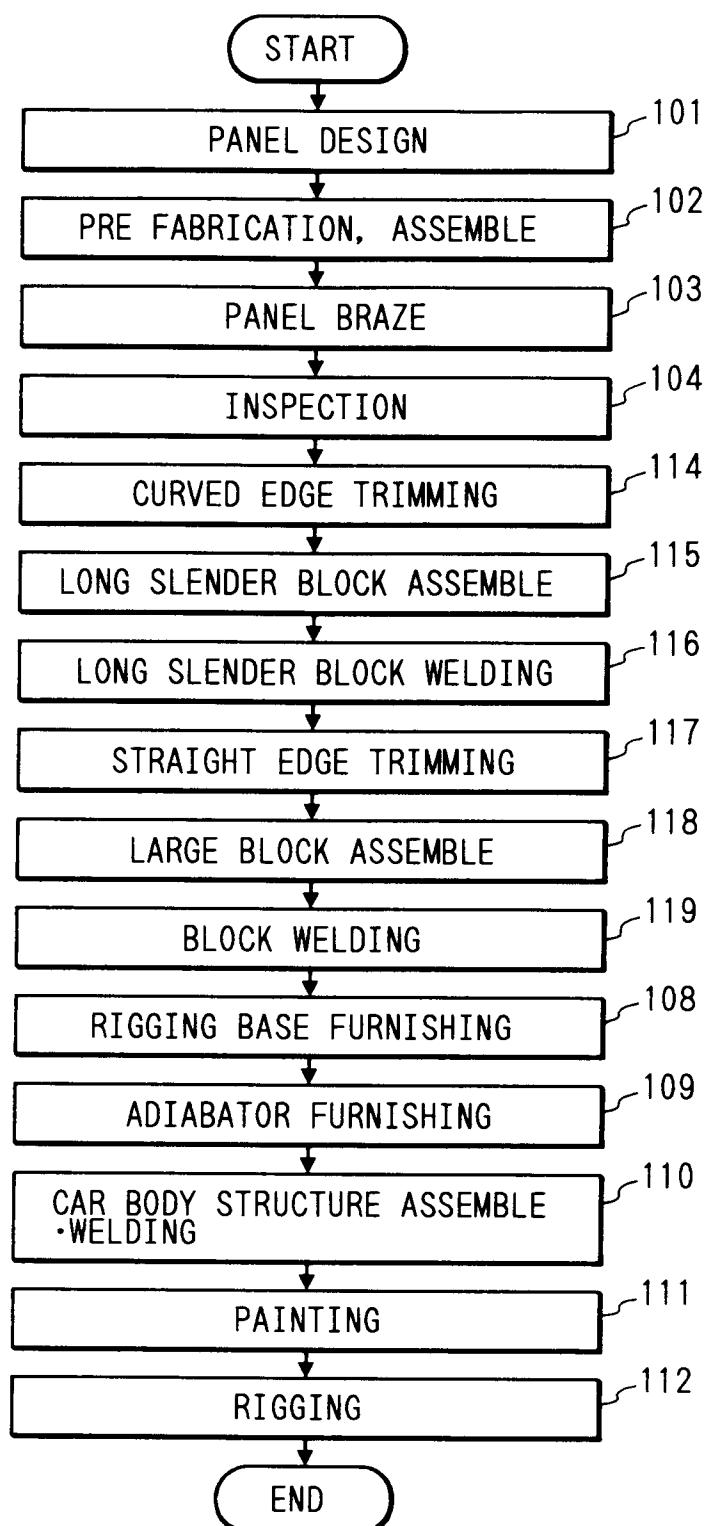
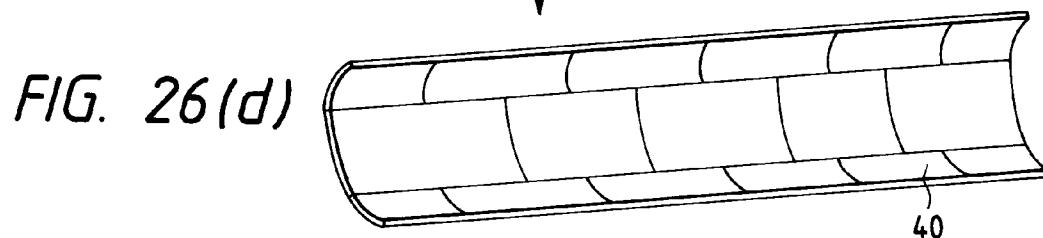
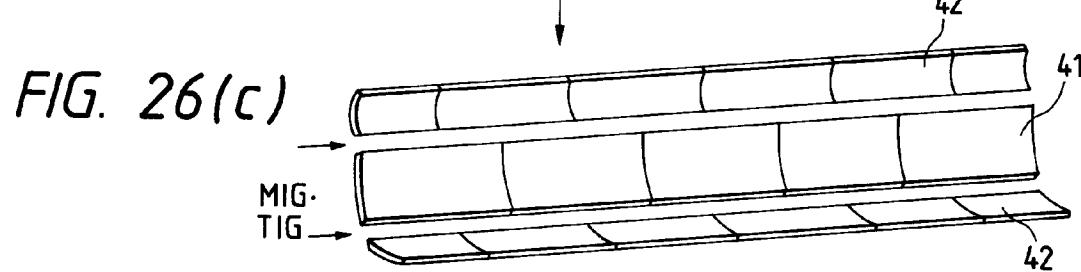
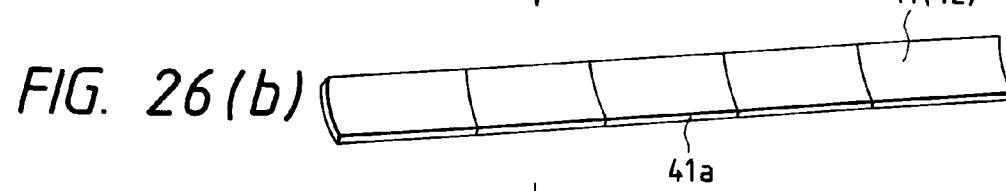
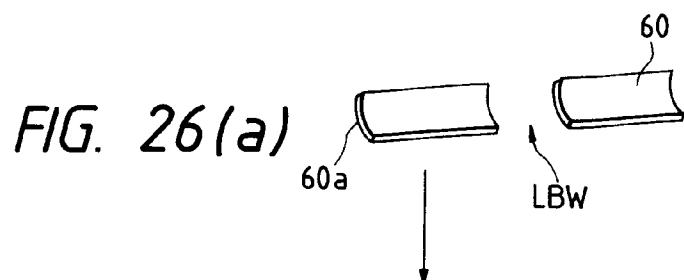
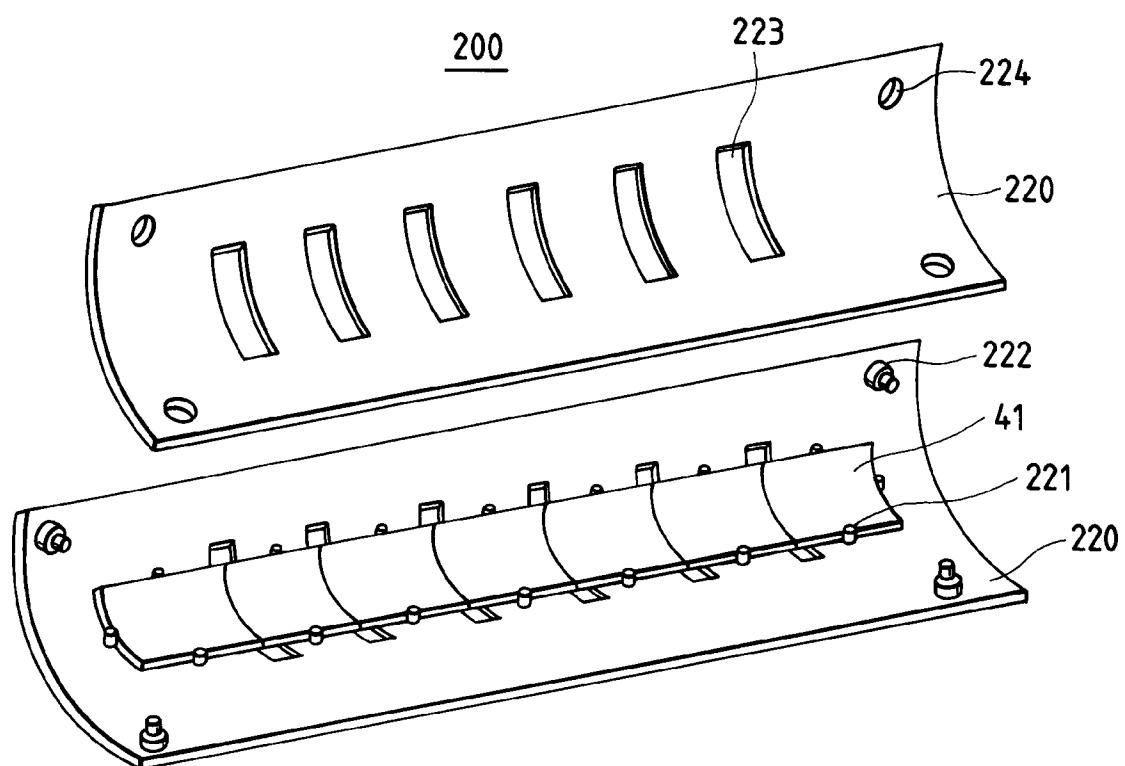


FIG. 25

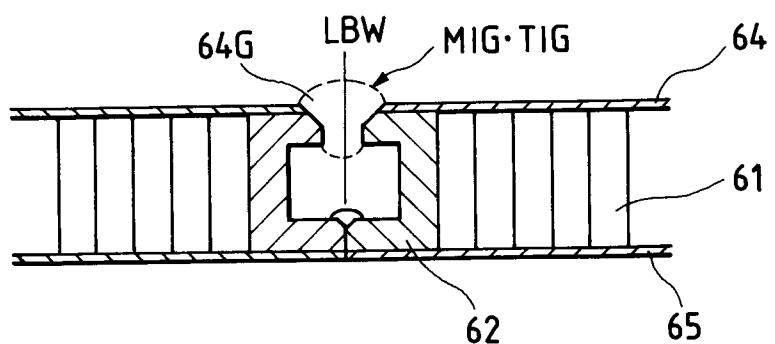




*FIG. 27*



*FIG. 28*



*FIG. 29*

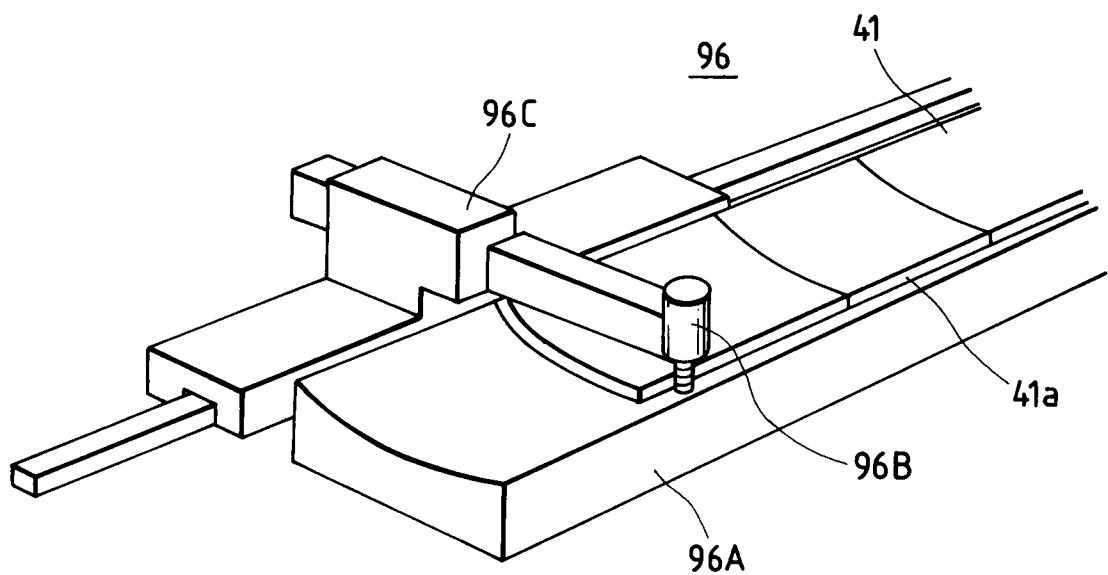


FIG. 30(a)

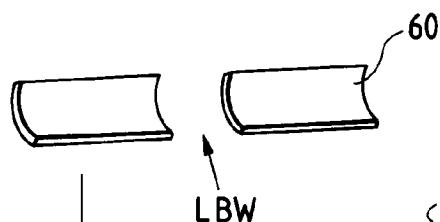


FIG. 30(b)

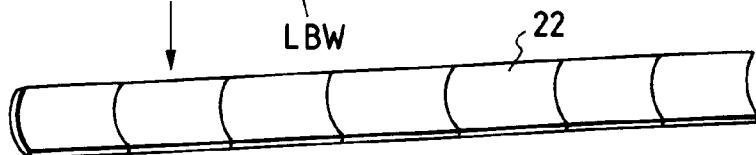


FIG. 30(c)

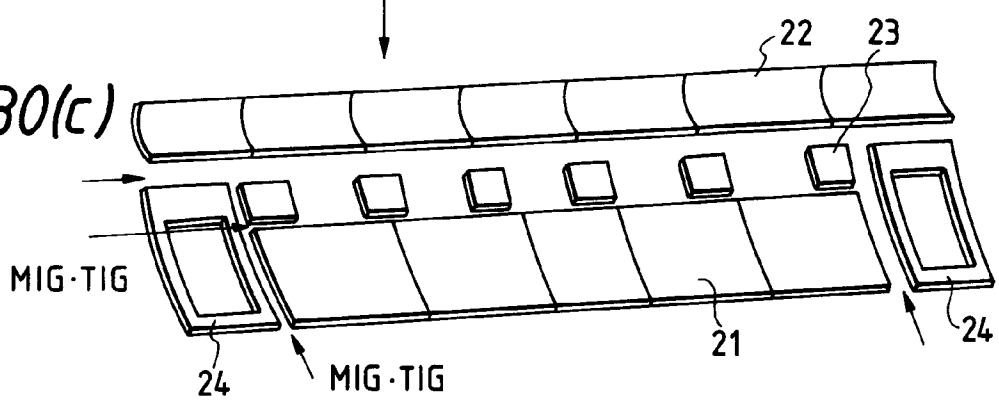
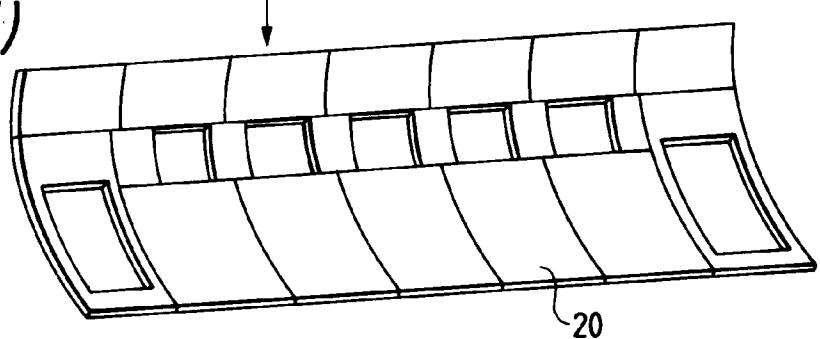
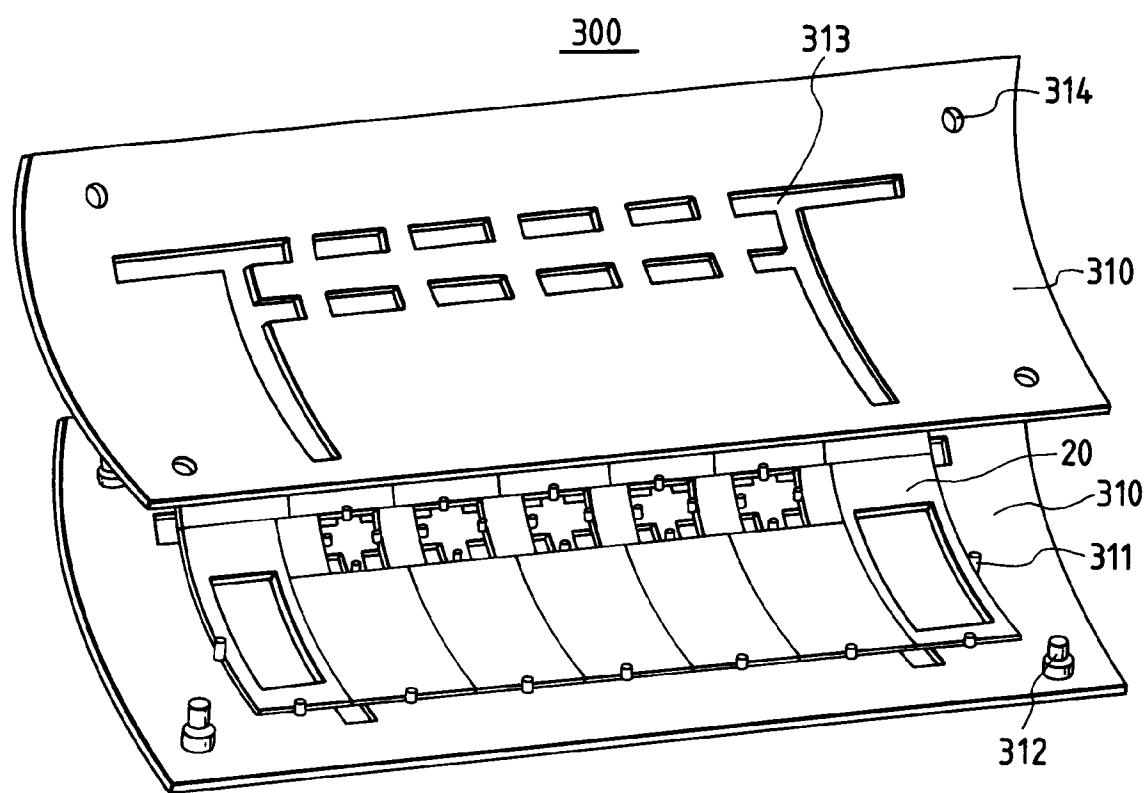


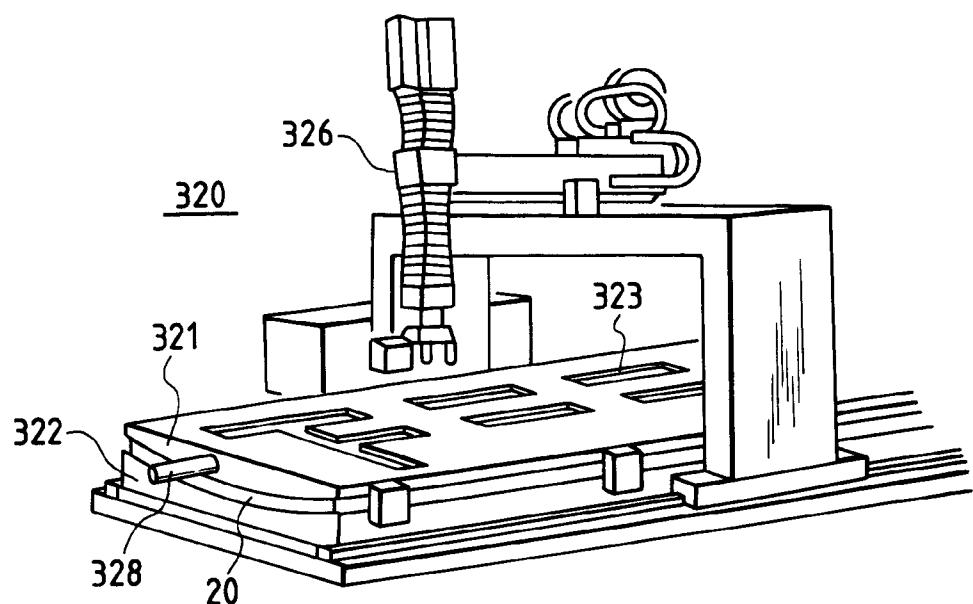
FIG. 30(d)



*FIG. 31*



*FIG. 32*



*FIG. 33*

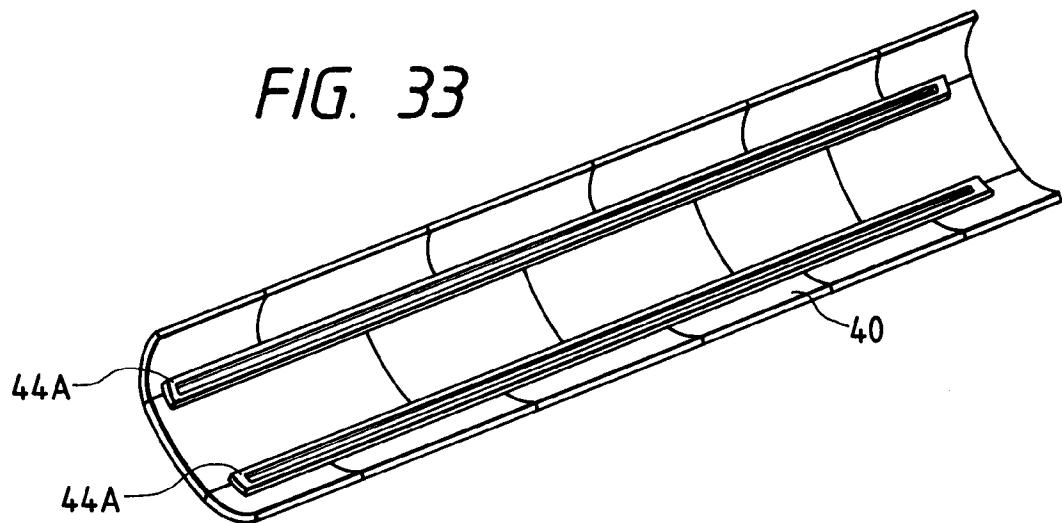


FIG. 34

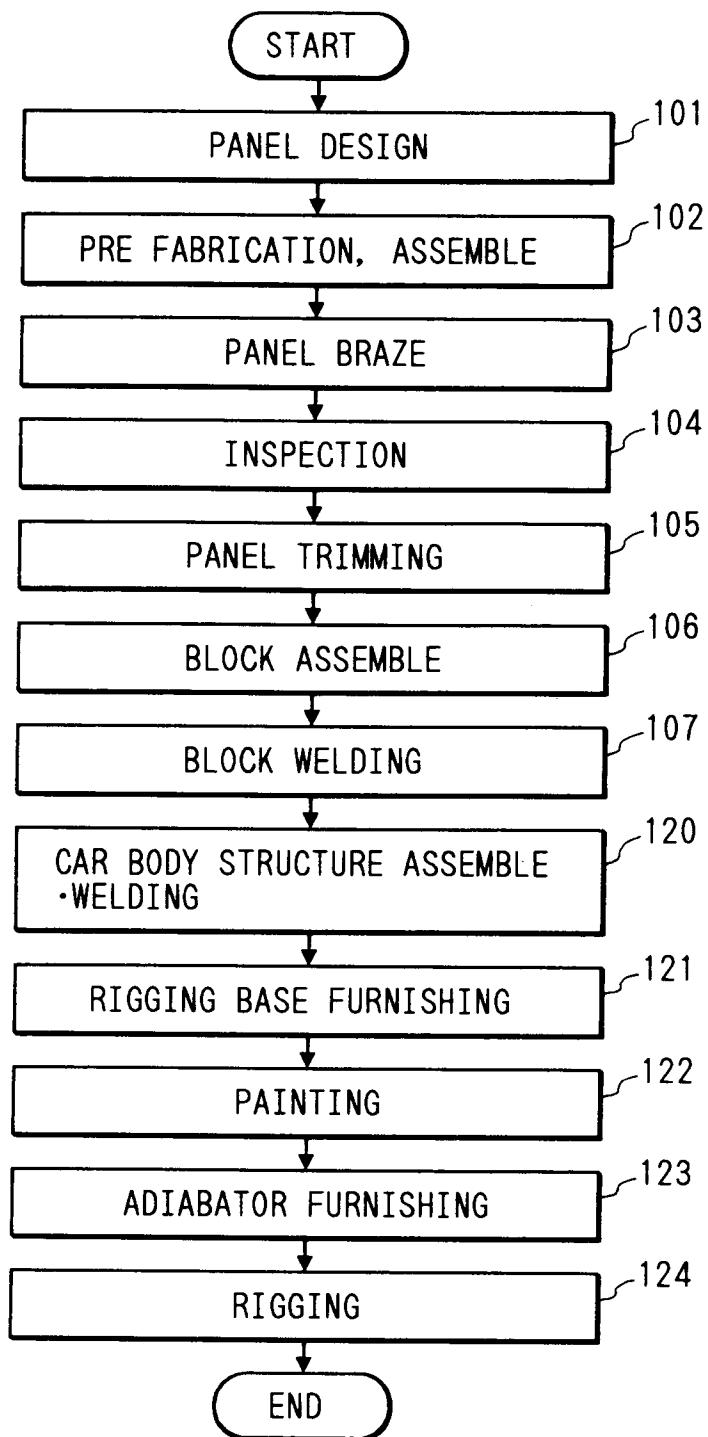


FIG. 35

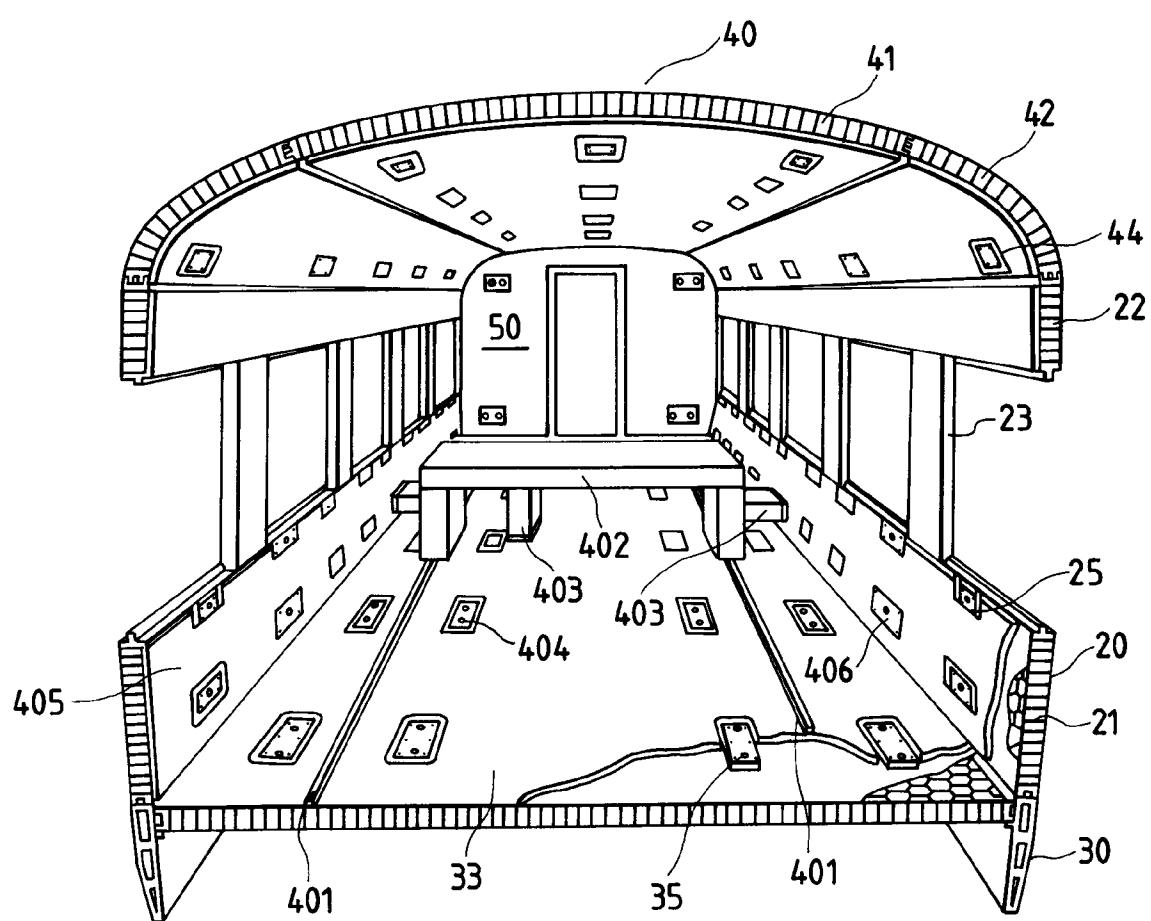
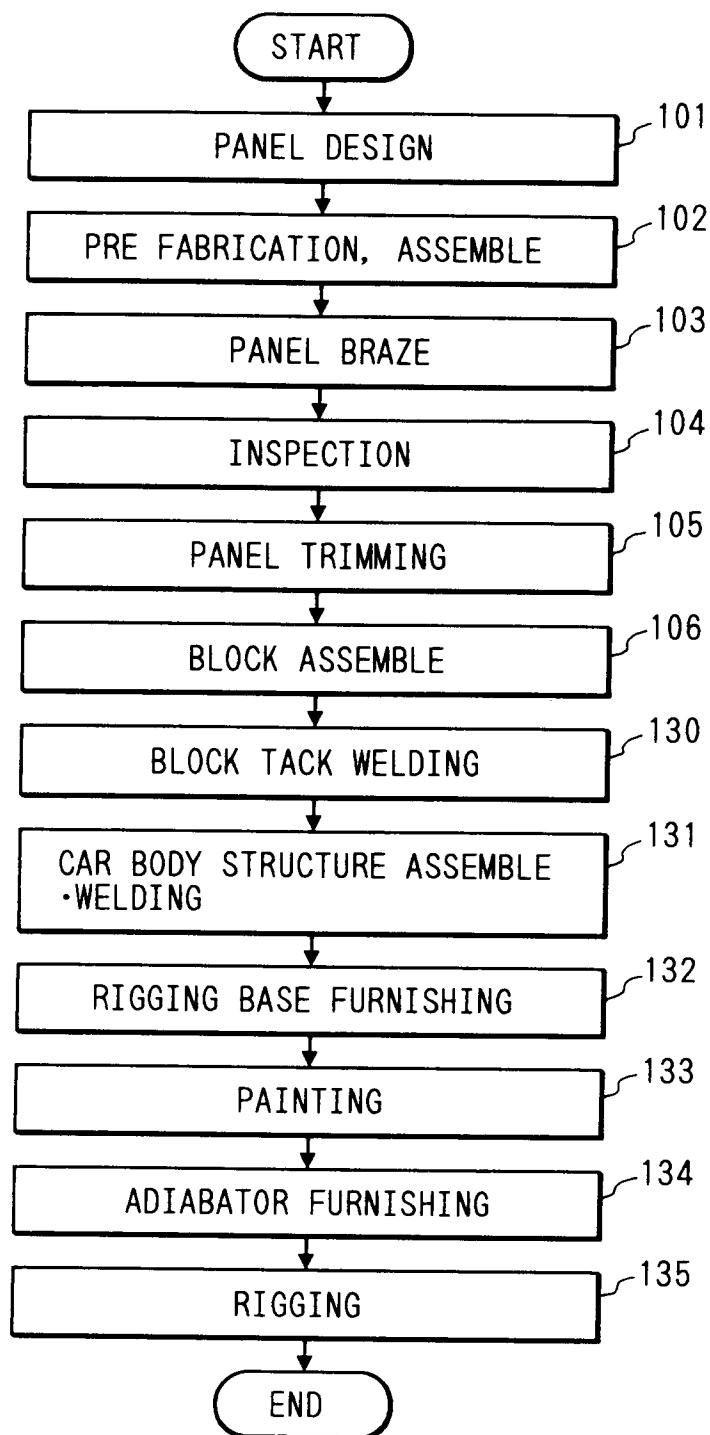
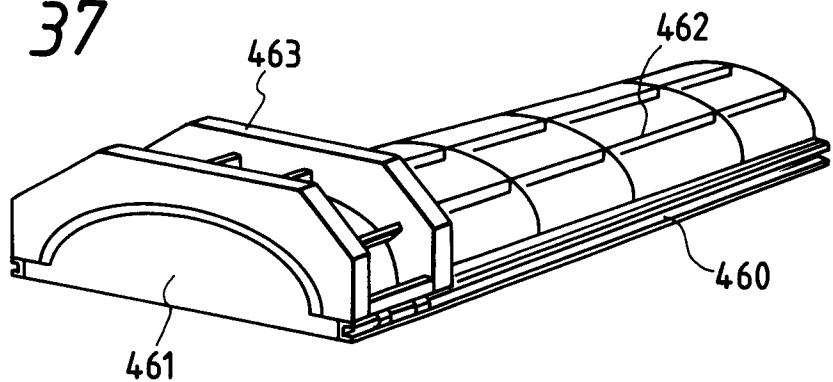


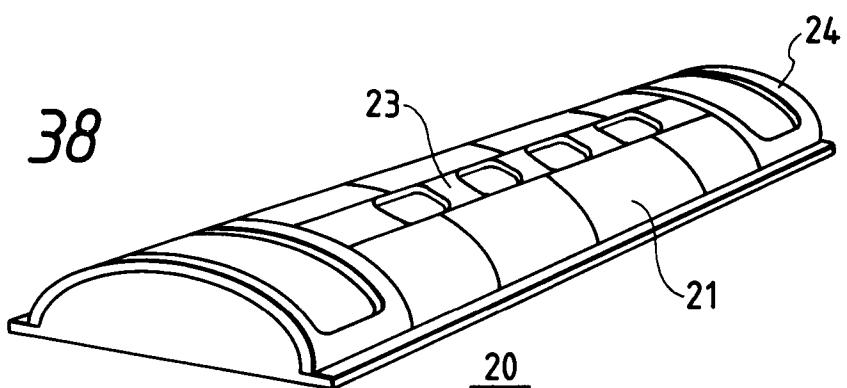
FIG. 36



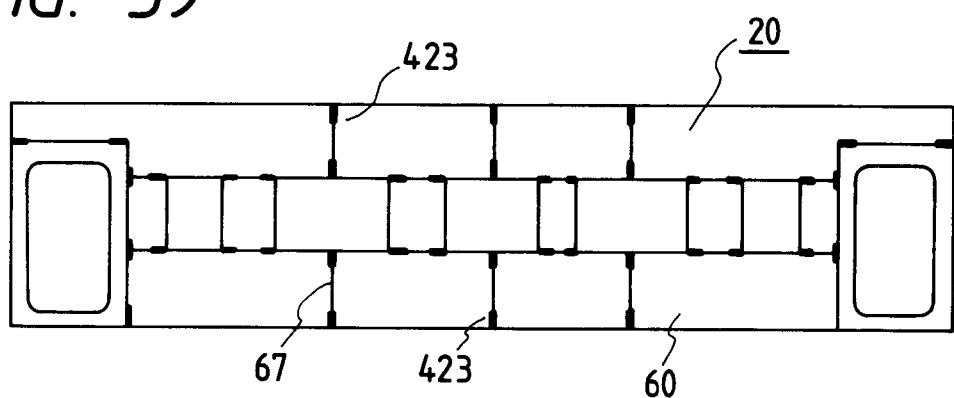
*FIG. 37*



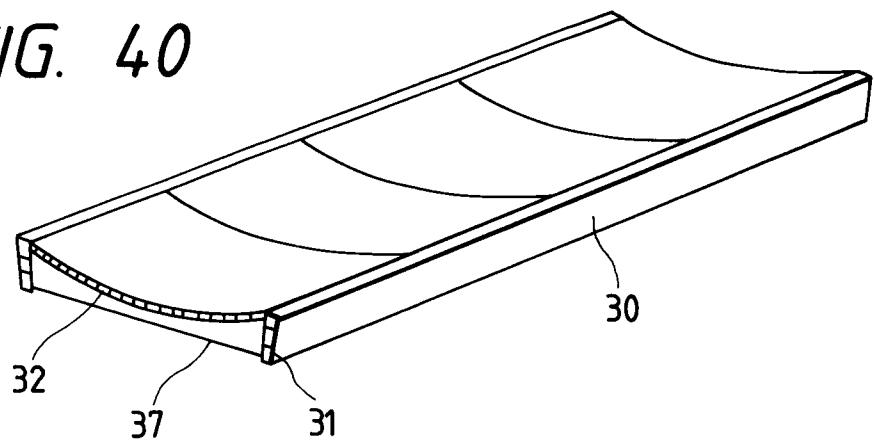
*FIG. 38*



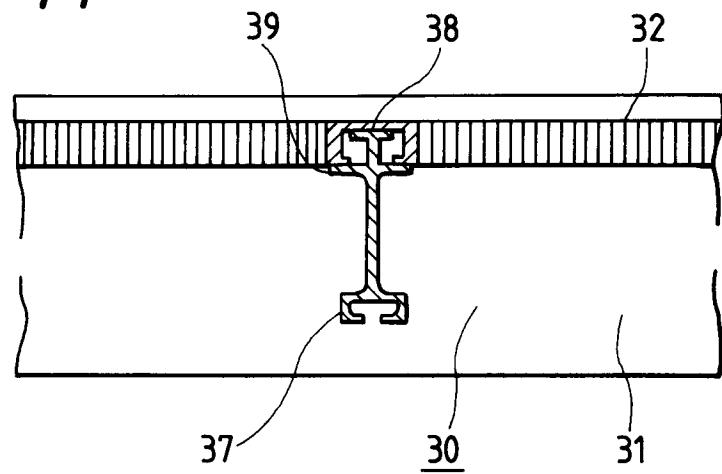
*FIG. 39*



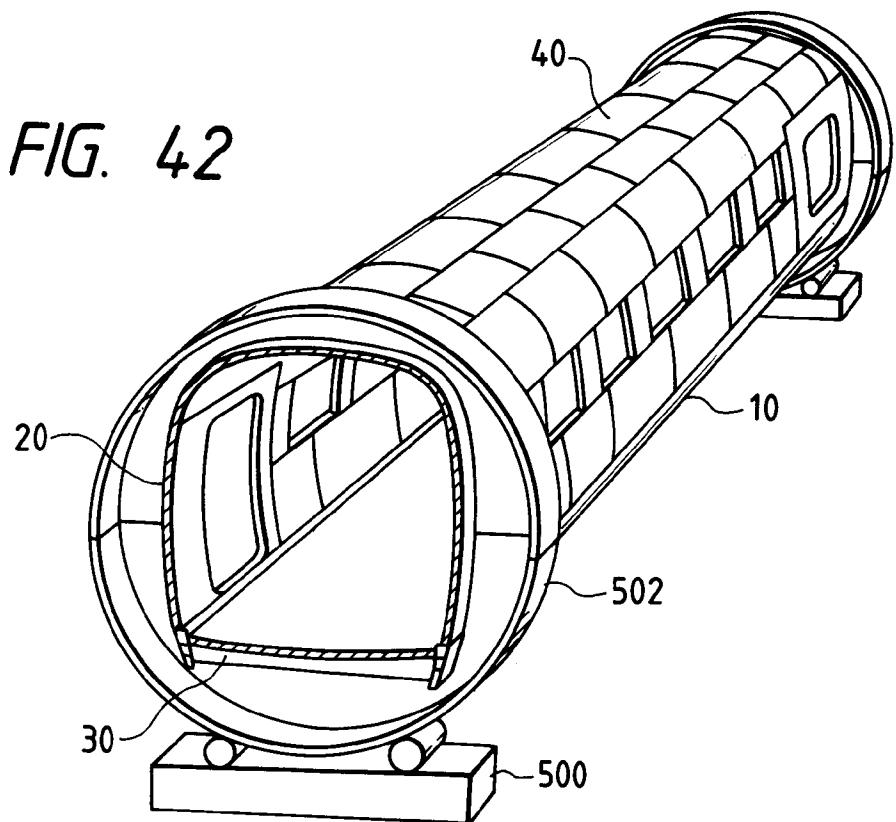
*FIG. 40*



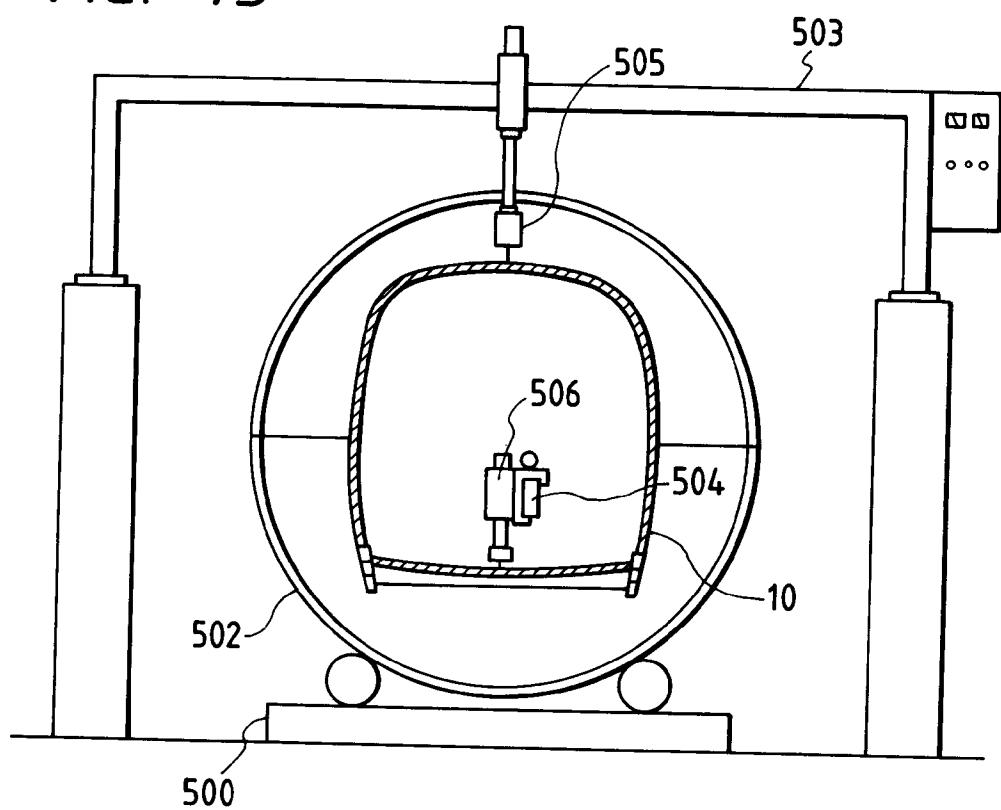
*FIG. 41*



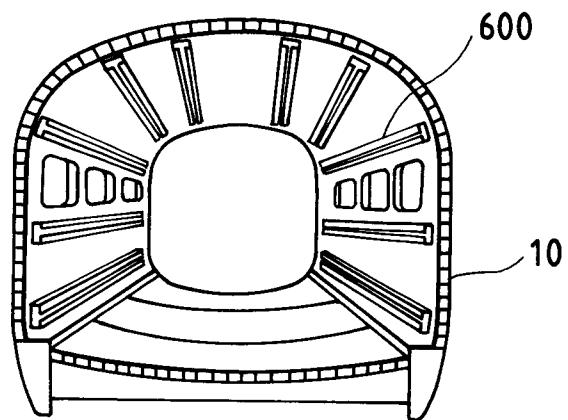
*FIG. 42*



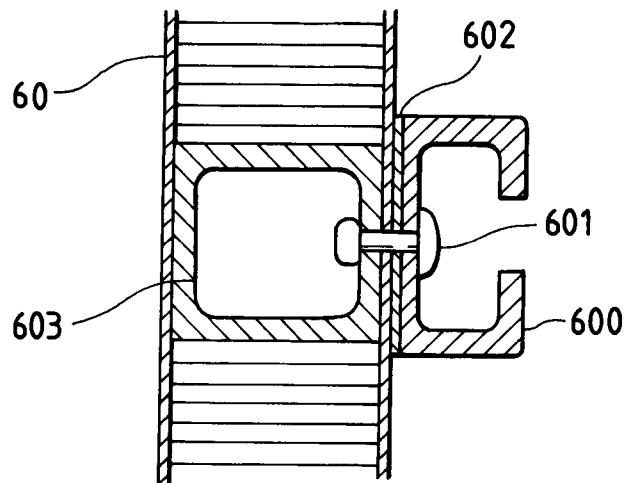
*FIG. 43*



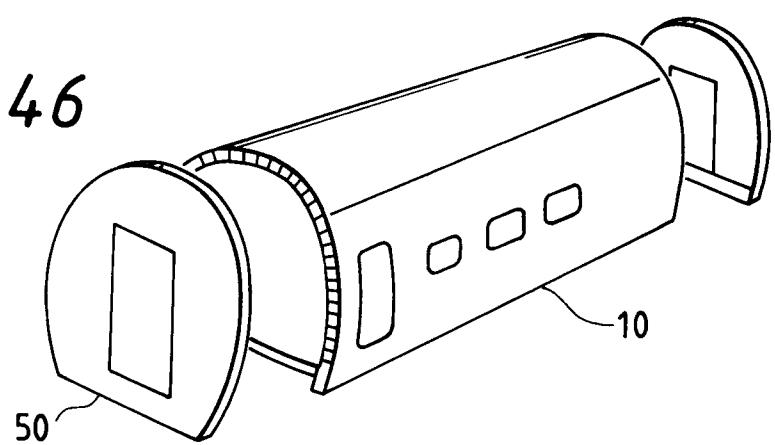
*FIG. 44*



*FIG. 45*



*FIG. 46*





European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number

EP 93 30 5573

DOCUMENTS CONSIDERED TO BE RELEVANT									
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)						
X	EP-A-0 474 510 (HITACHI)	1, 2, 4-7	B61D17/04						
A	* the whole document *	3, 8-25							
A	EP-A-0 260 200 (ALSTHOM)	1-8							
A	* column 4, line 19 - line 32; figure 1A *	1-8							
A	EP-A-0 354 436 (COMPAGNIE INDUSTRIELLE DE MATERIEL DE TRANSPORT C.I.M.T. LORRAINE)	1-8							
A	* column 2, line 33 - line 42; figure 6 *	1							
A	DE-A-2 031 546 (VEB WAGGONBAU GÖRLITZ)	1							
	* page 6, line 10 - line 27; figure 2 *	-----							
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)						
			B61D						
<p>The present search report has been drawn up for all claims</p> <table border="1"> <tr> <td>Place of search</td> <td>Date of completion of the search</td> <td>Examiner</td> </tr> <tr> <td>THE HAGUE</td> <td>04 OCTOBER 1993</td> <td>FOGLIA A.</td> </tr> </table>				Place of search	Date of completion of the search	Examiner	THE HAGUE	04 OCTOBER 1993	FOGLIA A.
Place of search	Date of completion of the search	Examiner							
THE HAGUE	04 OCTOBER 1993	FOGLIA A.							
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X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document									