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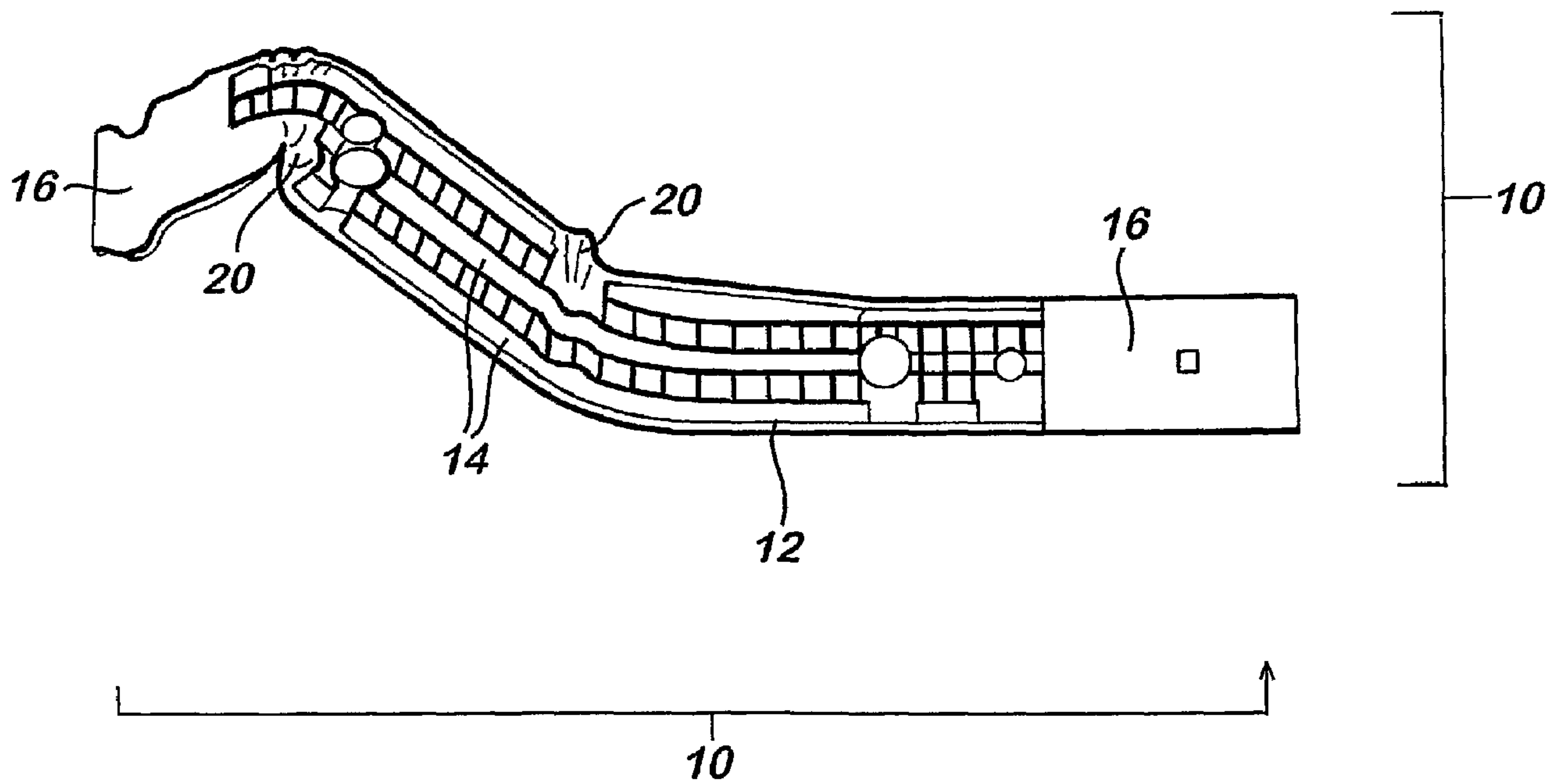

(57) Abrégé/Abstract:
An energy management system and device (10) for use in an automotive frame, rail, or other structural component of an automotive vehicle. The frame or rail (16) having a cavity or exposed surface capable of supporting at least one member. The member (12) having an interior portion and an exterior portion with the interior portion being defined by at least one trigger or step change (20) to the geometry of the inner portion to target and direct axial bending of the system. An expandable material (14), such as a polymer-based foamable material, is disposed along the exterior portion of a member prior to final assembly of the vehicle by the vehicle manufacturer. The system is activated as the vehicle undergoes the final vehicle assembly process and paint operation which activates and transforms the expandable material to expand, bond and structurally adhere the frame rail to mange, direct, and/or absorb energy in the event of an impact to the vehicle an applied load or an external force.

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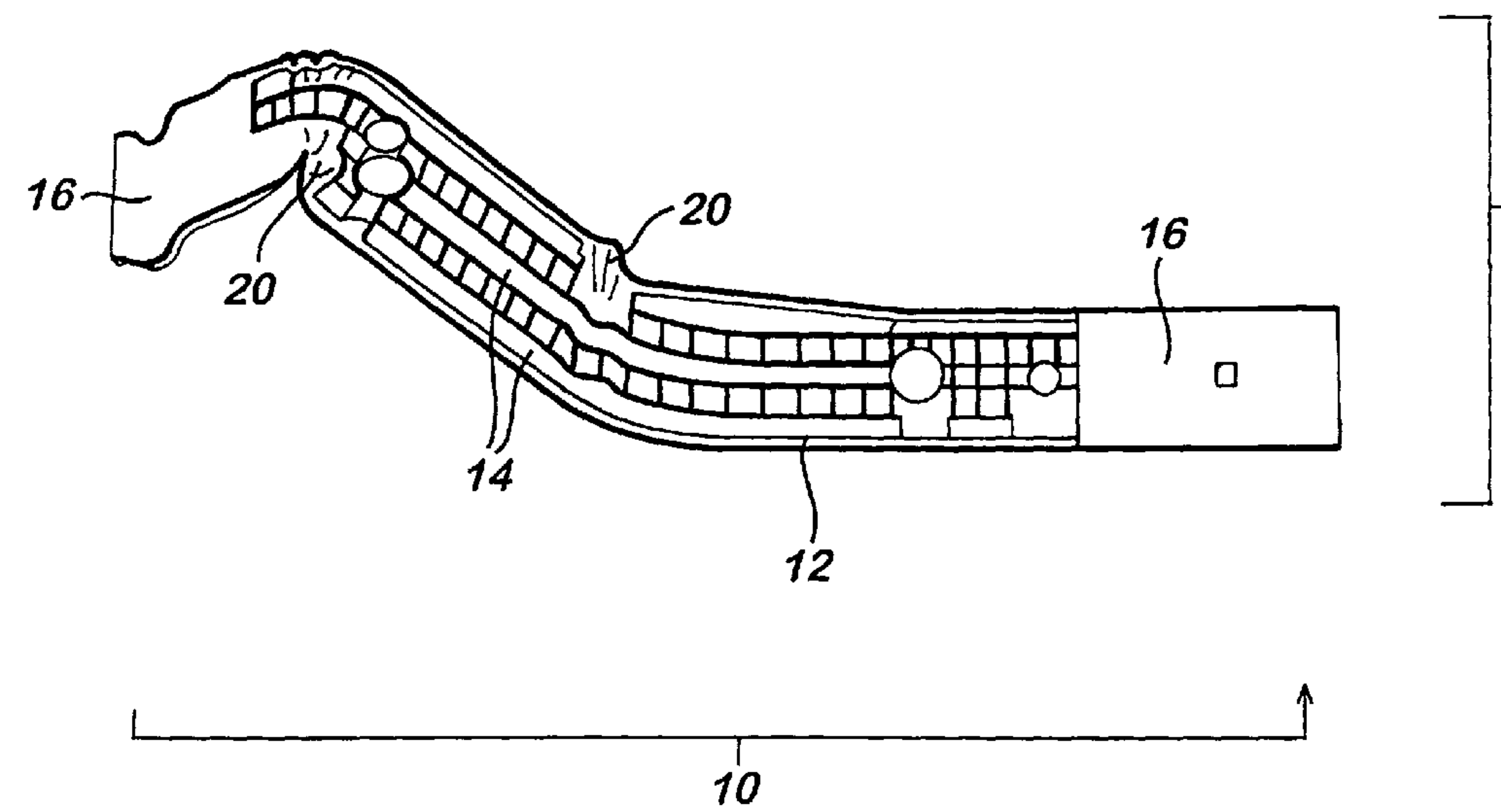
(54) Title: AUTOMOTIVE COMPOSITE STRUCTURE PART WITH SPECIFICATED IMPACT ENERGY ABSORPTION



(57) Abstract: An energy management system and device (10) for use in an automotive frame, rail, or other structural component of an automotive vehicle. The frame or rail (16) having a cavity or exposed surface capable of supporting at least one member. The member (12) having an interior portion and an exterior portion with the interior portion being defined by at least one trigger or step change (20) to the geometry of the inner portion to target and direct axial bending of the system. An expandable material (14), such as a polymer-based foamable material, is disposed along the exterior portion of a member prior to final assembly of the vehicle by the vehicle manufacturer. The system is activated as the vehicle undergoes the final vehicle assembly process and paint operation which activates and transforms the expandable material to expand, bond and structurally adhere the frame rail to mange, direct, and/or absorb energy in the event of an impact to the vehicle an applied load or an external force.

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AUTOMOTIVE COMPOSITE STRUCTURE PART WITH SPECIFICATED IMPACT ENERGY ABSORPTION

BACKGROUND OF THE INVENTION

For many years the transportation industry has been concerned with designing structural members that do not add significantly to the weight of a vehicle. At the same time, automotive applications require structural members capable of providing reinforcement to targeted portions of the vehicle and permit ingress and egress to the passenger compartment in the event of a collision. While the devices found in the prior art may be advantageous in some circumstances, the prior art methods typically require the use of additional manufacturing processes and steps in either a supplier facility, a pre-production manufacturer stamping facility, or the final vehicle assembly planet which often increases labor demand, cycle time, capital expense, and/or required maintenance clean-up. Accordingly, there is needed a simple, low cost structure or system for reinforcing vehicle rails, such as a front rail or frame member, which reinforces the vehicle and controls deformation in any crash, enhances structural integrity, and can be efficiently incorporated into the vehicle manufacturing process. In addition, there is also a need for a relatively low cost system or structure which provides reinforcement and inhibits distortion to the frame or front rail structures in a vehicle, and which can serve to manage energy in a frontal/offset impact to the vehicle by reinforcing the frame member or front rail to help target applied loads and help redirect or tune energy management of deformation.

Furthermore there has been an increase in the need for selective reinforcement of automotive structures in order to control deformation and/or to meet various government test standards. To that end, structural foams and carriers have been developed for the purpose of reinforcing specific locations in vehicles. The primary focus of these reinforcements is to add strength or stiffness to a structure.

As will be appreciated by those skilled in the art, the three factors of greatest general importance in the evaluation of reinforcement effectiveness are stiffness, weight and cost. With most prior art techniques, increasing stiffness results in a corresponding penalty of weight increase and/or cost increase. For example, while using thicker gauges of metal increases strength, it results in an unwanted increase in weight. Similarly the use of exotic high-strength alloys is effective to increase strength, but this adds considerably to the cost of the vehicle. Finally, it will be recognised that the cost of resins is also a concern and thus structural foams must be used sparingly.

Another concern in the use of structural foams is the problem associated with fully curing material that is very thick. That is, in some prior art applications the materials required to satisfactorily reinforce are so thick that it is difficult to achieve full cure. Therefore, it will be recognised that techniques for reinforcing hollow structures which do not cause a substantial weight and cost or curing problems have the potential to provide significant advantages.

It is therefore an object of the present invention to provide a structural reinforcement which utilises structural foam in a manner which conserves resin.

It is a further object of the invention to provide such a reinforcement which can be fully cured in a short time.

It is still a further object to provide a low-cost, lightweight structural reinforcement which provides significant strength and stiffness to the reinforced region.

It is still a further object to provide localised structural reinforcement in a manner that dissipates impact energy causing any, at least, initial deformation, at a selected location.

It is still a further object to provide a structural reinforcement which can be transported easily to the site of installation.

Yet a further object is to provide a structural member reinforced by a core bonded to the structural member by structural foam as previously described wherein channels are provided between the core and the structural member to allow the flow of moisture.

SUMMARY OF THE INVENTION

An object of the present invention is to redirect applied loads and manage impact energy by placing a reinforcement system in targeted areas of an automotive rail or frame member. The system generally employs at least one member or insert, which is attached or adhered to the chosen portion of the vehicle such as a frame or rail or any other portion of an automotive vehicle selected to inhibit deformation in the event of impact to the vehicle. At least one of the member or plurality of members are suitable for receiving an application of an expandable material coated over at least a portion of an exterior surface of the member. The expandable material disposed on the member is capable of activation and expansion when exposed to heat typically encountered in an automotive paint operation, such as e-coat and other paint cycles in a vehicle assembly plant. It is contemplated that the expandable material disclosed in the present invention, activates, expands, and adheres thereby structurally reinforcing and enhancing the strength and stiffness of the frame or front rail to redirect applied loads and energy. In one embodiment, the material is heat expandable and at least partially fills a cavity defined by the rail, frame, or selected portion of the vehicle by structurally adhering the rail and the frame depending upon the size and shape of the cavity, during the e-coat bake operation.

In another embodiment, the expandable material is a melt flowable material, which upon the application of heat will spread over a surface. The selected expandable material may also provide a variety of characteristics including structural reinforcement, stress-strain reduction, vibrational damping, noise reduction, or any combination thereof.

In a preferred embodiment the present invention therefore provides a structural reinforcing member to provide local reinforcement comprising a core to which is attached one or more pieces of structural foam the reinforcing member being provided with means for attachment to the member to be reinforced wherein the means for attachment is such that, prior to foaming, a channel is provided between the core, the structural foam and the internal surface of the member to be reinforced and that the foaming process enables the structural foam to expand and bond the core to the internal surface of the member to be reinforced.

In a preferred embodiment the structural foam is attached to the core as several strips or spots. In a further preferred embodiment the structural foam is provided in an amount that a rigid bond is formed between the core and the internal surface of the structure to be reinforced and air channels remain between the core and the internal surface for the flow of moisture which may be present due to condensation. We prefer that the structural foam cover from 20% to 45% of the surface of the core.

The present invention further serves to manage crash energy typically encountered during frontal or rear impact testing of an automotive vehicle. More specifically, the member or insert of the present invention may be positioned such that it directs the energy of impact and furthermore in a preferred embodiment, may contain at least one and preferably a plurality of triggers consisting of notches, holes, or any other form of step change or alteration to the geometry of the member such as alterations to the geometry of an inner portion or portions of the member. The position of the reinforcing member within the automobile frame may be such that the reinforcement of one region deflects the energy on impact to another second region such that deformation takes place at the second region. Similarly where internal triggers are provided they can effectively target and direct axial bending to selected portions of the system and allow management of crash energy typically encountered during front offset testing.

This is particularly useful in the reinforcement of vehicle rails which are typically curved so that greater reinforcement of one part of the curved structure can transfer energy to a part of the structure that is less reinforced so causing at least initial deformation at the least reinforced area. This can be used to control rear or frontal deformation on impact ensuring less deformation at, for instance, door sills. The variation in degree of reinforcement can be accomplished by varying the strength and thickness of the reinforcing material, such as the gauge and type of materials, such as steel, used, providing foam reinforcement around a core member in some parts and not in others, or by the deliberate provision of reinforcement in one region coupled with non reinforcement at another region. This has been found to be particularly useful when reinforcing the S shaped section of the front or rear rail of a vehicle where greater reinforcement in one, generally the lower bend of the S, can be used to ensure that controlled deformation takes place at the other bend of the S where there is less or in some instances no reinforcement.

The expandable material disposed over at least a portion of the member which can be extruded, molded, or "mini-application" bonded onto the member in either a pre-production setting, such as a stamping facility, or during the final assembly operation. The member, and the selected bonding or expandable material, is installed in the selected frame or rail prior to the e-coat or paint operation processing. Hence, the present invention provides flexibility in the manufacturing process since it can be utilized by either the frame or vehicle component (front rail) manufacturer/supplier or the final vehicle manufacturer with reduced labor, capital expense, maintenance requirements, and floor space demand. Once the expandable material bonds and cures to the selected rail or frame portion of the vehicle, distortion of the frame or rail, such as front or rear rail, may be inhibited or managed during a frontal/offset impact event or any other application of impact energy to the exterior of the vehicle. By absorbing and/or transferring certain impact energy and providing reinforcement to the frame or rail portion of the vehicle, the present invention provides a system for managing deformation to the vehicle in the event of a frontal, offset or rear impact.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and inventive aspects of the present invention will become more apparent upon reading the following detailed description, claims and drawings, of which the following is a brief description:

Figure 1 is an isometric view of a partially exploded automotive frame rail showing the energy management enhancement system in accordance with the teachings of the present invention.

Figure 2 is an exposed view of a portion of the present invention depicted in an automotive space frame architecture or body-in-white design showing the position of the at least one member with the expandable material in the uncured state attached to a rail of an automotive vehicle.

Figure 3 is a portion of the system illustrated in Figure 1, showing an alternative embodiment of the at least one member of the present invention with the expandable material in the uncured state prior to attachment to the frame or rail of an automotive vehicle and further showing an attachment means of the present invention in the form of a clip assembly.

Figure 4 is a portion of the system described in Figure 1, showing an alternative embodiment of the at least one member of the present invention with the expandable material in the uncured state prior to attachment to the frame or rail of an automotive vehicle.

Figure 5 is a portion of the system described in Figure 1, showing an alternative embodiment of the at least one member of the present invention with the expandable material in the uncured state prior to attachment to the frame or rail of an automotive vehicle.

Figure 6 is a portion of the system described in Figure 1, showing an alternative embodiment of the at least one member of the present invention with the expandable material in the uncured state prior to attachment to the frame or rail of an automotive vehicle.

Figure 7 is an exploded perspective view, showing an alternative embodiment of the system disposed within a closed form wherein the plurality of members are inter-locking and retained by a third member also incorporating a self-locking mechanism and a trigger of the present invention is depicted as a hole extending through the interior portion of the member.

Figure 8 shows the reinforcing member of Figure 7.

Figure 9 is an exploded perspective view of the automotive rail reinforcement system of the present invention prior to the impact of energy typically encountered in frontal impact testing of an automotive vehicle.

Figure 10 is an exploded perspective view of the automotive rail reinforcement system of the present invention after the impact of energy typically encountered in frontal impact testing of an automotive vehicle and the effect of axial bending to the system of the present invention.

The invention is further illustrated by reference to the accompanying Figures 11 and 12 in which Figure 11 shows a reinforcing member according to the present invention and Figure 12 shows the reinforcing member positioned inside the lower half of the front longitudinal section of an automobile.

Figure 13 is a schematic illustration of a vehicle front rail reinforced according to one embodiment of the present invention.

Figure 14 is a schematic illustration showing localised deformation of the system illustrated in Figure 13.

DETAILED DESCRIPTION OF THE INVENTION

The invention relates to methods and systems for managing energy and reducing impact deformation characteristics of automotive vehicles particularly to reduce deformation in the event of a frontal/offset impact event to the vehicle. More particularly, the present invention relates to a system for reinforcing, directing impact energy, and tuning the management of said impact energy to portions of an automotive vehicle, such as a frame or rail, which effectuates the reduction and inhibition of physical deformation or structural movement to the occupant compartment in the event of an impact to the exterior of the vehicle from another object. The system absorbs, dissipates and/or transfers the impact energy to reduce and inhibit the resulting deformation to the automotive vehicle. A reduction in impact deformation to the vehicle may serve to reduce occupant injury, allow continued passenger ingress and egress to the vehicle after an impact event, and reduce repair time and costs.

The automotive industry generally utilizes two primary modes for frontal impact testing of vehicles: full and offset. Full frontal impact testing is utilized for both United States federal compliance and assessment testing. While these tests are typically performed at different speeds (i.e. 30 mph for compliance and 35 mph for assessment), they both relate to impact of a barrier utilizing the full width of the front end structure of the tested vehicle. The primary goal of these tests is to assess occupant responses (femur loads, head injury criteria, chest deceleration, etc.) and validate the vehicle restraint systems (seatbelts, airbags, etc.). The offset impact test is performed at 40 mph with typically only 40% of the front end of the tested vehicle impacting the barrier. One of the primary goals of the offset impact test is to assess the structural integrity of the vehicle structure itself.

Design for frontal crash energy management is a multidisciplinary process. Crash energy management is typically performed through a combination of the vehicle structure and restraint systems. Many automotive manufacturers seek vehicle structures that can be designed to absorb energy. Structural efficiency, defined as the ability to optimize energy management as a vehicle structure deforms upon impact, depends upon the configuration of the design. For purposes of frontal impact testing, the severe crush loads created by the impact of energy managing structures tend to decelerate the occupant compartment. The ability of the energy managing structures to transfer manageable loads to an occupant compartment, coupled with the ability of the restraint system(s) to effectively dissipate such loads, may help dictate how well the occupant compartment responds to extreme loading, as well as how the compartment sustains minimal deformation and intrusion under certain conditions. For these reasons, the prior art focuses on at least two major considerations in the design of vehicle structures for crash energy management: (1) the absorption of kinetic energy of the vehicle, and (2) the crash resistance or strength needed to sustain the crush process inherent to the testing process and maintain passenger compartment integrity.

Traditional frontal energy management structures of automotive vehicles generally consist of three distinct crush zones. First, there will be a soft zone, typically the bumper area or other exterior fascia, followed by two stiffer zones. As defined and discussed herein, the two stiffer zones shall be referred to as primary and secondary. The primary crush zone is traditionally located immediately behind or adjacent to the soft crush zone, such as the bumper system of a vehicle, but in front of the powertrain compartment of a vehicle. The secondary crush zone is typically defined as the region bridging or tying the primary crush zone to the occupant compartment of the vehicle. For framed vehicles, such as trucks and larger automobiles, the secondary crush zone typically extends to the front body mount, as shown in Figure 1a. For smaller vehicles, the frame can be integrated into the body-in-white design. This type of design is known in the art as space-frame architecture as shown in Figure 2. In the case of space-frame vehicle structures, the secondary crush zone extends rearward bridging or tying the primary crush zone to the vehicle firewall and toe-board areas of the occupant compartment. Due to the proximity of the secondary crush zone to the occupant compartment of the vehicle, design requirements and energy management control techniques need to be utilized to minimize potential intrusion into the occupant compartment.

Accordingly, a main goal of the crush zone technology known in the art, is to manage the maximum amount of energy without compromising the integrity of the occupant compartment.

In one embodiment, the present invention addresses these needs through an energy management system and structure which provides a stable platform or system for the progressive collapsing of the primary crush zone. Namely, as shown at Figures 8 and 9, the present invention provides stability to the secondary crush zone which inhibits buckling or deformation while the primary crush zone is being crushed so that the overall structure is progressively collapsed in a predetermined and managed manner. As depicted in Figures 8 and 9, the present invention may comprise a plurality of triggers to effectuate axial collapse by creating opposing or dual bending modes. As illustrated in Figures 10 to 13, the invention may create local collapsing by reinforcing the lower part of the front rail but not the upper part. The system or structure of the present invention further serves to manage crash energy by attempting to control the deformation characteristics of either or both of the primary and secondary crush zones in such a way to minimize occupant compartment intrusion.

As is well known in the art, energy management structures deform (collapse) in a combination of axial and bending modes. Many existing energy management systems utilize the bending mode which results in lower energy management capabilities. For instance, since the bending mode is less efficient from an energy management standpoint, it typically requires much heavier designs or reinforcement configurations to manage the same amount and type of energy as an axially collapsing design. In most designs where weight is a criteria in vehicle design and performance, the axial mode is the preferred method of energy management. The bending mode, which involves the formation of localized hinge mechanisms and linkage type kinematics, is also a lower energy mode. For example, a structure will have a tendency to collapse in a bending mode due to the lower energy mode. Based upon this, even a structure specifically designed for axial collapse will default to the bending mode unless other structural features are provided in the design to enhance stability and resistance to off-angle loading.

Axial folding is also considered to be the most effective mechanism of energy absorption. It is also the most difficult to achieve due to potential instability and the lower energy default to the bending mode. Accordingly, in a preferred embodiment the energy management system or structure of the present invention seeks to maximize axial collapse of portions of an automotive vehicle, while minimizing bending, through the use of at least one, and preferably a plurality of triggers designed within either or both of the primary and secondary crush zones. The trigger or triggers of the present invention are defined as a change or discontinuity in the part geometry of either or both of the primary and secondary crush zones forming the structure of the present invention designed to create stress risers to cause localized bending. A plurality of triggers, or combinations of different geometrically designed triggers, are preferably utilized in the present invention to initiate folds in the structure inducing axial collapse in targeted portions of at least one of the three distinct crush zones of the frontal energy management structure shown in

Figures 1 and 2. When the triggers of the present invention are used they are sized and designed to ensure that axial collapse of the structure shown at Figures 1 and 2 can occur at sufficiently high loads in order to maximize the amount of energy managed by the structure or the amount of energy typically encountered in frontal impact testing.

Triggers currently found in the prior art have generally been modifications to the exterior portions of metal structural reinforcement members or inserts used to reinforce a chosen body portion or cavity of an automotive vehicle, such as a rail, pillar, cross-member, etc., as well as any other area immediately adjacent to the occupant compartment of an automotive vehicle. These prior art triggers typically consist of holes or part contours to the exterior portion of the structural reinforcement member or insert. However, in a preferred embodiment, through modifications to the internal portion of a structural reinforcement member or insert, the present invention provides at least one, and preferably a plurality of internal triggers for use in managing energy typically encountered by an automotive vehicle during frontal impact testing. When used, the internal triggers of the present invention effectively target and direct axial bending to selected portions of the structure and can comprise notches, holes, or any other form of step change or alteration to the geometry of an inner portion or portions of the structural reinforcement member or insert. For example, the structural reinforcement member or insert of the present invention, serves a plurality of purposes and provides a method for managing impact energy. First, the member or insert acts as a stabilizer which reinforces the secondary crush zone thereby allowing the primary crush zone to maximize axial crush. Once the primary crush zone has achieved maximum ability to absorb impact energy, the secondary crush zone of the structure of the present invention must be designed to absorb some additional energy as a means to reduce deformation to the occupant compartment of the vehicle. The structure of the present invention, utilizing a plurality of triggers such as notches or a cut-away section of the member or insert, serves to initiate bending of the structure based upon its existing geometry.

In one embodiment of the present invention, at least one member 12 or insert is placed within, attached, affixed, or adhered to at least a portion of a frame or rail of an automotive vehicle wherein at least one member 12 includes an expandable or foamable material 14 supported by, and disposed along portions of the member 12. The member 12 has an interior and an exterior portion and may be configured in any shape, design, or thickness corresponding to the dimensions of the selected frame or rail of the vehicle and may further comprise a plurality of triggers integrated within an interior portion of the member 12, which are designed and incorporated to specifically tune or target impact energy for either absorption or redirection to other portions of the vehicle. The expandable material 14 extends along at least a portion of the length of the exterior portion of the member 12, and may fill at least a portion of a cavity or space defined within the frame or rail.

The system 10 generally employs at least one member 12 adapted for stiffening the structure to be reinforced, such as a frame or front or rear rail found in automotive vehicles, and helping to better manage impact energy typically encountered in a frontal/offset impact to the vehicle. In use, the member or members are disposed within or mechanically attached, snap-fit, affixed, or adhered by adhesive onto at least a portion of the chosen frame or front or rear rail with the heat activated expandable material serving as a load transferring, energy absorbing medium disposed along at least one exterior surface of the member. In one embodiment, the member or members 12 are comprised of an injection molded polymeric carrier, an injection molded polymer, graphite, carbon, or a molded metal such as aluminum, magnesium, or titanium as well as an alloy derived from the materials or a foam derived from the materials or other metallic foam and is at least partially coated with an expandable material 14 on at least one of its sides, and in some instances on four or more sides.

In addition, it is contemplated that the member could comprise a nylon or other polymeric material as set forth in commonly owned U.S. Patent No. 6,103,341, as well as injection molded, extruded, die cast, or machined member comprising materials such as nylon, PBI, or PEI. The member or members may also be selected from materials consisting of extruded aluminum, aluminum foam, magnesium, magnesium alloys, molded magnesium alloys, titanium, titanium alloys, molded titanium alloys, polyurethanes, polyurethane composites, low density solid fillers, and formed SMC and BMC. Still further, the member adapted for stiffening the structure to be reinforced could comprise a stamped and formed cold-rolled steel, a stamped and formed high strength low alloy steel, a roll formed cold rolled steel, or a roll formed high strength low alloy steel.

A number of structural reinforcing foams are known in the art and may also be used to produce the expandable material of the present invention. A typical structural foam includes a polymeric base material, such as an epoxy resin or ethylene-based polymer which, when compounded with appropriate ingredients (typically a blowing agent, a curing agent, and perhaps a filler), typically expands and cures in a reliable and predictable manner upon the application of heat or another activation stimulus. The resulting material has a low density and sufficient stiffness to impart desired rigidity to a supported article. From a chemical standpoint for a thermally-activated material, the structural foam is usually initially processed as a thermoplastic material before curing. After curing, the structural foam typically becomes a thermoset material that is fixed and incapable of flowing.

The expandable material is generally a thermoset material, and preferably a heat-activated epoxy-based resin having foamable characteristics upon activation through the use of heat typically encountered in an e-coat or other automotive paint oven operation. As the expandable material is heated, it expands, cross-links, and structurally bonds to adjacent surfaces. An example of a preferred formulation is an epoxy-based material that may include polymer modificis such as an ethylene copolymer or terpolymer that is commercially available from L&L Products, Inc. of Romeo, Michigan, under the designations L-5204, L-5206, L-5207, L-5208, L-5209, L-5214, and L-5222. One advantage of the preferred structural foam materials over prior art materials is the preferred materials can be processed in several ways. Possible processing techniques for the preferred materials include injection molding, blow molding, thermoforming, direct deposition of pelletized materials, extrusion or extrusion with a mini-applicator extruder. This enables the creation of part designs that exceed the design flexibility capability of most prior art materials. In essence, any foamable material that imparts structural reinforcement characteristics may be used in conjunction with the present invention. The choice of the expandable material used will be dictated by performance requirements and economics of the specific application and requirements. Generally speaking, these automotive vehicle applications may utilize technology and processes such as those disclosed in U.S. Patent Nos. 4,922,596, 4,978,562, 5,124,186, and 5,884,960 and commonly owned, and PCT Application Nos. and WO02/14109 filed 08 August 2001, WO01/58741 filed 18 January 2001, WO01/68394 filed 01 March 2001, WO02/26550 filed 26 September 2001, WO02/26551 filed 26 September 2001, WO02/26549 filed 26 September 2001, and particularly, WO01/41950 filed 07 December 2000.

The structural foam may be applied to the surface of the core in any suitable manner and the preferred manner will depend upon the nature of the core material. For example if the core is of a plastic such as glass reinforced polyamide and produced by injection moulding then the structural foam may be applied by two shot injection moulding or over moulding.

Alternatively if the core is of metal produced, for example, by stamping, the structural foam may be applied by melt bonding or through use of an adhesive. In a further alternative irrespective of the nature of the core the structural foam may be mechanically attached to the core. Examples of means of mechanical attachment include pins or grooves as described in United States Patent 6,311,452. A preferred means of attachment is pushpins which may be pushed through holes formed in the core to receive the pins. In this preferred embodiment the need for special moulding and/or adhesion of the structural foam is avoided.

The invention provides a way to reduce cost, improve stiffness, and increase the possibility of achieving full cure of the structural foam all through the use of a composite construction. The surface of the reinforcement member may be keyed to permit uncured resin to be applied such that mechanical interlocking between the member and the applied uncured resin occurs. This interlocking permits the resin to be positioned on the reinforcement member without the necessity of heating the reinforcement member, using a secondary adhesive, heating the uncured structural foam, or using a pressure sensitive uncured structural foam. Similar benefits may be achieved if the structural foam is attached to the core with push pins. In addition to processing ease, the keyed surface push pins produce a structure that is strongly resistant to damage during shipping or handling in an assembly plant. In one aspect the primary uncured heat expandable material attached to the reinforcing member is not pressure sensitive. This enables packaging such that adjacent performed parts do not adhere to each other during shipping (i.e., the material does not behave as a pressure sensitive adhesive).

The construction of the present invention enables a number of different options for the preferred use of the invention the installation in a hollow structural part of a motor vehicle. One possibility is to attach end caps (not shown) to the reinforcing structure. These end caps may have an integral fastener or be spring loaded to enable installation and positioning in a vehicle. Another option is to form a part that has the near net shape of the structure that it is intended to reinforce such that when installed into a hollow cavity it becomes trapped and is thereby positioned. This would typically be a vehicle area that requires a reinforcement that is not linear and involves laying a part into a partial cavity that is later capped with another piece of sheet metal. An additional method of installation is to apply a pressure sensitive adhesive to some surface of the composite reinforcing structure. Depending on goals of the reinforcement, the pressure sensitive adhesive may or may not also have structural characteristics following cure.

In a preferred embodiment the structural reinforcing member of this invention is used to reinforce the front longitudinal section of an automobile sub frame. The front longitudinal section of an automobile form is the structural member which helps support the engine and which also carries fuel pipes to the engine. The front longitudinal section of an automobile is typically a bending box shaped tube and the reinforcement member is one that fits into the box shaped tube and reduces deformation of the section through bending upon end impact onto the section during a frontal crash of the vehicle. In this embodiment the reinforcing member preferably extends at least some way through the length of the longitudinal member most likely to undergo deformation upon frontal crash. In this instance the reinforcing member is preferably U or D shaped with strips of structural foam along the majority of the length of part of the walls of the member. Alternatively the structural foam may be spotted onto the reinforcing core.

Typically the front rail contains at least two bends, sometimes forming an S shape. It is often desired that the initial deformation of the front rail on impact occurs at the bend of the rail nearest the front of the vehicle. This can be accomplished by having a different degree of reinforcement in the two bends with a greater degree of reinforcement at the bend further from the front of the vehicle. This may be accomplished by the use of a single reinforcement member with different reinforcing ability at the two bends, this may be accomplished through the use of materials of different strengths and stiffnesses, the provision of less reinforcing foam or the absence of any reinforcement a the bend nearest the front of the vehicle. Alternatively it may be accomplished by reinforcing the first bend and not the second bend.

The resin whether it be as strips or spots are normally expandable. That is, upon the application of heat they will expand, typically by a foaming reaction, and preferably to at least 150% the volume of the unexpanded state, but more preferably twice. In a preferred embodiment, the resin used to form the resin strips or spots is an epoxy-based material.

Resin preferably forms about 5% to about 75% by weight and more preferably from about 15% to 65% by weight of the composition. Filler preferably forms from about 0% to about 70% by weight and more preferably from about 20% to about 50% by weight of the composition. Blowing agent preferably forms from about 0% to about 10% by weight and more preferably from about 0.2% to 5% by weight of the composition. Curing agent preferably forms from about 0% to about 10% by weight and more preferably from about 0.5% to 5% by weight of the composition. Accelerator preferably forms from about 0% to about 10% by weight and more preferably from about 0.3% to 5% by weight of the composition. One preferred formulation is set forth in Table 1 below.

Ingredient	% by weight
Epoxy Resin	15% to 65%
Ethylene Copolymer	0% to 20%
Blowing Agent	0.2% to 5%
Curing Agent	0.5% to 5%
Accelerator	0.3% to 5%
Filler	20% to 50%

As stated, the heat expandable material is most preferably a heat-activated, substantially epoxy-based material. However, other suitable materials may also be used. These include polyolefin materials, copolymers, and terpolymers with at least one monomer type an alpha-olefin, phenol/formaldehyde materials, phenoxy materials, polyurethane materials with a high glass transition and others. In general the desired characteristics of this heat expandable material will be high stiffness, high strength, high glass transition temperature, good corrosion resistance, ability to adhere to contaminated metallic and polymer surfaces, fast cure upon activation, good handling characteristics, low cure density, low cost, and long shelf life.

The core of the reinforcing member may be of any suitable material that has the strength/weight balance to provide the desired degree of reinforcement at minimum weight. The core may be of plastic material in which case it may be produced by injection moulding or extrusion. Where plastic is used glass filled polyamide (nylon) is a preferred material. Alternatively the core may be of a metal where steel or aluminium, are preferred. Where the core is of metal is may be formed by extrusion, die casting of stamping, extrusion and stamping being preferred.

In the preferred embodiment where the invention is used to provide structural reinforcement in automobiles the foamable material is such that it is activated to foam at a temperature above the temperatures employed in the anti-corrosion coating process (known as e coat). The foamable material is preferably activated at the temperature employed to bake the coating material which is typically 149°C or higher although there is a trend towards the use of lower temperatures. The core material, on the other hand, should be such that it is largely unaffected by the conditions, particularly temperature, to which the automobile is subjected during manufacture. In a preferred embodiment the invention is used to reinforce the format longitudinal section of an automobile. In this embodiment the reinforcing member should be such that pipes and wires and particularly fuel pipes can be pushed through the longitudinal section including the reinforcing member, prior to foaming. Accordingly it is preferred that the reinforcing member be channel shaped and be free from internal protuberances, such as ribs, which could inhibit the passage of such wires and pipes.

Additional foamable or expandable materials that could be utilized in the present invention include other materials which are suitable as bonding, energy absorbing, or acoustic media and which may be heat activated foams which generally activate and expand to fill a desired cavity or occupy a desired space or function when exposed to temperatures typically encountered in automotive e-coat curing ovens and other paint operation ovens. Though other heat-activated materials are possible, a preferred heat activated material is an expandable or flowable polymeric formulation, and preferably one that can activate to foam, flow, adhere, or otherwise change states when exposed to the heating operation of a typical automotive assembly painting operation. For example, without limitation, in one embodiment, the polymeric foamable material may comprise an ethylene copolymer or terpolymer that may possess an alpha-olefin. As a copolymer or terpolymer, the polymer is composed of two or three different monomers, i.e., small molecules with high chemical reactivity that are capable of linking up with similar molecules. Examples of particularly preferred polymers include ethylene vinyl acetate, EPDM, or a mixture thereof. Without limitation, other examples of preferred foamable formulations commercially available include polymer-based materials available from L&L Products, Inc. of Romeo, Michigan, under the designations as L-2018, L-2105, L-2100, L-7005, L-7101, L-7102, L-2411, L-2420, L-4141, etc. and may comprise either open or closed cell polymeric base material.

Further, it is contemplated that the expandable material of the present invention may comprise acoustical damping properties which, when activated through the application of heat, can also assist in the reduction of vibration and noise in the overall automotive frame, rail, and/or body of the vehicle. In this regard, the now reinforced and vibrationally damped frame or front rail will have increased stiffness which will reduce natural frequencies, that resonate through the automotive chassis thereby reducing transmission, blocking or absorbing noise through the use of the conjunctive acoustic product. By increasing the stiffness and rigidity of the frame or front rail, the amplitude and frequency of the overall noise/vibration that occurs from the operation of the vehicle and is transmitted through the vehicle can be reduced.

Still further, it will be appreciated that the carrier of the reinforcing member used in the present invention, as well as the material forming the geometric step-changes or triggers found in the carrier or member of the present invention, may comprise a reactive or non-reactive material, which yields high compressive strength and moduli and may either form the carrier or member itself or be capable of filling or coating the carrier or member. Generally speaking, a desired material, which exhibits such higher compressive strength and moduli may be selected from the group consisting of a syntactic foam, syntactic-type foam, or low density fillers, such as spheres, hollow spheres, ceramic spheres, including pelletized and extruded formulations thereof. In addition, the carrier or member may comprise a concrete foam, syntactic foam, aluminum foam, aluminum foam pellets, or other metallic foam, as well as alloys thereof.

Other materials suitable for use as the carrier or member in the present invention include polysulfone, aluminum and other metal foams, concrete, polyurethane, epoxy, nylon, phenolic resin, thermoplastic, PET, SMC, carbon fillers including materials sold under the trade name KEVLAR. In addition, it is also contemplated that the carrier or member of the present invention, or portions of the carrier or member of the present invention, may utilize or comprise a material sold under the trade name ISOTRUSS, as described and set forth in U.S. Patent No. 5,921,048 for a Three-Dimensional Iso-Truss Structure issued July 13, 1999, WO/0210535 for Iso-Truss Structure published by the World Intellectual Property Organization on February 7, 2002, and a pending U.S. provisional patent application before the U.S. Patent & Trademark Office entitled: Method And Apparatus For Fabricating Complex, Composite

Structures From Continuous Fibers, all of which have been commonly-assigned to Brigham Young University and are hereby incorporated by reference herein.

It is further contemplated that any number of the suitable materials disclosed and set forth herein for use as the carrier or member of the present invention may be formed, delivered, or placed into a targeted or selected portion of a transportation vehicle (i.e. land, rail, marine, or aerospace vehicle) through a variety of delivery mechanisms and systems that are known in the art. For example, the material may be poured, pumped, extruded, casted, or molded into any number of desired shapes or geometry depending upon the selected application or area to be reinforced. Further, the material may be reactive, non-reactive, expandable, or non-expandable and may be further utilized, incorporated, or filled into a hollow core, shell, or blow-molded carrier for later placement within a selected portion of the vehicle during any phase of the pre-manufacturing or manufacturing process.

Although the use of such impact absorbing materials and members are directed to an automotive frame, it is contemplated that the present invention can be utilized in other areas of an automotive vehicles that are used to ensure ingress and egress capability to the vehicle by both passengers as well as cargo, such as closures, fenders, roof systems, and body-in-white (BIW) applications which are well known in the art.

In addition to the use of an acoustically damping material along the member, the present invention could comprise the use of a combination of an acoustically damping material and a structurally reinforcing expandable material along different portions or zones of the member depending upon the requirements of the desired application. Use of acoustic expandable materials in conjunction with structural material may provide additional structural improvement but primarily would be incorporated to improve NVH characteristics.

While several materials for fabricating the impact absorbing or expandable material have been disclosed, the material can be formed of other materials provided that the material selected is heat-activated or otherwise activated by an ambient condition (e.g. conductive materials, welding applications, moisture, pressure, time or the like) and expands in a predictable and reliable manner under appropriate conditions for the selected application. One such material is the epoxy based resin disclosed in U.S. Patent 6,131,897, the teachings of which are incorporated herein by reference, filed with the United States Patent and Trademark Office on March 8, 1999 by the assignee of this application. Some other possible materials include, but are not limited to, polyolefin materials, copolymers and terpolymers with at least one monomer type an alpha-olefin, phenol/formaldehyde materials, phenoxy materials, polyurethane materials with high glass transition temperatures, and mixtures or composites that may include even metallic foams such as an aluminum foam composition. See also, U.S. Patent Nos. 5,766,719; 5,755,486; 5,575,526; 5,932,680. In general, the desired characteristics of the expandable material include high stiffness, high strength, high glass transition temperature (typically greater than 70 degrees Celsius), and good adhesion retention, particularly in the presence of corrosive or high humidity environments.

In applications where a heat activated, thermally expanding material is employed, an important consideration involved with the selection and formulation of the material comprising the structural foam is the temperature at which a material reaction or expansion, and possibly curing, will take place. In most applications, it is undesirable for the material to activate at room temperature or the ambient temperature in a production line environment. More typically, the structural foam becomes reactive at higher processing temperatures, such as those encountered in an automobile assembly plant, when the foam is processed along with the automobile components at elevated temperatures. While temperatures encountered in an automobile assembly body shop ovens may be in the range of 148.89 °C to 204.44 °C (300 °F to 400 °F), and paint shop oven temps are commonly about 93.33 °C (215 °F) or higher. If needed, various blowing agents activators can be incorporated into the composition to cause expansion at different temperatures outside the above ranges.

Generally, prior art expandable acoustic foams have a range of expansion ranging from approximately 100 to over 1000 percent. The level of expansion of the material may be increased to as high as 1500 percent or more, but is typically between 0% and 300%. In general, higher expansion will produce materials with lower strength and stiffness properties.

It is also contemplated that the foamable or expandable material could be delivered and placed into contact with the member through a variety of delivery systems which include, but are not limited to, a mechanical snap fit assembly, extrusion techniques commonly known in the art as well as a mini-applicator technique as in accordance with the teachings of commonly owned U.S. Patent No. 5,358,397 ("Apparatus For Extruding Flowable Materials"). In another embodiment, the expandable material is provided in an encapsulated or partially encapsulated form, which may comprise a pellet, which includes an expandable foamable material, encapsulated or partially encapsulated in an adhesive shell, which could then be attached to the member in a desired configuration. An example of one such system is disclosed in commonly owned, U.S. patent No. 6,422,575 ("Expandable Pre-Formed Plug"). In addition, preformed patterns may also be employed such as those made by extruding a sheet (having a flat or contoured surface) and then die cut in accordance with a predetermined configuration.

As stated, the reinforcement parts of the present invention are particularly useful for the purpose of structural reinforcement of a hollow vehicle cavity. When the vehicle is heated, the heat expandable material (structural foam) expands to contact the surface of the hollow cavity that it is intended to reinforce. It is not necessary that the space between the member and the inner surface of the hollow cavity or other surface being reinforced be fully filled with expanded heat expandable material for substantial reinforcement to occur. It is often preferred that the hollow cavity not be fully filled to allow channels for the flow of moisture derived from condensation.

A particular additional benefit of the present invention is that it permits large sections to be reinforced with full confidence that the structural foam material will fully cure. Because the material must be heated to cure, it is important that full cure occur to obtain optimum properties. If very large sections are filled with structural foam alone, then the difficulty of obtaining sufficient heat transfer through the material can be difficult. Use of a composite reinforcing member greatly increases the probability that full cure will occur. This is possible both because it permits the possibility of using less heat activated foam and the rigid reinforcement provides a heat transfer conduit to the inner surface of the heat-activated material. An additional benefit is that a reinforcement with less weight and lower cost can be provided for certain design types. A further additional benefit is that it permits the possibility of producing a part that is highly resistant to damage during transport owing to the support that the keyed reinforcing member provides to the heat expandable material.

Composite reinforcing structure may be constructed by dispensing heat activated expandable material onto the reinforcing member using an extruder, including an extruder that is articulated by a robot. This process relies on the extruder being positioned such that molten heat expandable material is dispensed into the reinforcement member. Upon cooling, the heat expandable material will stiffen and resist deformation while being transported. Upon sufficient reheating (a temperature necessarily higher than the temperature used to shape the heat expandable material), the heat expandable material will be activated such that it will expand and cure in the hollow vehicle cavity and thereby provide the desired reinforcement. A particularly preferred way of dispensing material onto a reinforcing member is to use a robot articulated extruder to press the molten heat expandable material into the sections. An additional method is to insert injection mould this material onto the reinforcing structure. Another way of constructing this kind of reinforcement is to separately extrude the heat expandable material into a shape that mimics the section of a keyed location and then slide or snap the heat expandable material into the keyed section of a keyed reinforcing member. A further additional way of making the composite construction is to press molten of deformable heat expandable material into the keyed section of the reinforcing member.

Alternatively the foamable material may be fastened to the reinforcing member by, for example, pins.

The present invention is graphically represented in Figure 1 and includes of an automotive frame or rail energy management enhancement system 10 formed in accordance with the teachings of the present invention. The system 10 imparts an increased capability redirect applied loads and impact energies to a preferred portion of an automotive vehicle and, thus, may be used in a variety of applications and areas of an automotive or other moving vehicle. For instance, the energy management enhancement system 10 may be used to inhibit deformation and distortion to targeted portions of an automotive vehicle, including the frame, rail, door, or other structural members used in vehicles, in the event of an impact to the exterior of the vehicle by an outside body. The system 10 serves to target, tune, or manage energy for absorption and/or transfer to other portions of the vehicle. As shown in Figures 1 and 2, the present invention comprises at least one member 12 having an interior portion and an exterior portion composed of an injection molded carrier provided with a suitable amount of an expandable material 14 molded on its sides which can be placed, geometrically constrained, attached, or adhered to at least a portion of an automotive structural rail or frame 16 through an attachment means 18 (not shown) used to place the member 12 within the rail or frame 16. The attachment means 18 may consist of a self-interlocking assembly, gravity/geometrically constrained placement, adhesive, a molded in metal fastener assembly such as a clip, push pins or snaps, integrated molded fasteners such as a clip, push pins, or snaps as well as a snap-fit assembly which is well known in the art. As shown in Figures 3 and 4, the attachment means 18 may consist of a clip. The automotive frame or rail 16 imparts structural integrity to the vehicle and may serve as the carrier of certain body panels of the automotive vehicle which may be viewable, and capable of receiving impact energy, from the exterior of the vehicle. By attaching the member 12 having the expandable material 14 to the frame or rail 16, additional structural reinforcement is imparted to the targeted portion of the frame or rail 16 where the member 12 is attached.

The present invention serves to place this targeted reinforcement in selected areas of a frame or rail 16 and provides the capability to absorb, direct, or manage impact energy typically encountered during an impact event from an external source or body, such as that typically encountered during a frontal/offset impact or collision. It is contemplated that the member 12 and the expandable material 14, after expansion, create a composite structure whereby the overall system 10 strength and stiffness are greater than the sum of the individual components. In the event of an impact to the exterior of the vehicle, the impact energy is managed by either energy absorption/dissipation or targeted direction of the energy to specific areas of the vehicle.

The energy management features of the present invention may also utilize targeted placement of a plurality of triggers 20 incorporated within the interior portion of the member 12 or outside of the member 12 along the frame or rail 16, as shown in Figure 1. The triggers 20 are targeted or otherwise tuned for placement along either or both of selected areas of the frame or rail 16 and/or the plurality of members 12 to direct the placement of energy to targeted areas of the vehicle during an impact and initiate folds in the structure inducing axial collapse. As shown in Figures 2-6, the system 10 of the present invention can be integrated within vehicle cavities utilizing a plurality of members 12 in a variety of predetermined shapes, forms, and thicknesses corresponding to the size, shape, and form of the cavity of the specific automotive application selected for energy management without compromising the visual appearance, functionality, or aesthetic quality of the exterior portions and paintable surfaces of the vehicle. The trigger or plurality of triggers 20 are incorporated and integrated within an interior portion of the member 12 and designed as notches, holes, or any other step change in the geometry of the interior portion of the member. In some cases the triggers 20 may simply consist of a segment of the interior portion of the member that is specifically not coated with an expandable material as shown in Figure 2. In other applications, a plurality of triggers 20 may be utilized such as a notch as shown in Figure 1 or a cut-out hole of a portion of the member 12, as also shown in Figure 1. As graphically shown in Figures 3 and 4, a trigger 20 of the present invention may also comprise a hole or other step change in the geometry of member 12 comprising a varying wall thickness of the trigger 20.

The expandable material 14 includes an impact energy absorbing, structural reinforcing material, which results in either a rigid or semi-rigid attachment to at least one member 12 having at least one trigger 20. It is contemplated that the material 14 could be applied to at least one member 12 in a variety of patterns, shapes, and thicknesses to accommodate the particular size, shape, and dimensions of the cavity to be filled by the expandable material after activation. The placement of the member 12 along the selected frame or rail 16 as well as placement of the material 14 along the surfaces of the member 12 itself, and particularly either or both of the interior portion and exterior portion of the member 12, can be applied in a variety of patterns and thicknesses to target or tune energy management enhancement or deformation reduction in selected areas of the vehicle where a reduction or redirection of impact energy would serve to limit damage to the vehicle passenger compartment and permit ingress and egress to the vehicle for passengers. The material 14 is activated to accomplish expansion through the application of heat typically encountered in an automotive e-coat oven or other heating operation in the space defined between the member 12, now attached to the frame or rail 16 in either or pre-production facility or the final vehicle assembly operation. The resulting composite structure includes a wall structure formed by the rail or frame 16 joined to the at least one member 12 with the aid of the material 14. It has been found that structural attachment through the use of the member 12 and the material 14 is best achieved when the material 14 is selected from materials such as those offered under product designations L-5204, L-5205, L-5206, L-5207, L-5208, L-5209, L-5214, and L-5222 sold by L&L Products, Inc. of Romeo, Michigan. For semi-structural attachment of the frame or rail 16 through the use of the member 12 and the material 14, best results were achieved when the material 14 is selected from materials such as those offered under product designations L-4100, L-4200, L-4000, L-2100, L-1066, L-2106, and L-2108 sold by L&L Products, Inc. of Romeo, Michigan.

The properties of the expandable material include structural foam characteristics, which are preferably heat-activated to expand and cure upon heating, typically accomplished by gas release foaming coupled with a cross-linking chemical reaction. The material 14 is generally applied to the member 12 in a solid or semi-solid state. The material 14 may be applied to the outer surface of the member 12 in a fluid state using commonly known manufacturing techniques, wherein the material 14 is heated to a temperature that permits the foamable material to flow slightly to aid in substrate wetting. Upon curing the material 14 hardens and adheres to the outer surface of the member 12. Alternatively, the material 14 may be applied to the member 12 as precast pellets, which are heated slightly to permit the pellets to bond to the outer surface of the member 12. At this stage, the material 14 is heated just enough to flow slightly, but not enough to cause the material 14 to thermally expand. Additionally, the material 14 may also be applied by heat bonding/thermoforming or by co-extrusion. Note that other stimuli activated materials capable of bonding can be used, such as, without limitation, an encapsulated mixture of materials that, when activated by temperature, pressure, chemically, or other by other ambient conditions, will become chemically active. To this end, one aspect of the present invention is to facilitate a streamlined manufacturing process whereby the material 14 can be placed along the member 12 in a desired configuration wherein the member 12 is then attached by the attachment means 18 or geometrically constrained to the frame or rail 16 without attachment means at a point before final assembly of the vehicle. As shown in Figures 3 and 4, the attachment means 18 of the present invention may comprise a clip which is well known in the art. In this regard, the system 10 of the present invention provides at least one, but possibly a plurality of, members 12 which are placed along and attached to the selected frame or rail 16 such that adequate clearance remains for existing and necessary hardware that may be located inside a traditional automotive body cavity to provide window movement, door trim, etc. As shown in Figure 7, the system 10 may also be used in hydroform applications wherein a plurality of interlocking members 12 are shaped for placement within a closed and then restrained by an attachment means 18 consisting of a self-interlocking retention piece. In the particular hydroform embodiment shown in Figure 7, the trigger 20 of the present invention consists of a hole or deformation extending through the interior portion of the interlocking members 12 and may further comprise step change in the geometry of the wall thickness of the interlocking members 12.

The energy management enhancement system 10 disclosed in the present invention may be used in a variety of applications where reinforcement is desired to transfer, direct, and/or absorb impact energy that may be applied to structural members of an automotive vehicle through an external source or collision to the vehicle. As shown in Figure 9 in a pre-impact state, the system 10 may be used to control and direct energy management in frontal impact testing of automotive vehicles through targeted bending, buckling, and collapsing of the system in a progressive manner while still providing some reinforcement stability in the bending process resulting in the system shown in a post-impact state in Figure 10. Namely, as shown in Figures 9 and 10, axial collapse may be created by opposing or dual bending modes through the use of a plurality of triggers 20. The system 10 has particular application in automotive frame or rail applications where the overall weight of the structure being reinforced is a critical factor and there is a need for reinforcement and/or inhibition of deformation and distortion resulting from an impact to the vehicle. For instance, the system 10 may be used to reduce or inhibit structural distortion of portions of automotive vehicles, aircraft, marine vehicles, building structures or other similar objects that may be subject to an impact or other applied structural force through either natural or man-made means. In the embodiment disclosed, the system 10 is used as part of an automobile frame or rail assembly to inhibit distortion of selected areas of an automobile through the transfer and/or absorption of applied energy, and may also be utilized in conjunction with rockers, cross-members, chassis engine cradles, roof systems, roof bows, lift gates, roof headers, roof rails, fender assemblies, pillar assemblies, radiator/rad supports, bumpers, body panels such as hoods, trunks, hatches, cargo doors, front end structures, and door impact bars in automotive vehicles as well as other portions of an automotive vehicle which may be adjacent to the exterior of the vehicle. The skilled artisan will appreciate that the system may be employed in combination with or as a component of a conventional sound blocking baffle, or a vehicle structural reinforcement system, such as is disclosed in commonly owned U.S. patent Nos. 6,482,486 or 6,469,834.

Figure 11 shows the U shaped metal reinforcing core 21 to which strips of structural foam 22, 23 and 24 are attached to the exterior walls by the push pins 25. Also provided are push pins 26 which can be used to attach the reinforcing member to the internal surface of the channel to be reinforced.

Figure 12 shows the part illustrated in Figure 11 located in the lower piece of the front longitudinal section 27. When the upper piece of the front longitudinal section is provided and welded to the section 27, the pin 26 will attach the reinforcement to the upper piece whilst providing a space between the metal 22 and the structural foam 24 and the inner surface of the upper piece to allow effective flow of the anticorrosion e coat fluid. After application of the e coat fluid the section is baked to cure the coating and the structural foam expands during the coating to bond the core to the inner surfaces of the front longitudinal section.

Figure 13 is a schematic illustration of the front rail longitudinal section shown in Figure 12 showing the rail 27 with two curved sections 28 and 29. The first curved section being the curved section furthest away from the front of the vehicle. In this embodiment no reinforcement is provided in the second curved section of the front rail, the second curved section being the curved section nearer to the front of the vehicle. The reinforcing core member 21 is shown reinforcing the curved section 28 whereas the curved section 29 has no reinforcement. Figure 14 shows how, on impact, the reinforcement at section 28 directs the energy so that deformation occurs at the curved point 29 rather than also at point 28.

The preferred embodiment of the present invention has been disclosed. A person of ordinary skill in the art would realize however, that certain modifications would come within the teachings of this invention. Therefore, the following Claims should be studied to determine the true scope and content of the invention.

CLAIMS

1. A structural reinforcing system (10) for reducing and inhibiting distortion characteristics of an automotive vehicle in the event of impact from an external force, comprising:
   i. at least one reinforcing member (12); (21) having an interior and an exterior portion adapted for placement in a cavity disposed in an automotive frame assembly; and containing at least one weak point (20) comprising a change or discontinuity in the geometry of the member along said interior portion of said member and
   ii. an expandable structural material (14), (22), (23) (24) disposed over at least a portion of said exterior portion of said member in an amount that upon expansion the expanded material provides a rigid bond between the member and the internal surface of the automotive frame.

2. A structural reinforcing system according to Claim 1 in which the expandable material is disposed over a portion of the member so that air channels remain between the surface and the internal surface after expansion.

3. The system as claimed in Claim 1 or Claim 2, wherein said member comprises a plurality of weak points (20).

4. The system as claimed in any one claims 1 to 3, wherein said member is adapted for reinforcing portions of an automotive vehicle selected from the group consisting of a rail member, a frame member, a door assembly, a rocker, and a frame cross member.

5. The system as claimed in any one of Claims 1 to 3, wherein said member is adapted for reinforcing portions of an automotive vehicle selected from the group consisting of a vehicle window frame, a vehicle deck lid, a lift gate, a vehicle pillar assembly, and a vehicle hatch.

6. The system as claimed in any one of Claims 1 to 3, wherein said member is adapted for reinforcing portions of an automotive vehicle selected from the group consisting of a vehicle roof system, a roof bow, a roof rail, and a roof header.

7. The system as claimed in any one of Claims 1 to 3, wherein said member is adapted for reducing impact energy deformation of portions of an automotive vehicle selected from the group consisting of a fender assembly, a bumper, and a front end structure.

8. The system as claimed in any of Claims 1 to 7, wherein said reinforcing member is comprised of a material selected from the group consisting of extruded aluminum, an aluminum foam, a magnesium alloy, a molded magnesium alloy, a magnesium foam, a titanium alloy, a molded titanium alloy, and a titanium foam.

9. The system as claimed in any one of Claims 1 to 8, wherein said reinforcing member is comprised of a material selected from the group consisting of a stamped and formed cold rolled steel, a stamped and formed high strength low alloy steel, a roll formed cold rolled steel, and a roll formed high strength low alloy steel.

10. The system as claimed in any one of Claims 1 to 9, wherein said reinforcing member comprises a plurality of members (12) adapted for placement within a defined member of a cavity disposed in an automotive frame wherein a second member (12) is contiguous with a first member (12), and second member having a surface carrying an expandable material (14), which upon expansion helps absorb and distribute impact energy over said surface in response to said load.

11. The system as claimed in Claim 10, wherein said member further comprises a third member contiguous with one of said first and second portions, said third portion containing a plurality of weak points.

12. A system as claimed in one of claims 1 to 11, wherein said expandable material is a polymeric material having foamable characteristics.

13. A system as claimed in Claim 12, wherein said polymeric material is an epoxy-based polymeric material having foamable characteristics.

14. A system as claimed in any one of claims 1 to 13, wherein said expandable material is a heat activated expandable polymer material.

15. A system as claimed in any one of claims 1 to 14, wherein said expandable material is an expandable plastic material that is generally free of tack to the touch.

16. A system as claimed in any one of claims 1 to 15, wherein said expandable material is an expandable plastic material that can be activated at a temperature encountered in an automotive vehicle paint operation.

17. A system according to any one of claims 1 to 16, wherein the expandable material is attached to the member as several strips or spots.

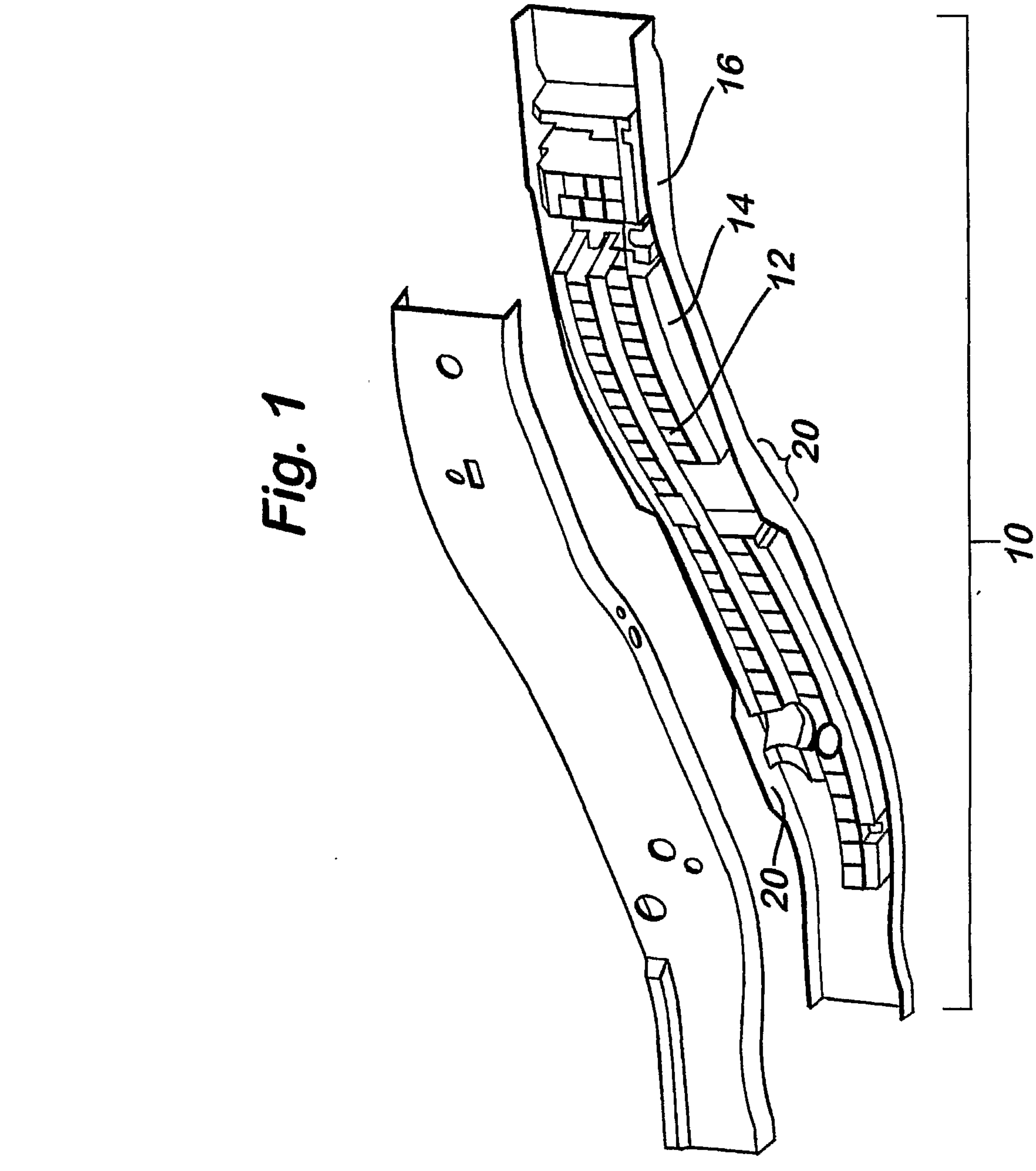


Fig. 1

Fig. 2

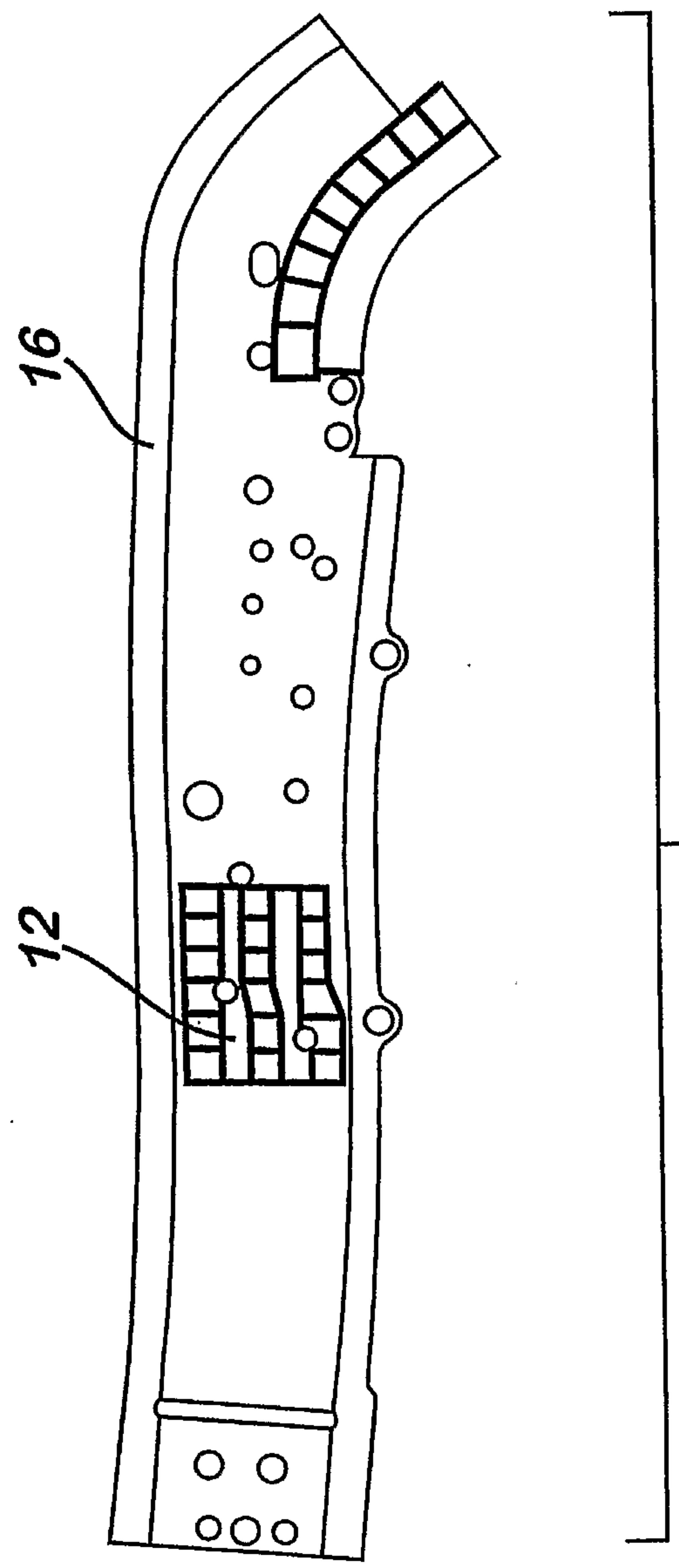


Fig. 3

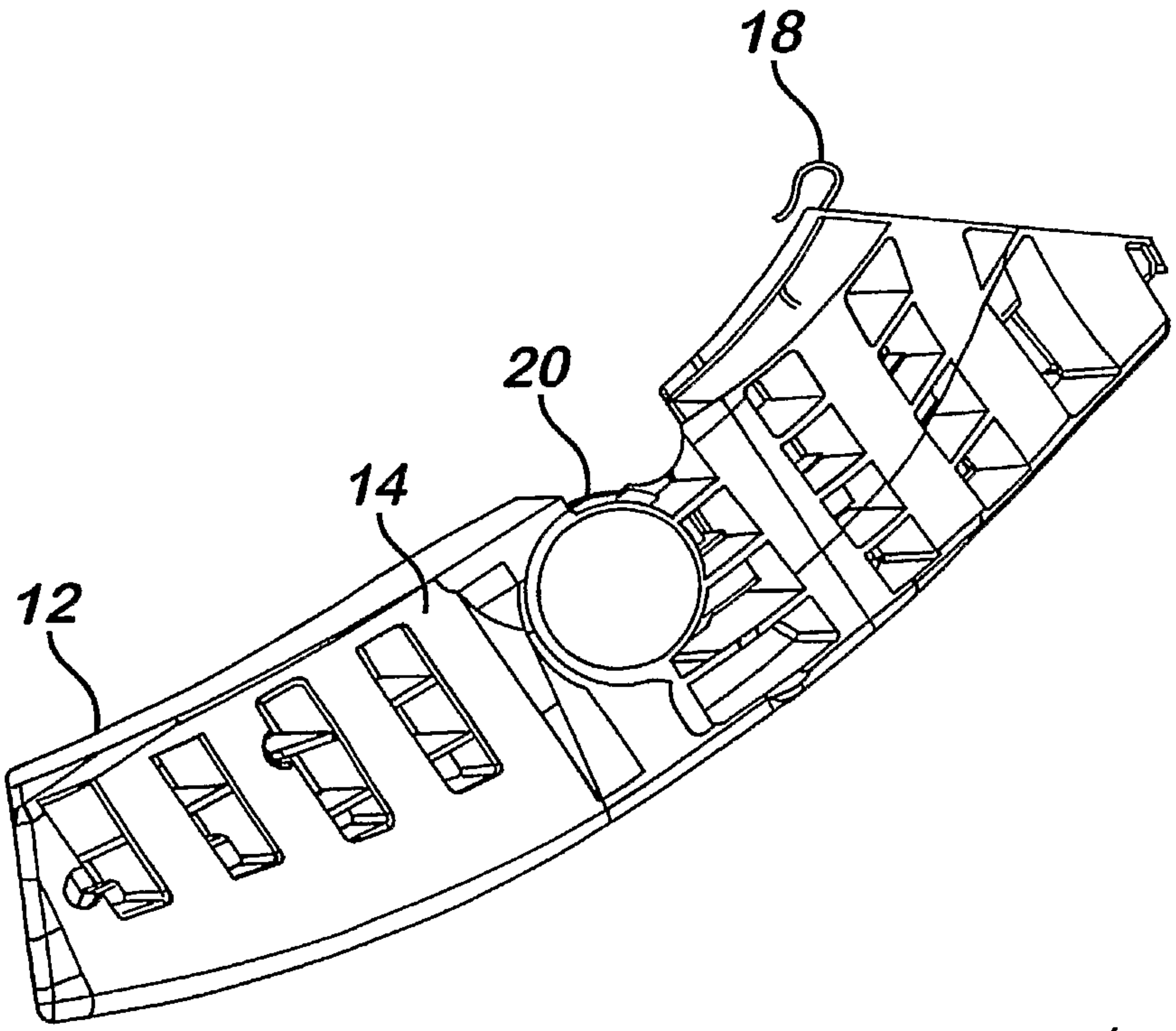


Fig. 4

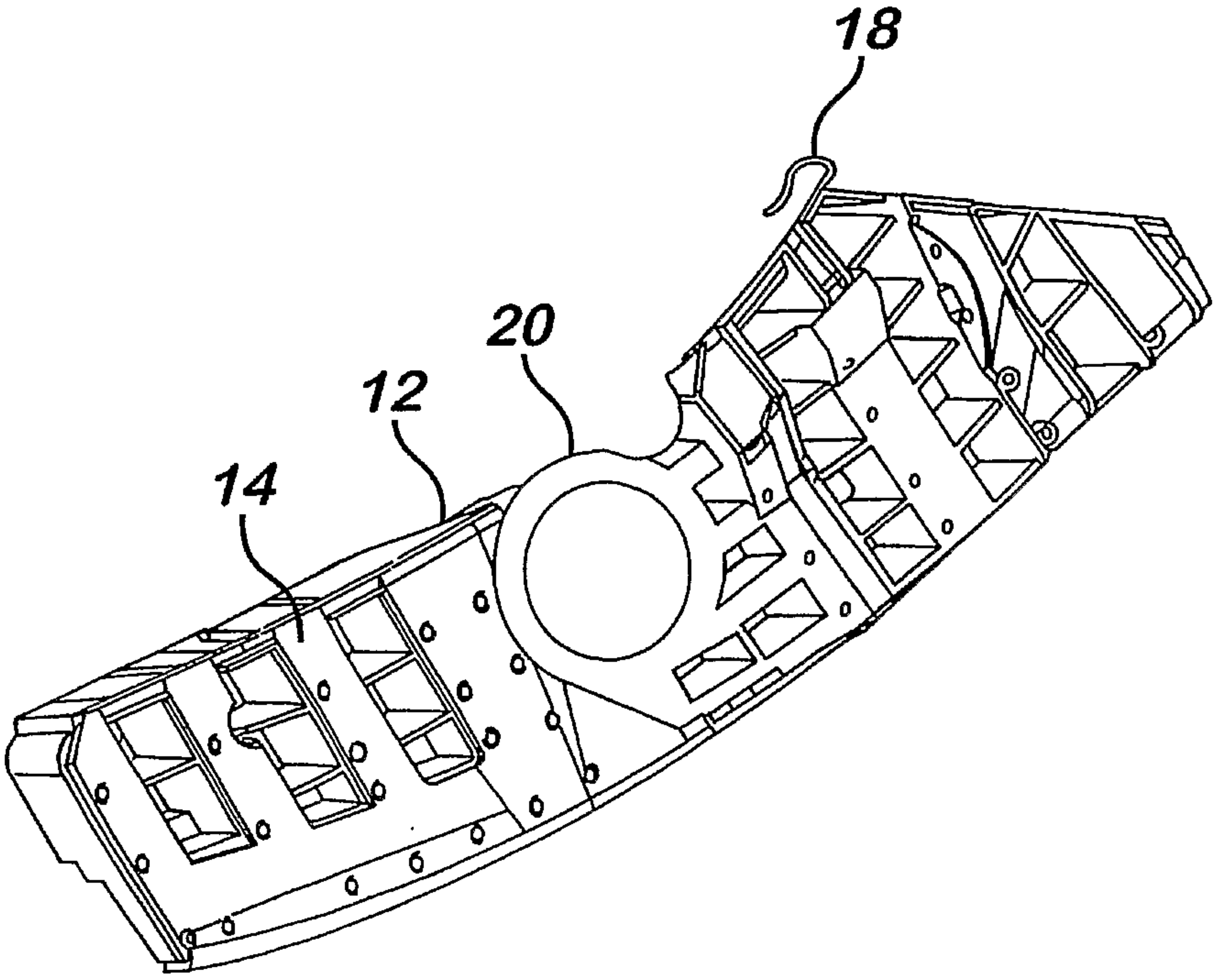


Fig. 6

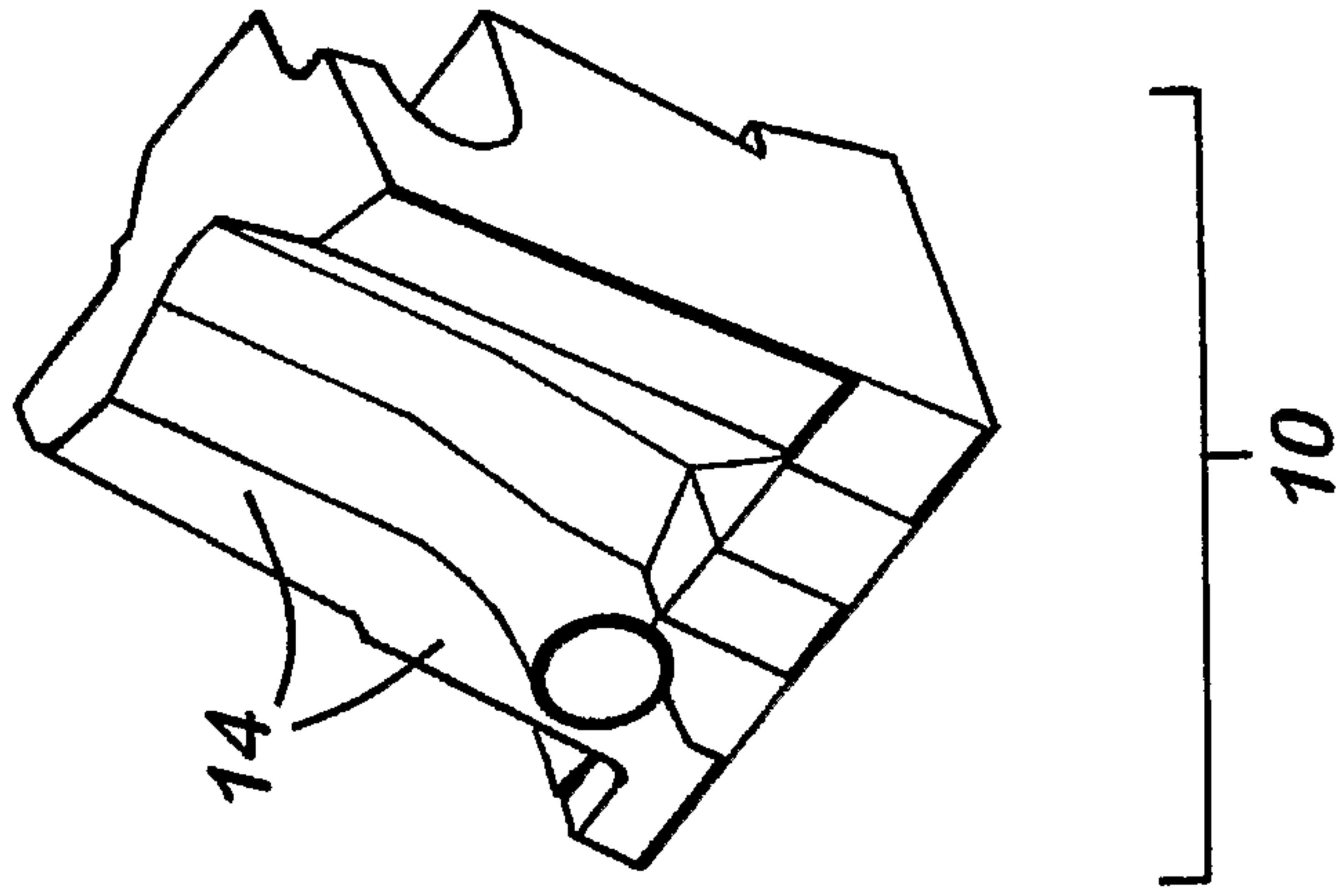
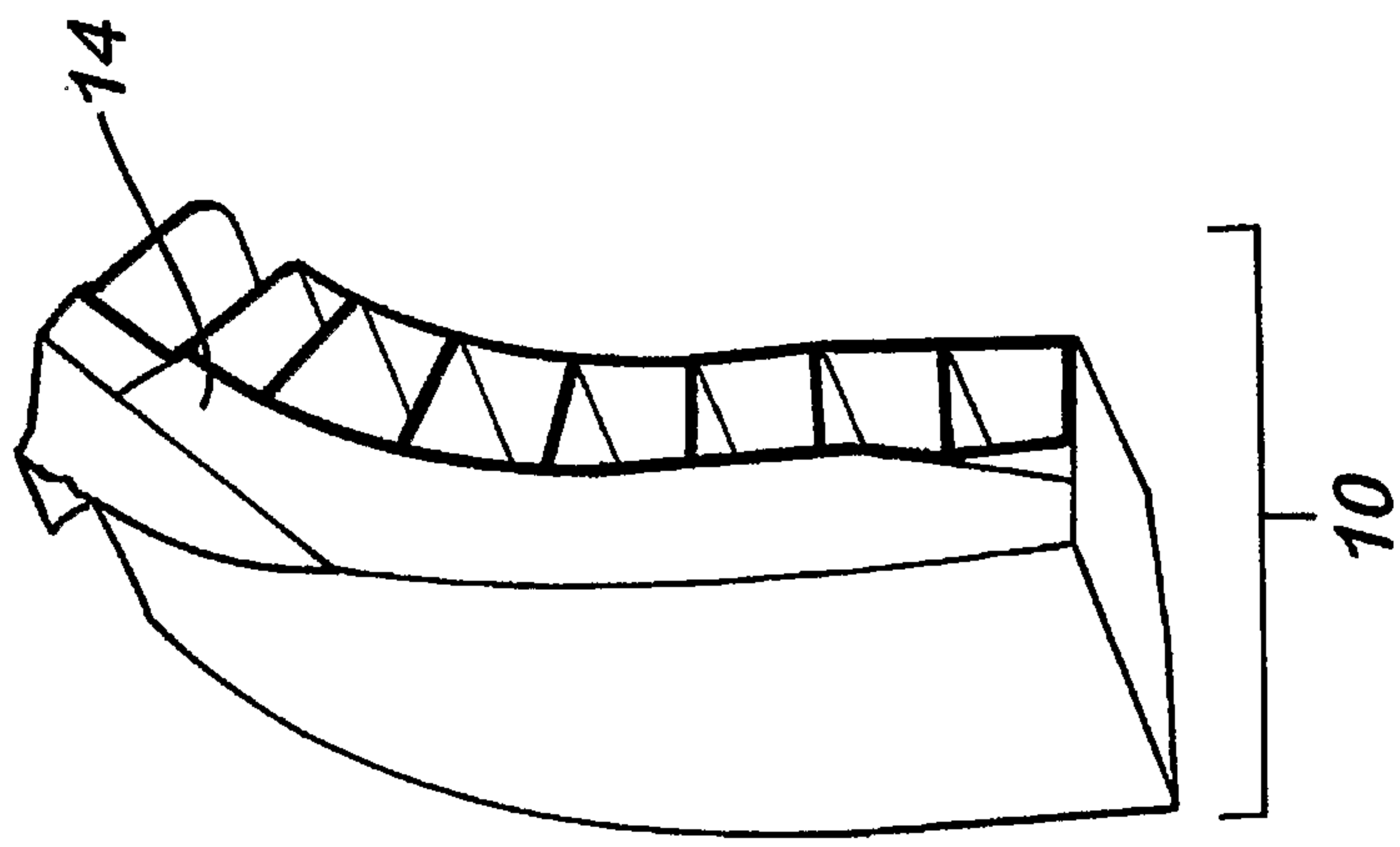


Fig. 5



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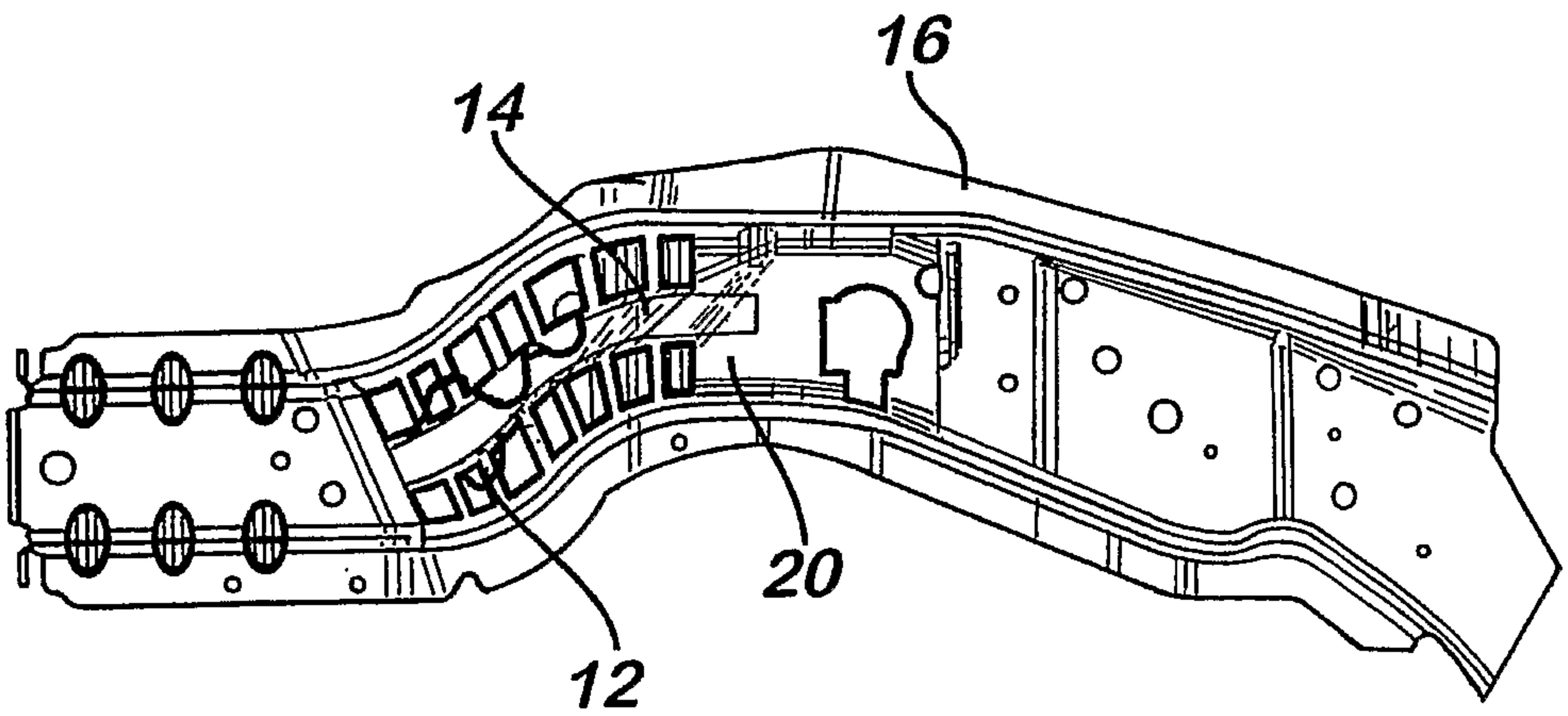

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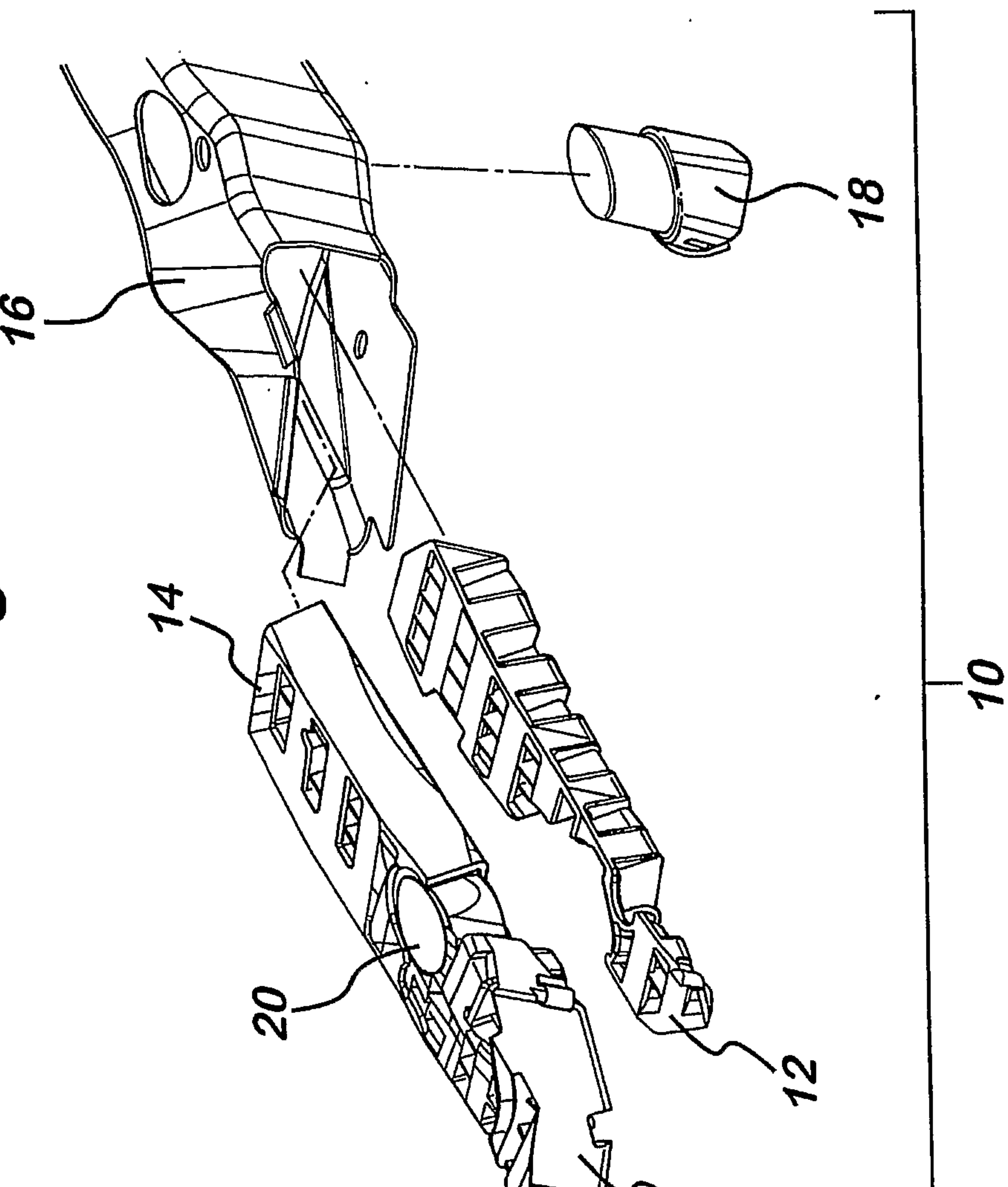
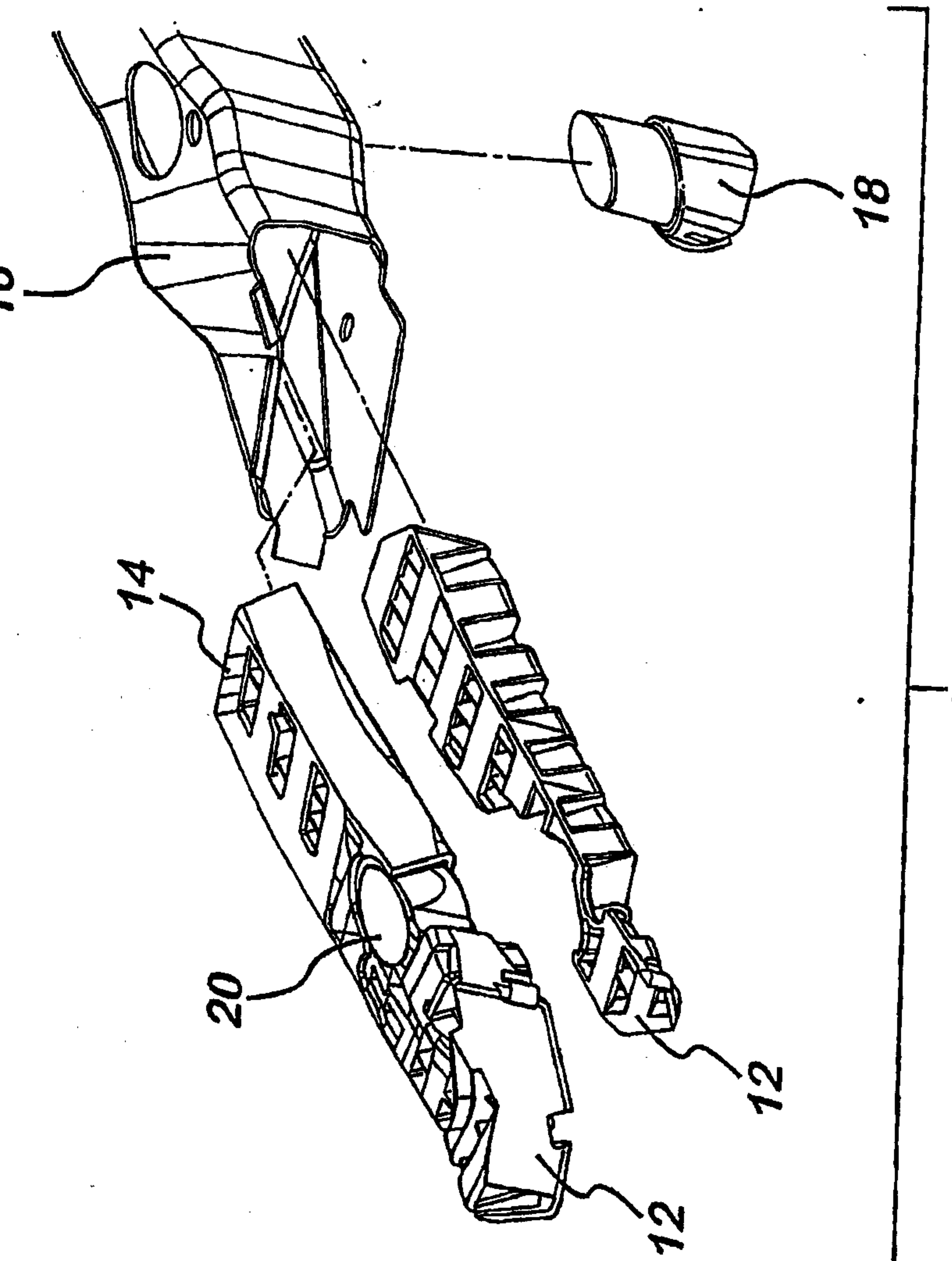
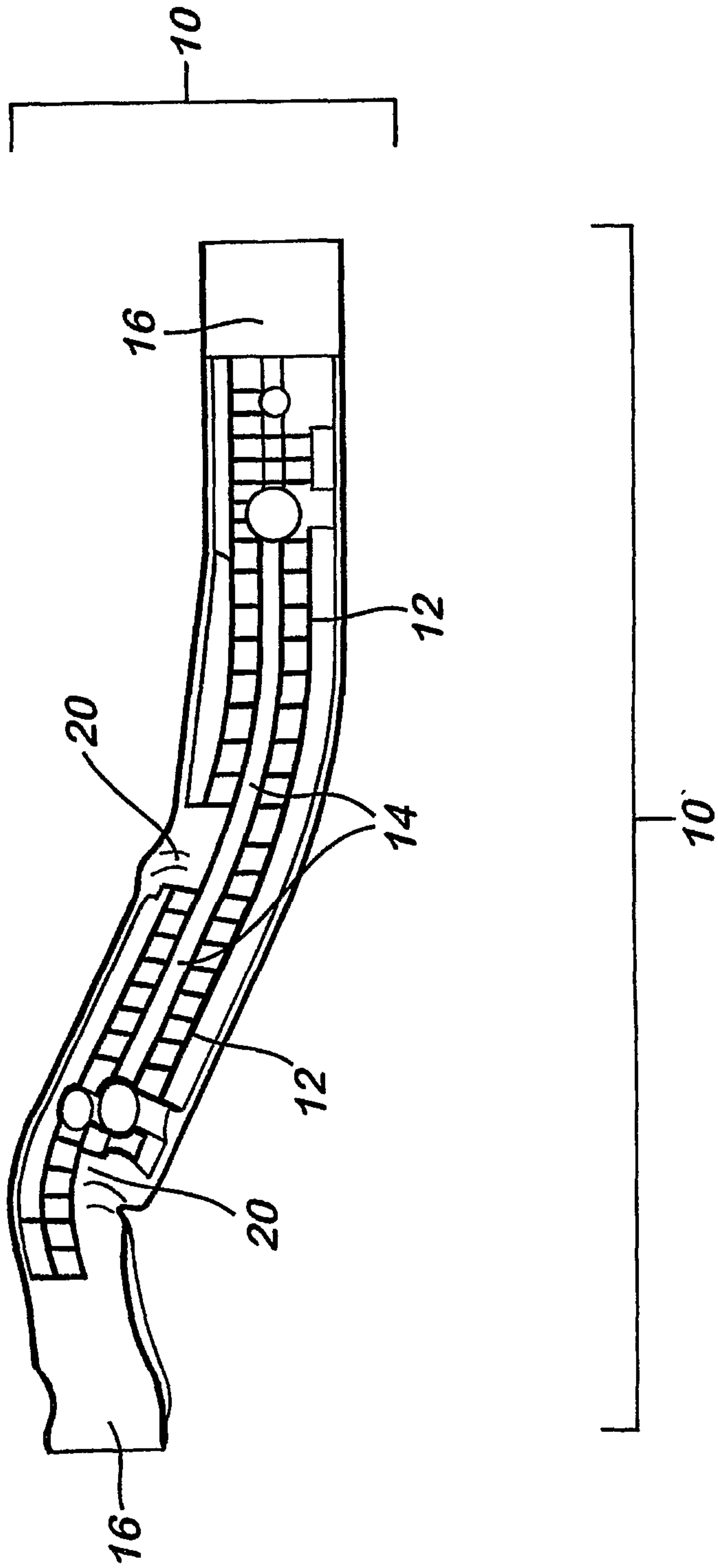


Fig. 8





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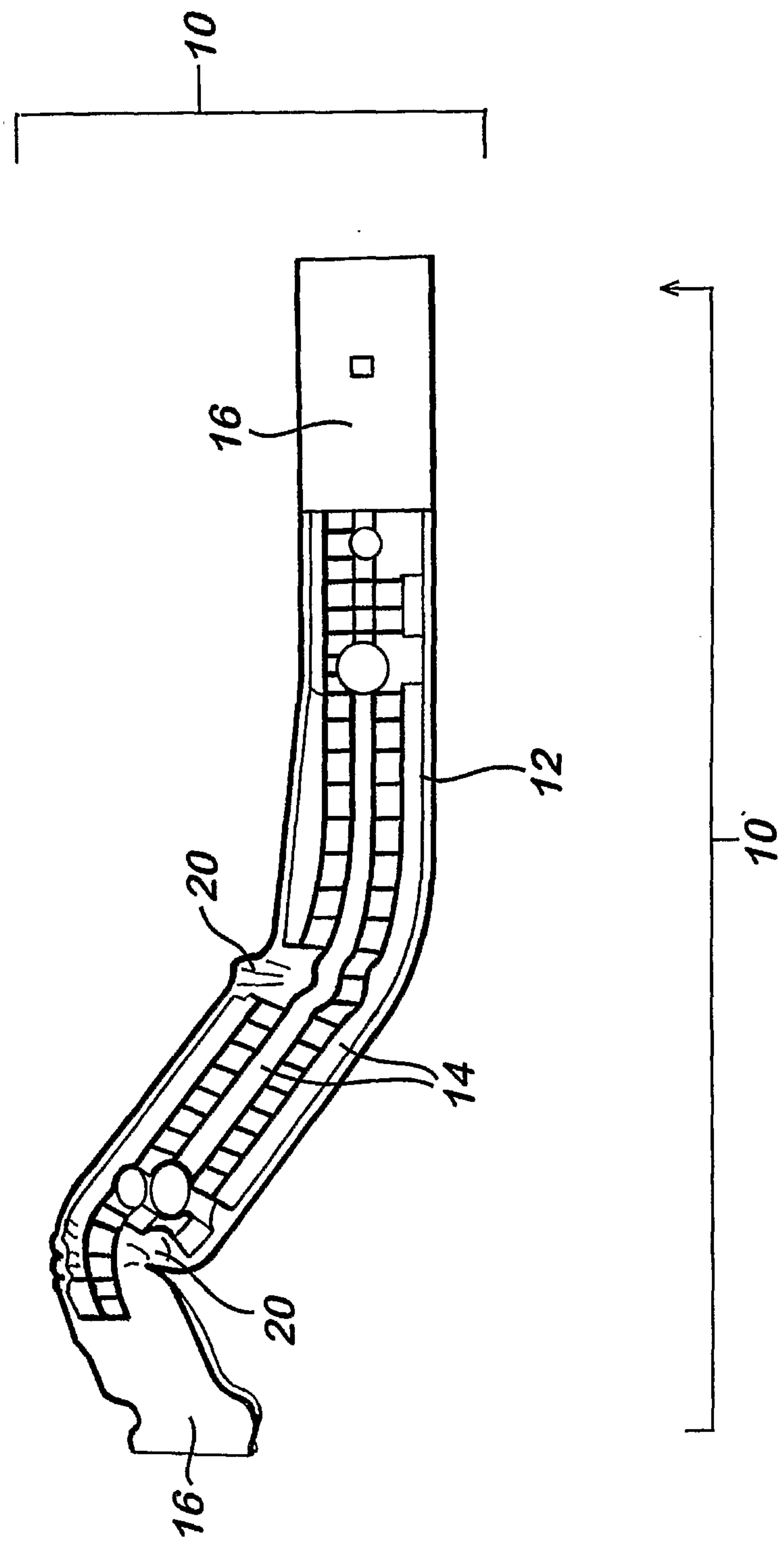


Fig. 10

Fig. 11

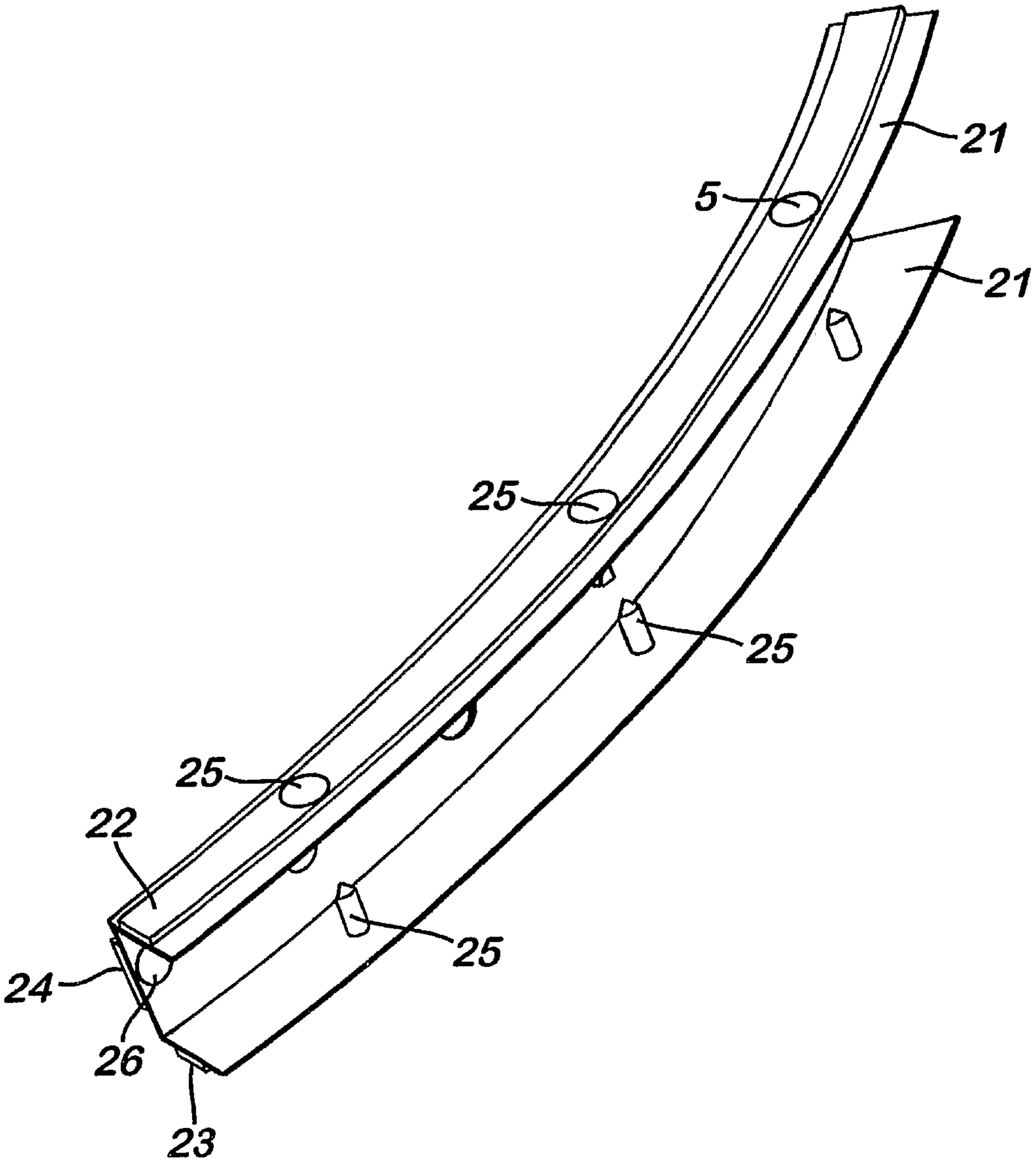


Fig. 12

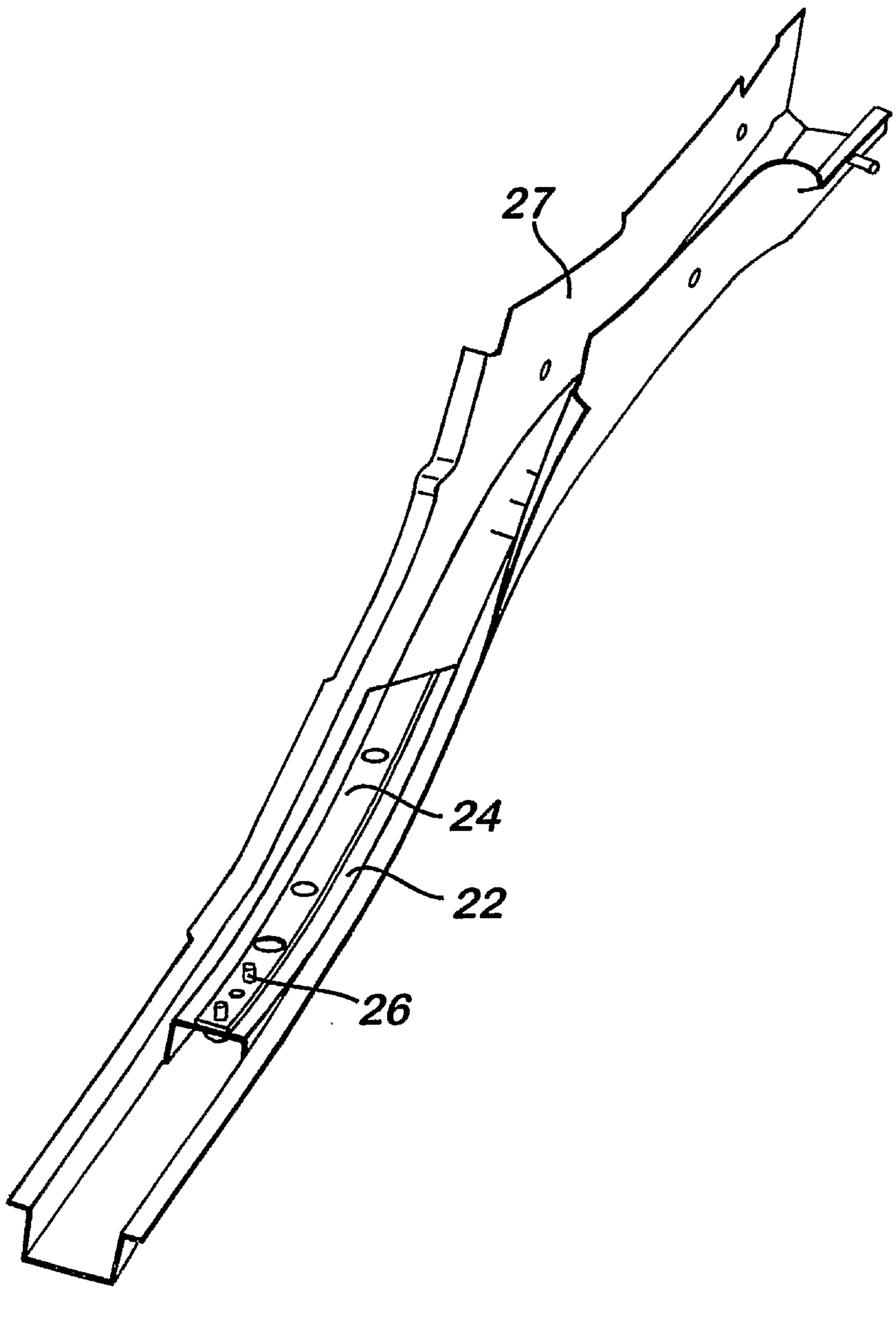
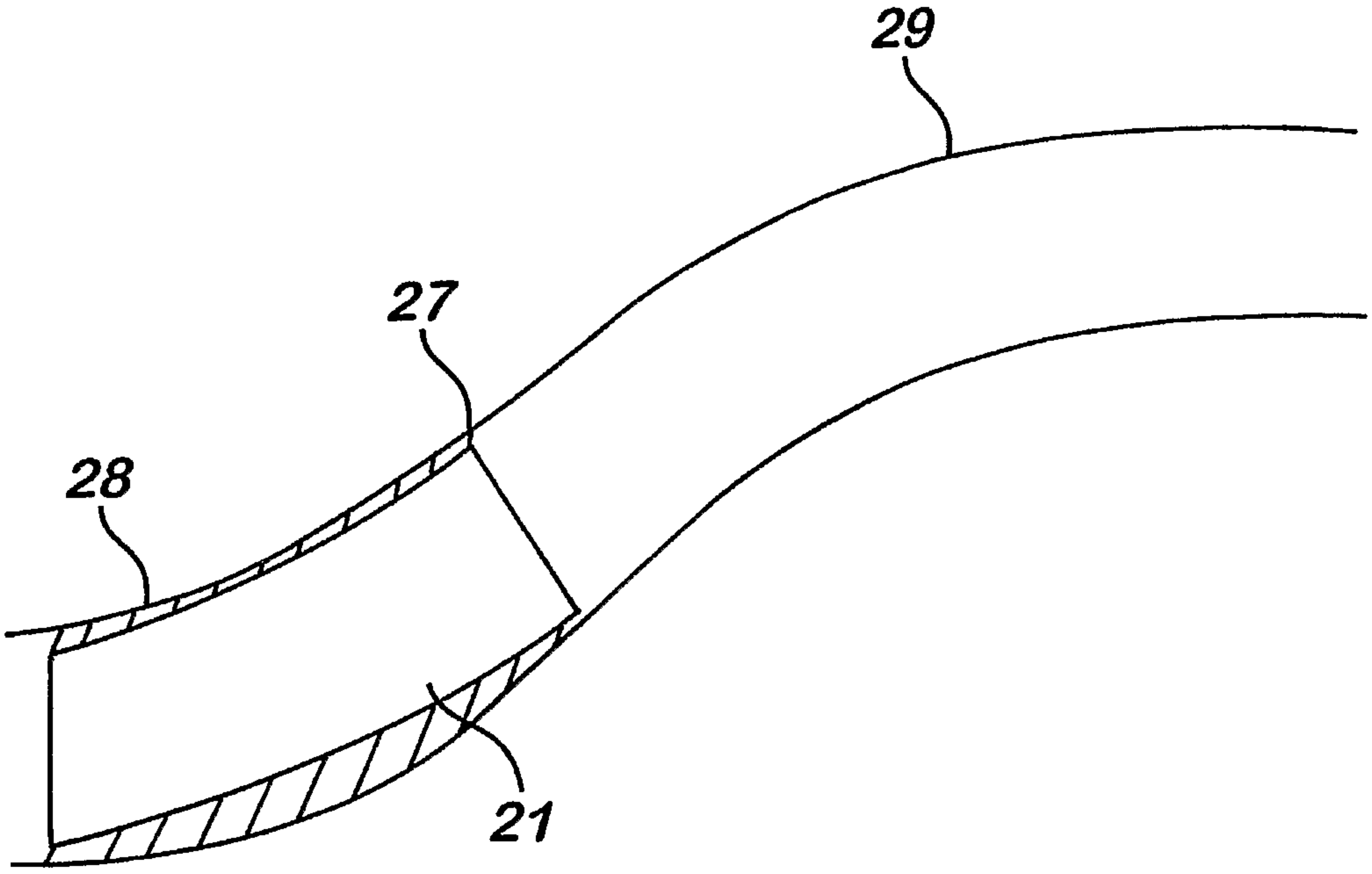


Fig. 13



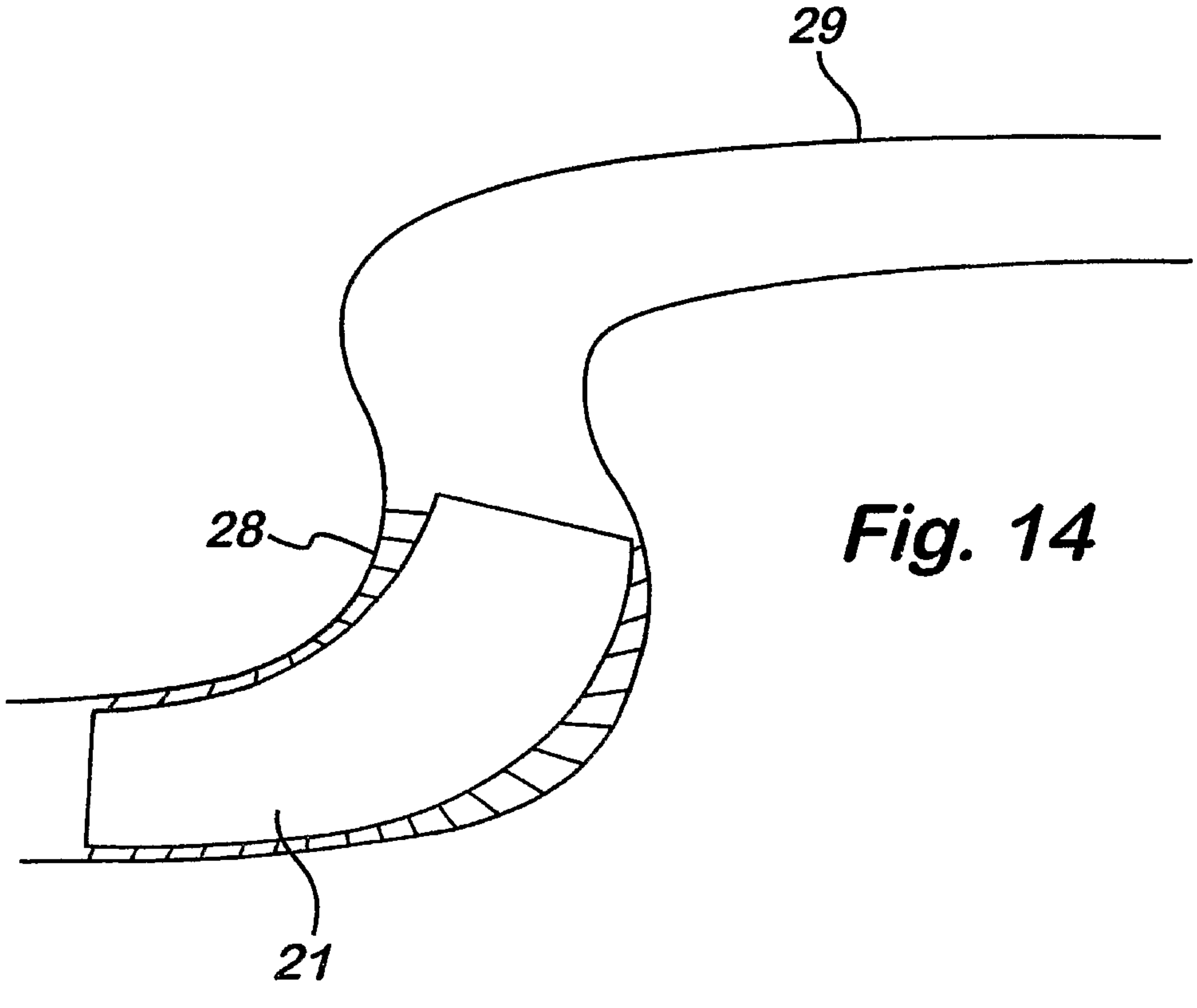


Fig. 14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