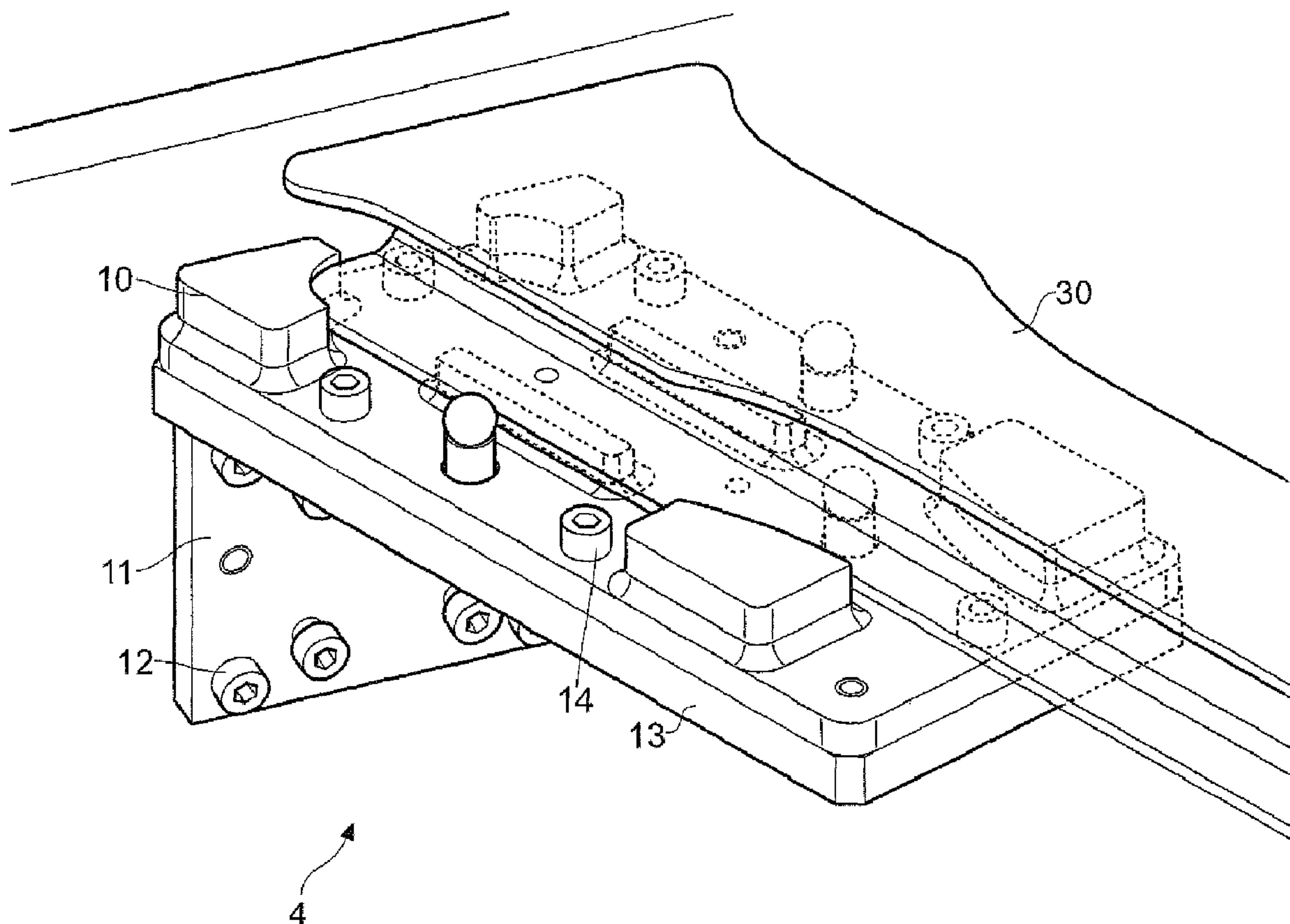




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(54) **Titre : PROCÉDE DE FABRICATION D'UN PANNEAU RIGIDIFIÉ**
(54) **Title: METHOD OF MANUFACTURING A STIFFENED PANEL**



(57) **Abrégé/Abstract:**

A method of manufacturing a stiffened panel, and a datum part for use in such a method. The method comprises: holding the panel with a jig; holding a datum part with the jig; engaging the panel and the datum part with a stringer; and joining the stringer to the panel. Preferably an additive process is used to form the datum part. By growing the datum part in a series of layers, the shape of each layer can be selected to enable the shape or size of the datum part to be optimised.

ABSTRACT

A method of manufacturing a stiffened panel, and a datum part for use in such a method. The method comprises: holding the panel with a jig; holding a datum part with the jig; engaging the panel and the datum part with a stringer; and joining the stringer to the panel. Preferably an additive process is used to form the datum part. By growing the datum part in a series of layers, the shape of each layer can be selected to enable the shape or size of the datum part to be optimised.

METHOD OF MANUFACTURING A STIFFENED PANEL

FIELD OF THE INVENTION

The present invention relates to a method and apparatus for manufacturing a stiffened panel, and a datum part for use in such a method.

5 BACKGROUND OF THE INVENTION

A stringer tang is a tab of metal that extends longitudinally from the end of a stringer. This tab is used as a reference datum and has a bolt-hole therein. The tang is secured to a reference point on a jig (which is a known datum with respect to a panel) and hence locates the stringer spatially in relation to the panel.
10 The stringer tang itself allows the stringer to be bolted to and structurally supported by the jig. Thus, the stringer is located in the correct position in relation to the panel.

The stringers are then riveted or fastened to the panel whereupon the entire assembly is released from the jig by removing the panel plus the stringers from the jig. The tangs are then cut off and the areas around them are treated to
15 remove any protuberances or rough edges. This is a time consuming and laborious process.

SUMMARY OF THE INVENTION

A first aspect of the invention provides a method of manufacturing a stiffened aircraft panel, the method comprising:

20 holding the panel and a plurality of datum parts with a jig, at least two of the datum parts having a different shape or size;

engaging the panel with a plurality of stringers and engaging each datum part with a respective one of the stringers; and

joining the stringers to the panel, wherein the datum parts have been manufactured by an additive process.

The first aspect of the invention removes the requirement of stringer tangs. That is, the datum part enables the stringer to be located in the correct position in relation to the panel without requiring the stringer to be formed with a tang. Datum blocks with different shapes and sizes can be used in the manufacture of a single panel, each tailor-made to fit a respective stringer. In this case the method comprises: holding a plurality of datum parts with the jig, at least two of the datum parts having a different shape or size; engaging the panel with a plurality of stringers; engaging each datum part with a respective one of the stringers; and joining the stringers to the panel.

An additive process is used to form the datum part. By growing the datum part in a series of layers, the shape of each layer can be selected to enable the shape or size of the datum part to be optimised.

A second aspect of the invention provides a method of manufacturing a stiffened aircraft panel, the method comprising:

holding the panel with a jig;
holding a datum part with the jig;
engaging the panel and the datum part with a stringer; and
joining the stringer to the panel,

wherein the datum part comprises a base, said base having a periphery, and a pair of side stop blocks extending from the base and positioned towards the periphery of the base,

wherein one of the side stop blocks is formed with a resilient spring,
and

wherein the method further comprises the steps of:

engaging the stringer with the side stop blocks; and

flexing the resilient spring to account for variation in width of the stringer, wherein the stringer is secured to the datum part with a resilient clip
5 comprising a flexible cantilever arm and a projection by pushing the stringer down so that the arm bends back and then snaps back resiliently into place to provide a snap-fit joint.

Typically each layer is grown by directing energy and/or material from a head to selected parts of a build region. The head and the build region may
10 remain stationary during the growth process: for example the head may have a fixed array of lasers and/or nozzles which extend over the entire build region and are modulated as required to directing energy and/or material to selected parts of the build region. However more preferably the method further comprises causing relative movement between the head and the build region. Preferably this relative
15 movement is caused by moving the head, but it will appreciated that the relative movement may be caused by moving the component or by a combined movement of both parts.

Various additive fabrication techniques may be used, including techniques in which the head directs material to selected parts of the build region,
20 and techniques in which a series of beds of material are deposited on the build region and the head directs energy to selected parts of each bed.

Examples of the former include fused deposition modelling (in which the head extrudes hot plastic through a nozzle) and powder feed fabrication (in which a laser beam directs energy to fuse a powdered material as it is delivered to
25 the build region). Advantages of these methods are that:

- the amount of wastage of material in the fabrication process is minimized;
- the datum part can be made from a different material to the component; and
- the datum part can be rotated relative to the head during the fabrication process in order to form a complex shape.

5 Examples of the latter include stereolithography (in which a laser is used to cure selected parts of a bed of liquid photopolymer) and powder bed fabrication (in which a series of beds of powder are deposited on the build region and selected parts of each bed are fused by a laser). Advantages of using the head to deliver energy to the selected parts of a previously deposited bed of material are
10 that:

- unconsolidated parts of each bed can support successive beds, enabling relatively complex shapes to be formed.

Typically the datum part is formed by fusing a powder, for instance in a powder bed process or a powder feed process.

15 Typically the stringer extends lengthwise between a pair of end faces, and the datum part engages one of the end faces of the stringer.

Typically the datum block comprises one or more resilient members which engage the stringer. At least one of the resilient members may comprise a flexible cantilever arm and a projection which is configured to engage the stringer to
20 form a snap-fit joint. Alternatively, or in addition, at least one of the resilient members may comprise a flexible spring which can flex to account for slight variations in width of the stringer.

Typically the datum part comprises a base; one or more height stops extending from the base by a first distance, and two or more side stops extending
25 from the base by a second distance greater than the first distance.

The datum part may comprise a base; one or more side stop blocks extending from the base and positioned towards the periphery of the base; and one or more resilient members. In this case the method further comprises: engaging the stringer with the side stop block(s); and securing the stringer to the datum part with
5 the resilient member(s).

At least one of the resilient members may comprise a flexible cantilever arm and a projection which is configured to engage the stringer to form a snap-fit joint. Alternatively, or in addition, at least one of the resilient members may comprise a flexible spring which engages the stringer and can flex to account for
10 slight variations in width of the stringer.

A fourth aspect of the invention provides apparatus for manufacturing a stiffened panel by the method of the first aspect of the invention as defined above, the apparatus comprising: a jig; and one or more datum parts which have been manufactured by an additive process.

15 BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 shows a jig profile board, a skin and a set of stringers.

Figure 2 shows a jig profile board, a datum part and a stringer run-out.

20 Figure 3 is a perspective view of the datum part.

Figure 4 is a perspective view of the stringer run-out and datum part.

Figure 5 is an enlarged perspective view of the stringer run-out and datum part.

Figure 6 is an end view of the stringer run-out and datum part.

Figure 7 is a perspective view of a nest plate.

Figure 8 is a perspective view of the nest plate showing the pair of tips removed.

Figure 9 shows another part of a stringer.

5 Figure 10 is a perspective view of the datum part shown in Figure 9.

Figure 11 is a plan view of the datum part shown in Figure 9.

Figure 12 is a perspective view of an alternative datum part.

Figure 13 is a perspective view of an alternative datum part.

10 Figure 14 is a perspective view of a stringer fitted to the datum part of Figure 13. Figure 15 shows a powder bed additive manufacturing system.

DETAILED DESCRIPTION OF EMBODIMENT(S)

Figure 1 shows a step in the assembly of a stiffened panel which forms the upper or lower skin of a wing box. The wing box comprises an upper and lower skin, each skin carrying a series of stringers on its inner surface which run in a span-wise direction along the wing box. A series of ribs run in a chord wise direction across the wing box and are joined to the upper and lower skins. Each stringer has an inboard end (conventionally known as a "stringer run-out") adjacent to the inboard rib (which is conventionally known as "rib 1") and an outboard end.

15

Figure 1 shows the inboard run-outs of three stringers 1-3, a profile board 4 and a skin 5. The profile board 4 forms part of a jig, and has the same shape and size as "rib 1" of the wing box. The skin 5 is held by another part (not shown) of the jig.

20

As shown in Figure 2 a datum part 10 is held by the profile board 4. Note that the datum parts are not shown in Figure 1. A vertical plate 11 of an L-shaped bracket is secured to the profile board 4 by fasteners 12, and the datum part 10 is secured to a horizontal plate 13 of the L-shaped bracket by fasteners 14.

5 The upper face of the datum part 10 is shown in detail in Figure 3. A plate 20 carries three stringer height stop blocks 21, a pair of resilient clips 22, and four stringer side stop blocks 23-26 at the periphery of the plate 20. The left-hand stop blocks 23 and 25 are formed with resilient springs 23a and 25a.

10 After the datum part 10 has been fixed in place on the profile board 4, the inboard end of a stringer 30 is clipped into place on the datum part as shown in Figure 2. The structure of the stringer 30 is shown most clearly in Figures 4 and 6. The stringer 30 comprises a web 31, a pair of upper flanges 32,33 and a pair of lower flanges 34,35. As shown most clearly in Figure 4, the upper flanges 32,33 are terminated short of the end of the stringer, and the web 31 has a tapered edge 36
15 extending beyond the end of the upper flanges 32,33.

When fixed to the datum part, the lower faces of the lower flanges 34,35 engage the stringer height stop blocks 21, and the sides and ends of the lower flanges 34,35 engage the nesting faces of the four stringer side stop blocks 23-26, as well as being secured against vertical movement by the clips 22.

20 As can be seen most clearly in Figure 6, the height stop blocks 21 extend from the plate 20 by a first distance, and the side stop blocks 23-26 extending from the base by a second distance greater than the first distance.

Figure 5 is an enlarged perspective view showing one of the clips 22 in detail. The other clip 22 has a similar form and works in a similar manner. The clip
25 22 has a cantilever arm 27, and a projecting nose configured with a curved upper edge 28 and sharp lower edge 29. As the stringer is pushed down, the edge of the flange 34 engages the curved upper edge 28 and the arm 27 bends back. As the

edge of the stringer flange 34 clears the sharp edge 29, the clip snaps back resiliently into place to provide a cantilever snap-fit joint which locks the stringer securely against vertical movement as shown in Figure 4.

5 The resilient springs 23a,25a can flex to account for slight variations in width of the stringer.

Figure 7 shows a nest plate 40. A series of such nest plates are held by the jig at spaced locations along the length of the stringer. The nest plate comprises a series of holes 41 which receive fasteners (not shown) for fixing the nest plate to the jig, and a slot 42 in an upper edge of the plate. The upper edge of the plate also carries a pair of renewable tips 43,44. After the inboard end of the stringer 30 has been fixed in place as shown in Figure 2, the nest plates 40 are moved towards the stringer by the jig, until the upper flanges of the stringer are received in the slot 42, and each lower flange 34,35 is engaged by a respective one of the renewable tips 43,44 which press the lower flanges 34,35 against the skin. A resilient spring 47 is provided on one side of the slot 42. The spring 47 is separated from the body of the nest plate by a gap 48, and can flex to account for slight variations in width of the stringer.

As shown in Figure 8, each renewable tip 43,44 has a pair of pegs 45 which are received in holes 46 in the upper edge of the nest plate 40. This enables the tips 43,44 to be removed and replaced by new tips in the event that they become flattened over time due to the clamping pressure. Furthermore, the tips 43,44 are formed by a harder material than the nest plate 40 to provide increased resistance to such flattening.

Figure 9 shows another part of the stringer 30. At this point the skin is relatively thin, so a different method of interfacing with the jig is required. A datum part, shown in detail in Figures 10 and 11, is held by a profile board (not shown) of the jig. The datum part comprises an arm 51 which extends from a block 50 and

carries a pair of clips 52 at its distal end which grip the sides of the lower flanges as shown in Figure 9. The upper edge of the block 50 has a pair of blocks 53, one formed with a resilient spring 53a which can flex to account for slight variations in width of the stringer..

5 An alternative datum part 60 is shown in Figure 12. In this case the datum part has an end stop 61 which engages an end edge of the lower flanges of the stringer, and the sides of the stringer are engaged by resilient springs 62-65. Note that no clips are provided with this datum block.

10 A further alternative datum part 70 is shown in Figure 13. The datum part 70 comprises a plate 71 carrying two stringer height stop blocks 72, a pair of resilient clips 73, and four stringer side stop blocks 75-77. The stop blocks 76 and 77 are formed with resilient springs 76a and 77a.

15 As shown in Figure 14, after the datum part 70 has been fixed in place to a profile board 81 of the jig, the inboard end of a stringer 80 is fitted to the datum part. The profile board 81 represents "rib 1" of the wing - that is, the inboard rib. When fixed to the datum part 70, the lower faces of the lower flanges of the stringer 80 engage the stringer height stop blocks 72, the lower flanges are gripped by the clips 73, and the upper flanges engage the springs 76a,77a and the nesting faces of the blocks 74,75.

20 After the stringers have been fitted to the various datum parts 10,50,60,70 and the nest plates 40 have been clamped in place, then the stringers are joined along their length to the skin by fasteners (not shown). The datum parts 10,50,60,70 ensure that the stringers are held against the skin by the jig in precisely the correct position before the fasteners are fitted.

25 The datum parts 10,50,60,70 and nest plates 40 are each grown in a series of layers by a powder bed additive manufacturing system shown in Figure 15. The powder bed system grows the part by scanning a laser head laterally across a

powder bed and directing the laser to selected parts of the powder bed. More specifically, the system comprises a pair of feed containers 90, 91 containing powdered metallic material such as powdered Titanium. A roller 92 picks up powder from one of the feed containers (in the example of Figure 15, the roller 92 is picking
5 up powder from the right hand feed container 91) and rolls a continuous bed of powder over a support member 93. A laser head 94 then scans over the powder bed, and a laser beam from the head is turned on and off under the control of computer-aided design (CAD) model of the part, to melt the powder in a desired two-dimensional pattern. The support member 93 then moves down by a small distance
10 (typically of the order of 0.1mm) to prepare for growth of the next layer. After a pause for the melted powder to solidify, the roller 92 proceeds to roll another layer of powder over support member 93 in preparation for sintering. Thus as the process proceeds, a sintered part 95 is constructed, supported by unconsolidated powder parts 96. After the part has been completed, it is removed from the support member
15 93 and the unconsolidated powder 96 is recycled before being returned to the feed containers 90, 91.

The additive process shown in Figure 15 provides a convenient method of manufacturing the datum parts 10,50,60,70 and nest plates 40 in precisely the right shape and size for their intended purpose. Different datum parts
20 can be made by simply changing the CAD model. This enables the same jig to be used to manufacture a variety of different panel designs, as well as giving the ability of using datum blocks with different shapes and sizes in the manufacture of a single panel, each tailor-made to fit a respective stringer.

Although the invention has been described above with reference to one
25 or more preferred embodiments, it will be appreciated that various changes or modifications may be made without departing from the scope of the invention as defined in the appended claims.

CLAIMS

1. A method of manufacturing a stiffened aircraft panel, the method comprising:

holding the panel and a plurality of datum parts with a jig, at least two
5 of the datum parts having a different shape or size;

engaging the panel with a plurality of stringers and engaging each datum part with a respective one of the stringers; and

joining the stringers to the panel, wherein the datum parts have been manufactured by an additive process.

10 2. The method of claim 1, wherein the respective one of the stringers extends lengthwise between a pair of end faces, and wherein the datum part engages one of the end faces of said respective one of the stringers.

3. The method of claim 1 or 2, comprising growing the datum part in a series of layers, each layer being grown by directing energy and/or
15 material from a head to selected parts of a build region.

4. The method of claim 3, further comprising causing relative movement between the head and the build region.

5. The method of claim 3 or 4, including depositing a series of beds of material on the build region and directing energy from the head to selected
20 parts of each bed.

6. The method of any one of claims 1 to 5, wherein the datum part is formed by fusing a powder.

7. The method of any one of claims 1 to 6, wherein the datum part comprises a base; one or more height stops extending from the base by a first distance, and two or more side stops extending from the base by a second distance greater than the first distance.

5 8. The method of any one of claims 1 to 7, wherein the datum part has a resilient member which engages said respective one of the stringers.

9. The method of any one of claims 1 to 6, wherein the datum part comprises a base; one or more side stop blocks extending from the base and positioned towards the periphery of the base; and one or more resilient members,
10 and wherein the method further comprises:

engaging said respective one of the stringers with the side stop block(s); and

securing said respective one of the stringers to the datum part with the resilient member(s).

15 10. Apparatus for manufacturing a stiffened panel by the method of any one of claims 1 to 9, the apparatus comprising: a jig; and one or more datum parts which have been manufactured by an additive process.

11. A method of manufacturing a stiffened aircraft panel, the method comprising:

20 holding the panel with a jig;

holding a datum part with the jig;

engaging the panel and the datum part with a stringer; and

joining the stringer to the panel,

wherein the datum part comprises a base, said base having a periphery, and a pair of side stop blocks extending from the base and positioned towards the periphery of the base,

wherein one of the side stop blocks is formed with a resilient spring,

5 and

wherein the method further comprises the steps of:

engaging the stringer with the side stop blocks; and

flexing the resilient spring to account for variation in width of the stringer, wherein the stringer is secured to the datum part with a resilient clip
10 comprising a flexible cantilever arm and a projection by pushing the stringer down so that the arm bends back and then snaps back resiliently into place to provide a snap-fit joint.

12. The method of claim 11 wherein the datum part has been manufactured by an additive process.

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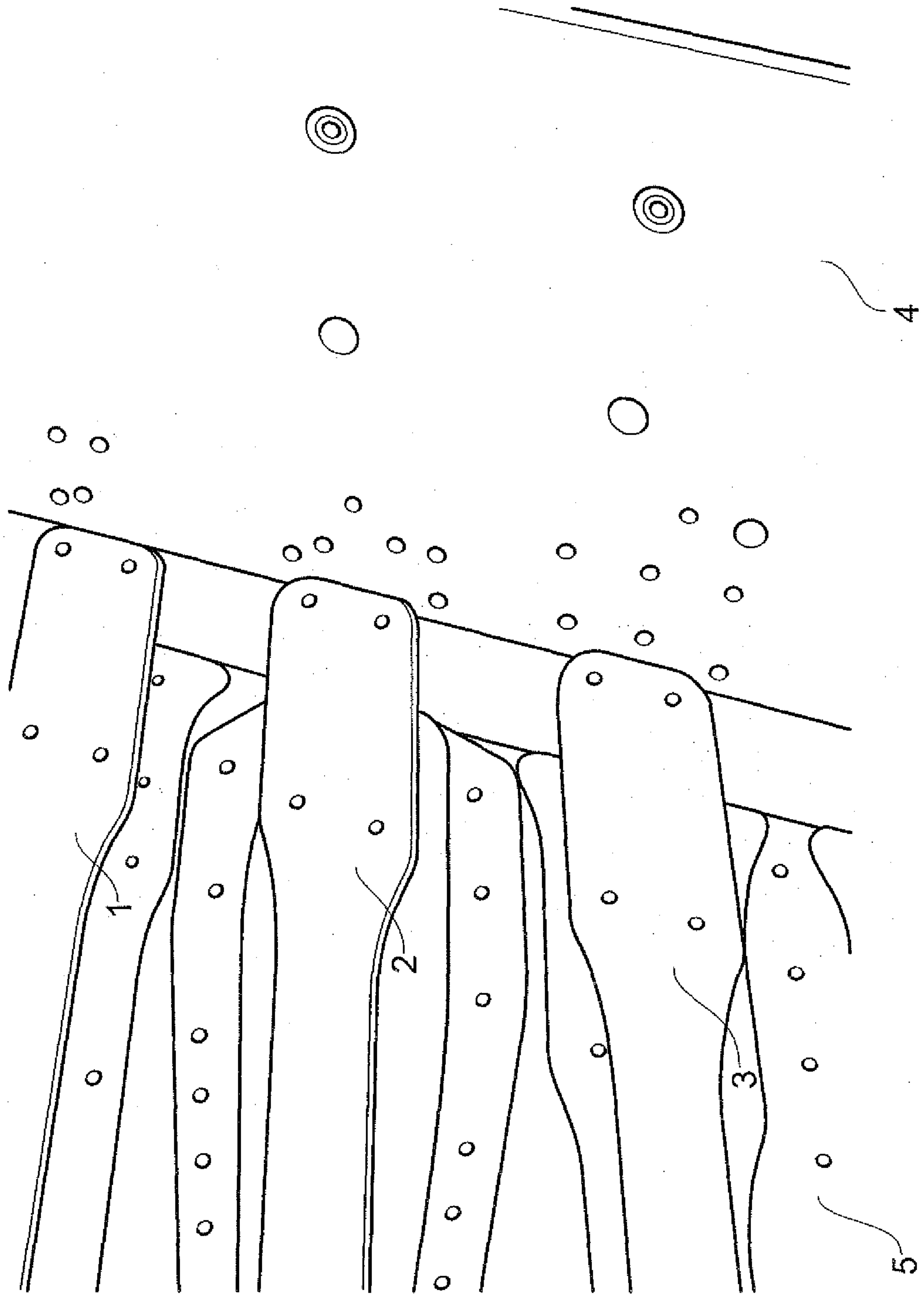


FIG. 1

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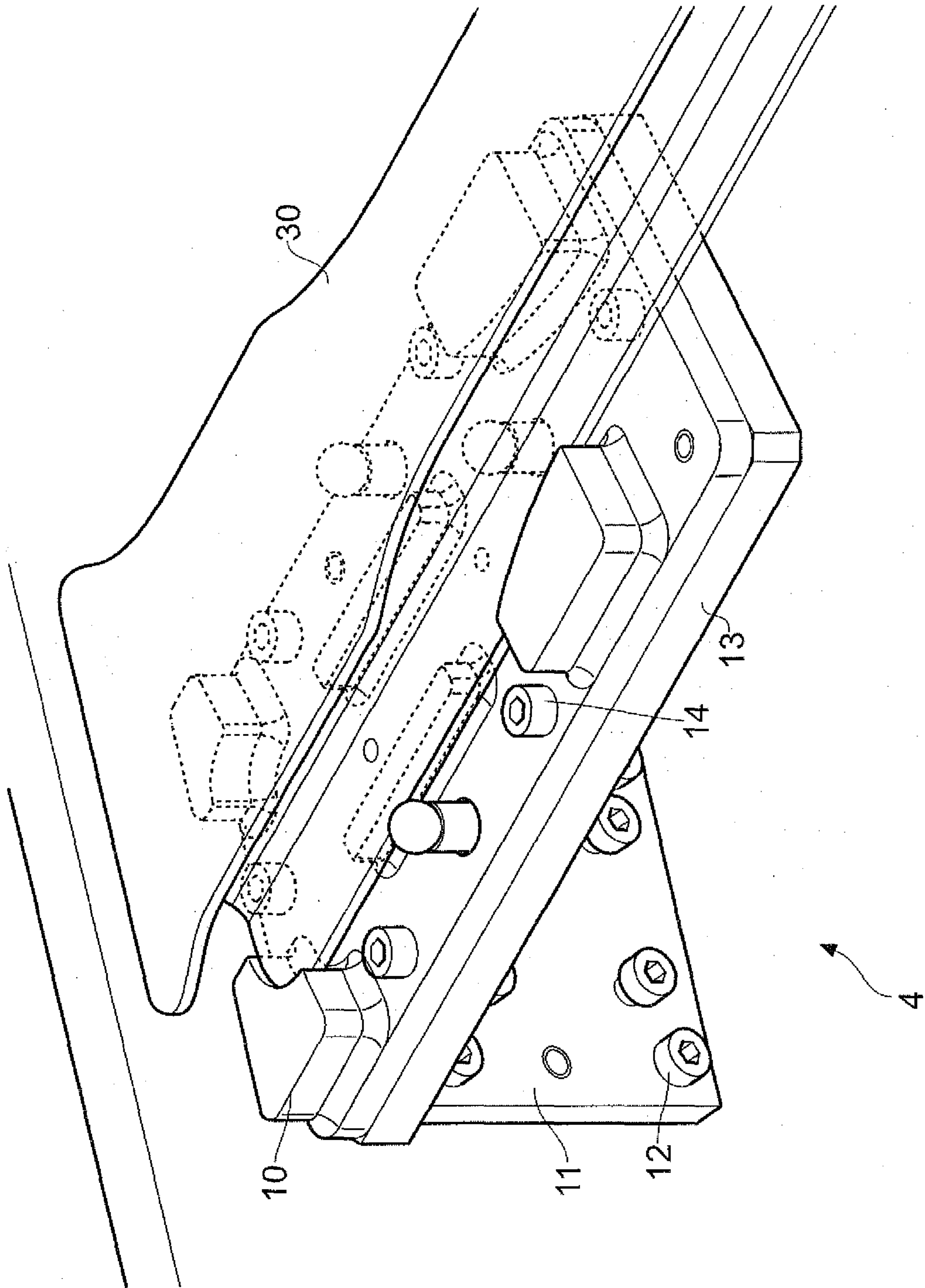


FIG. 2

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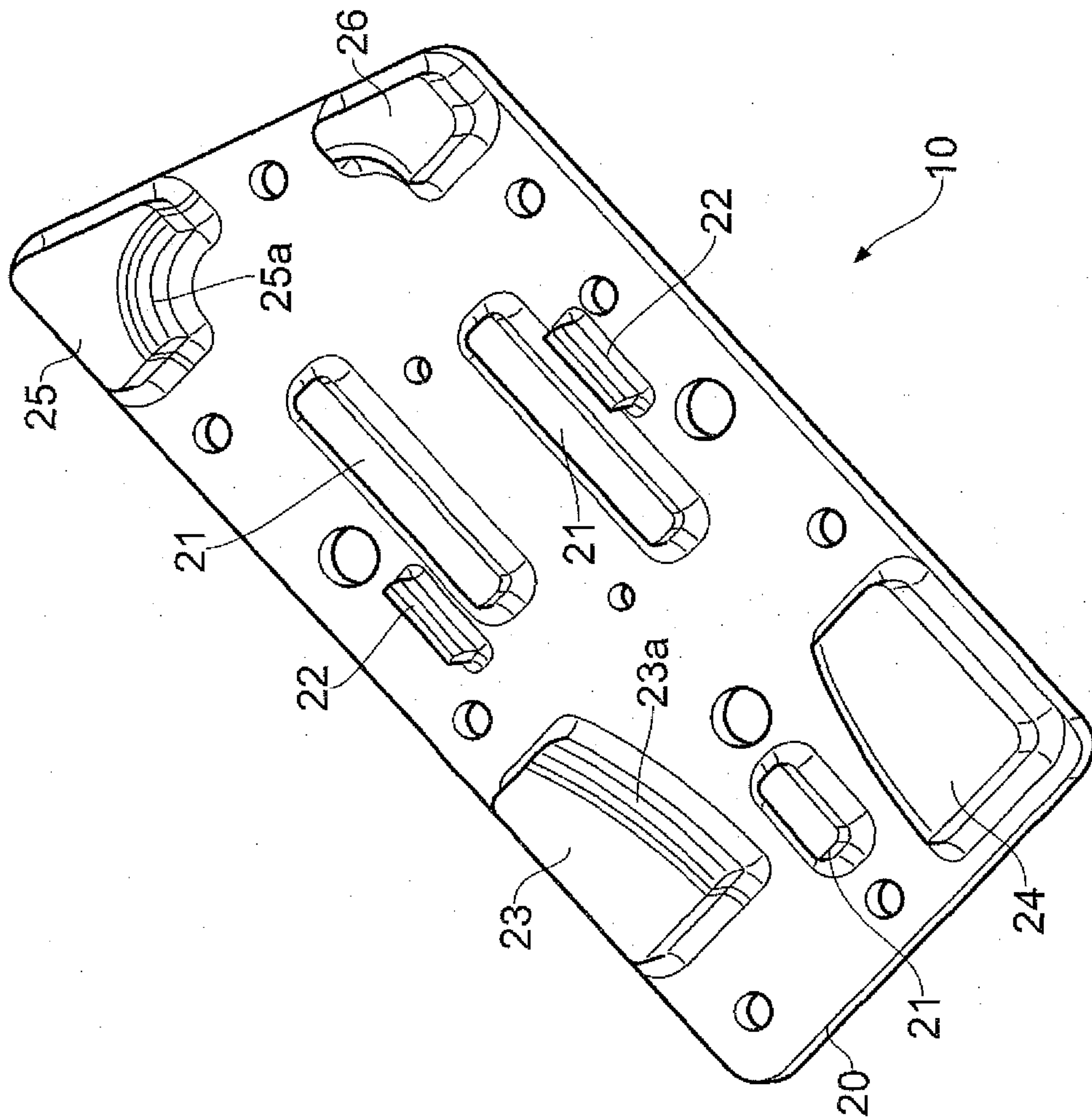


FIG. 3

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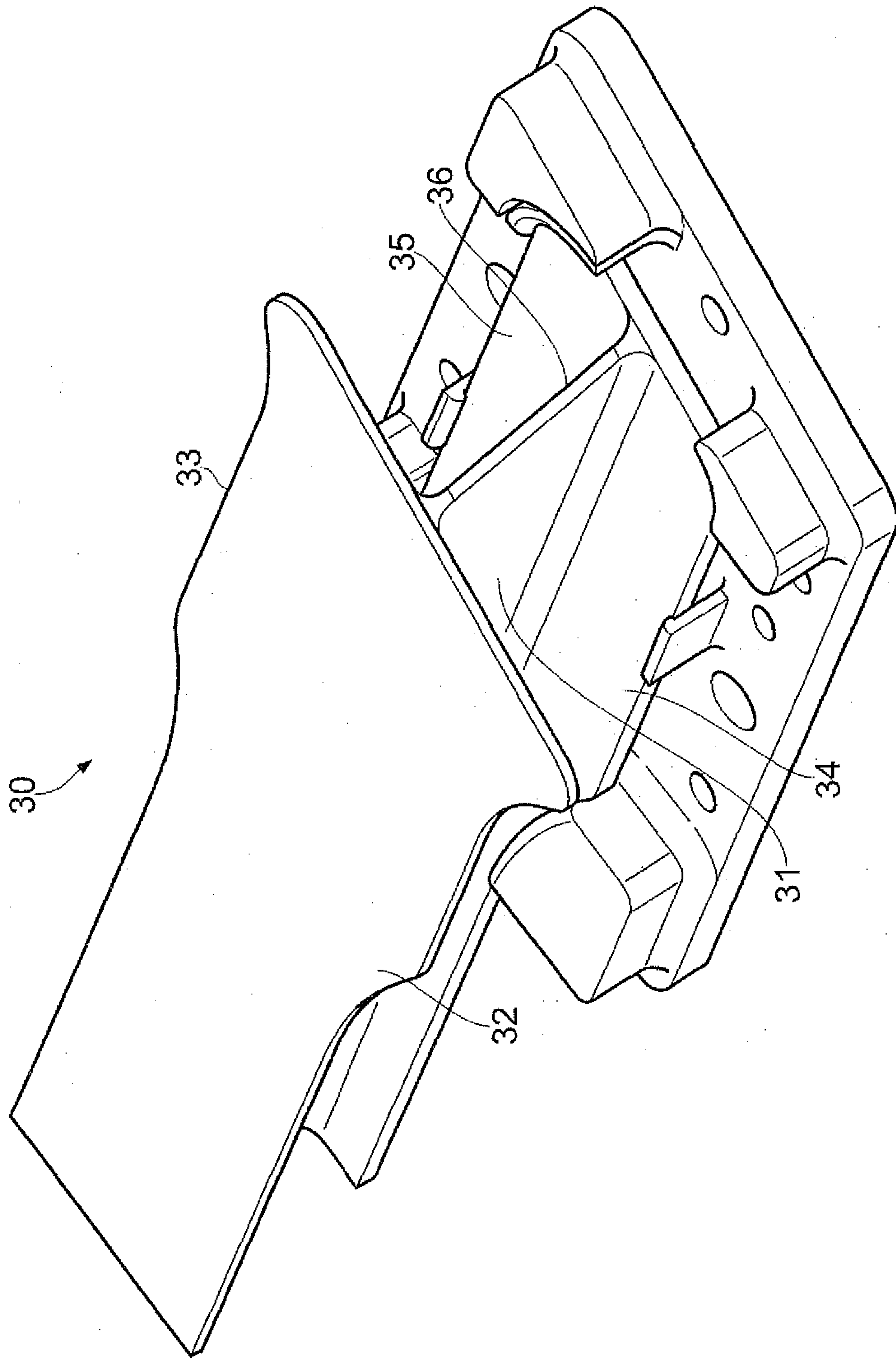


FIG. 4

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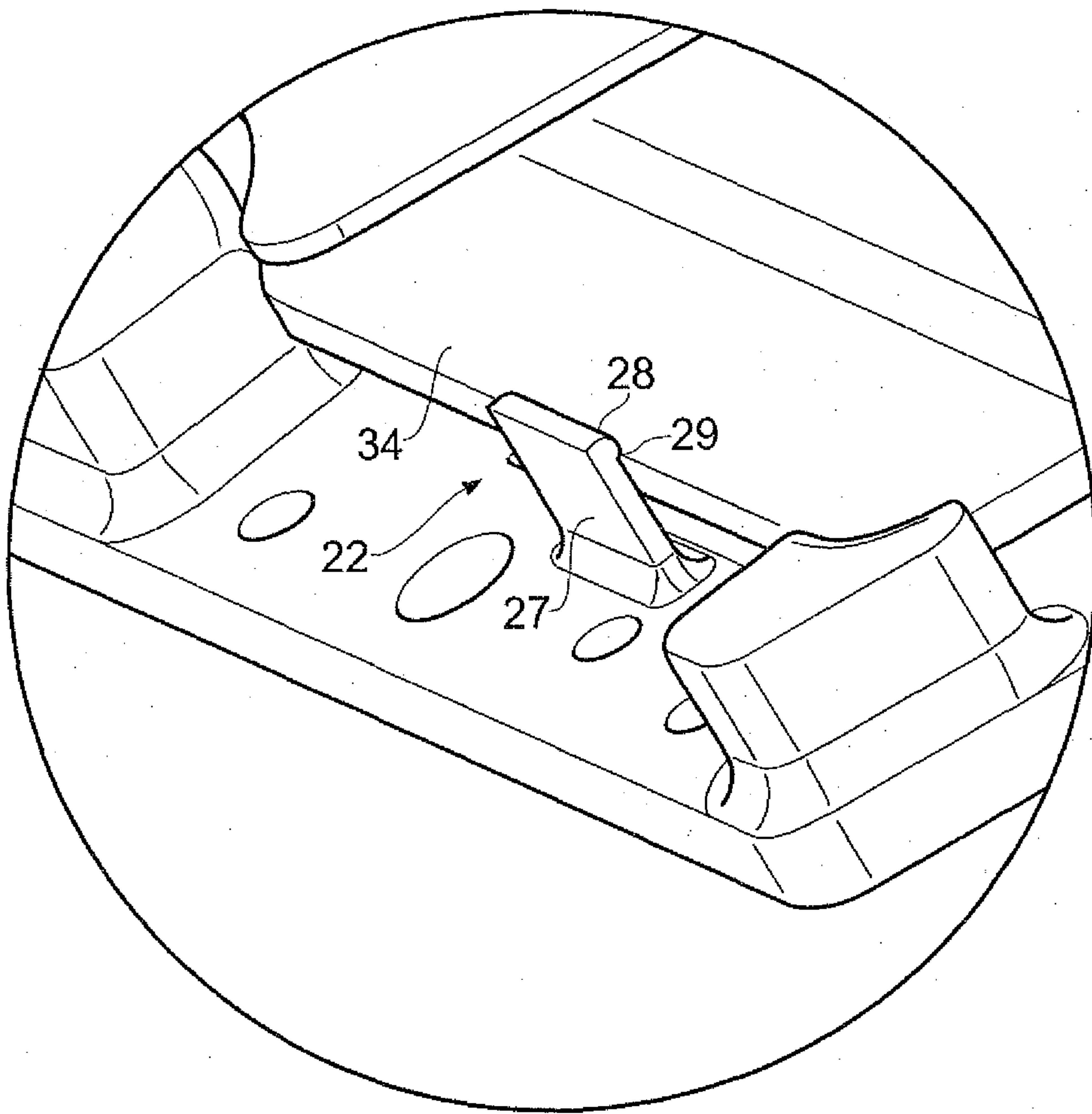


FIG. 5

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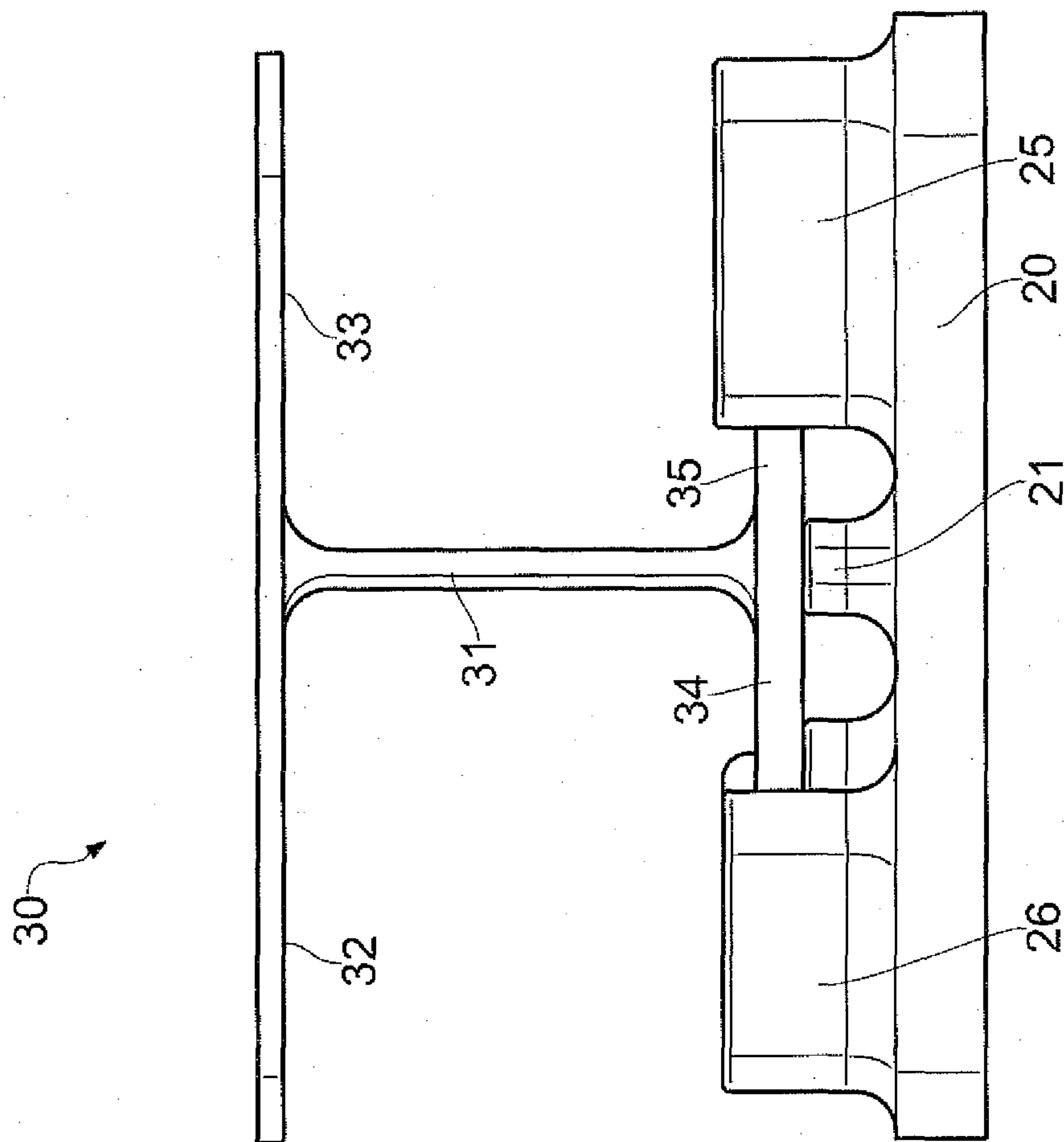


FIG. 6

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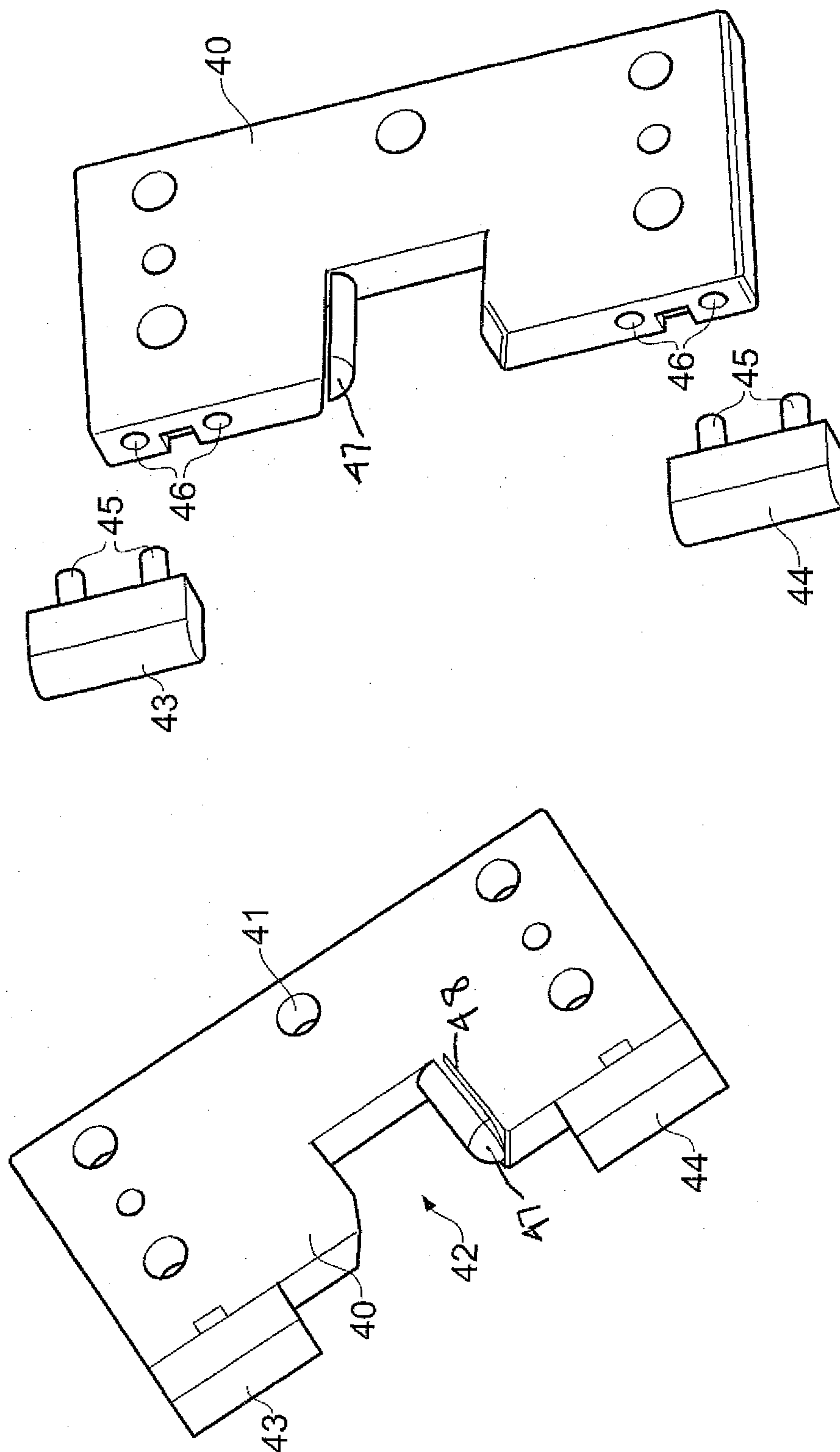


FIG. 7

FIG. 8

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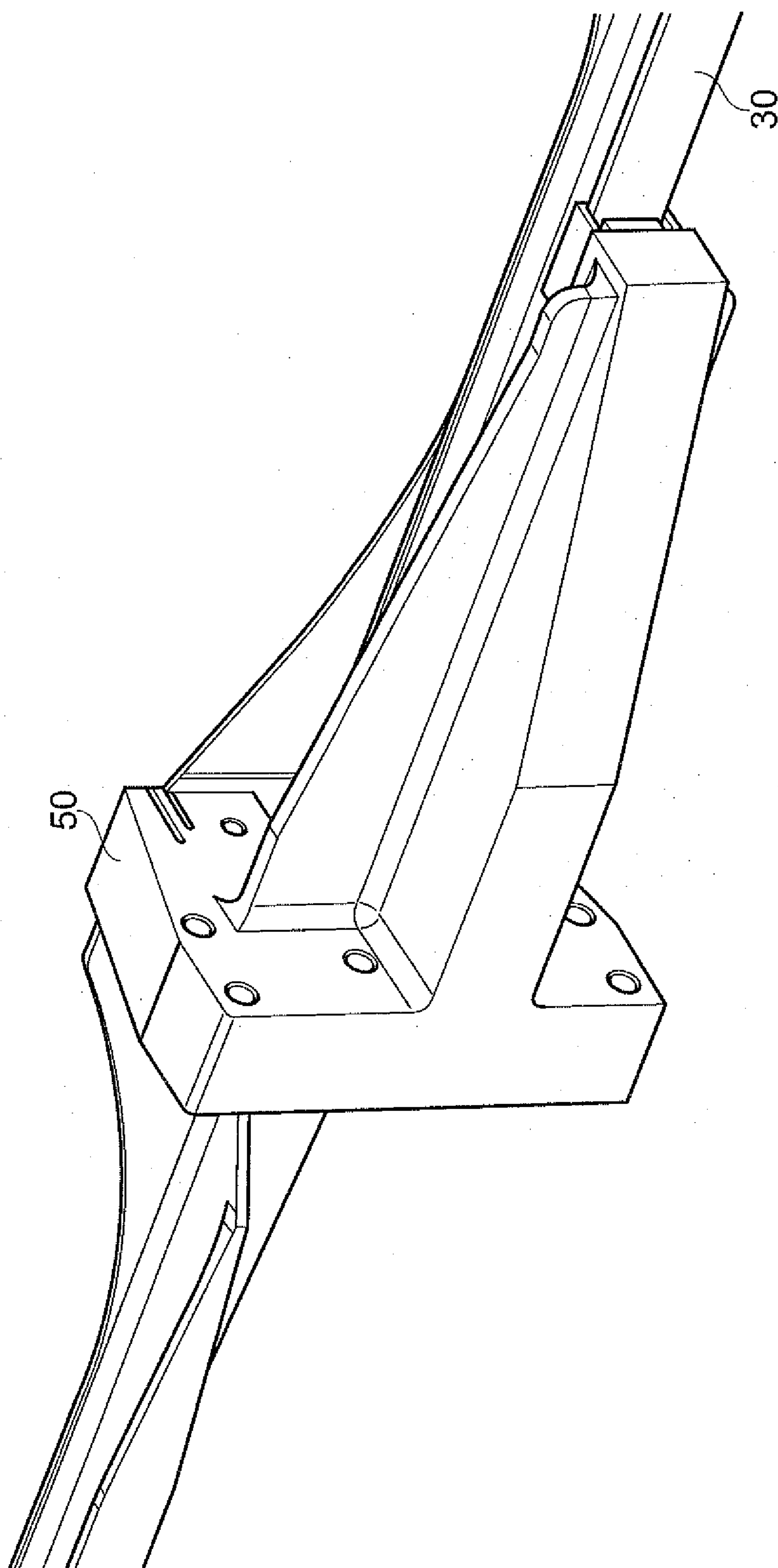


FIG. 9

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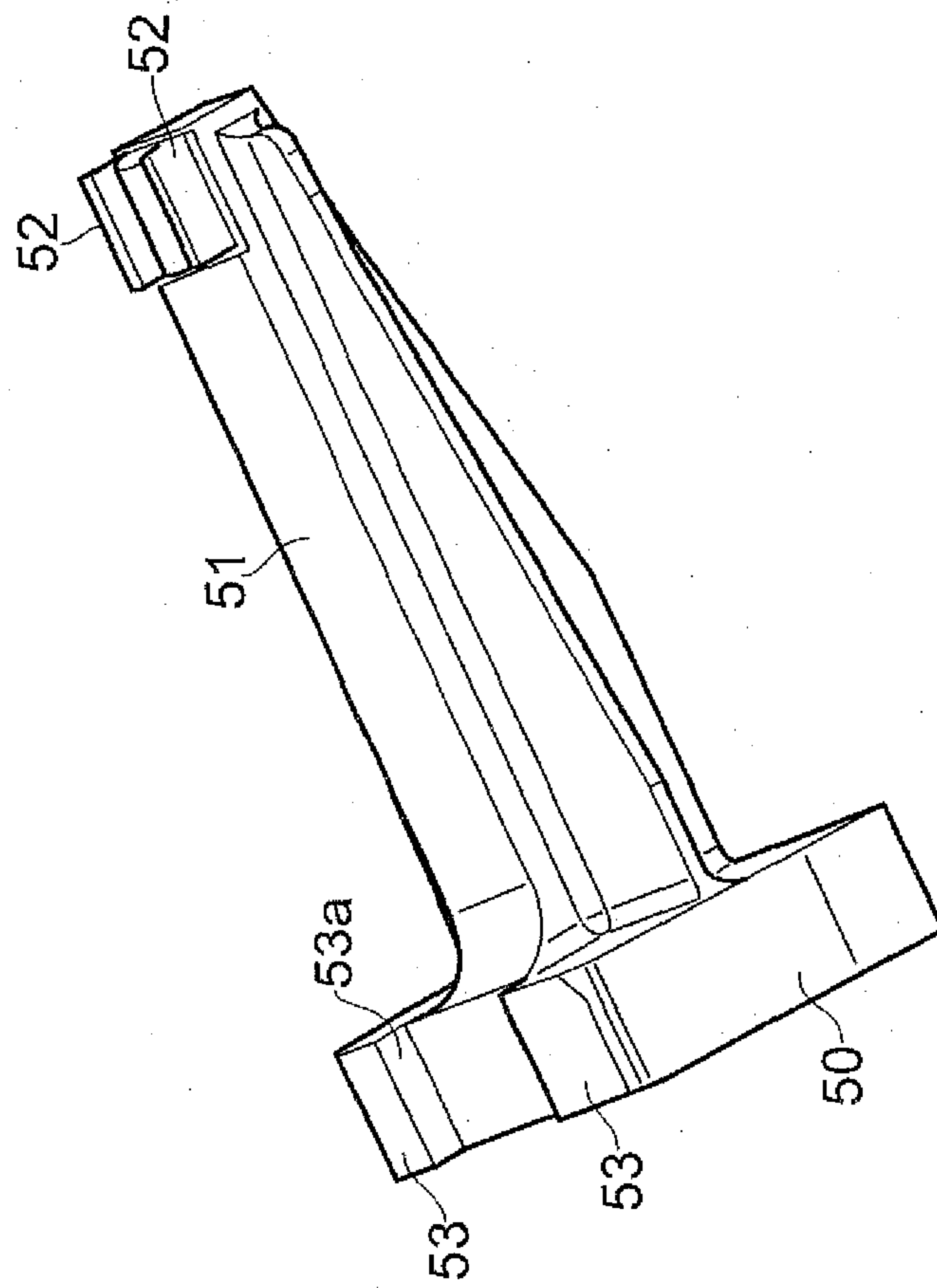


FIG. 10

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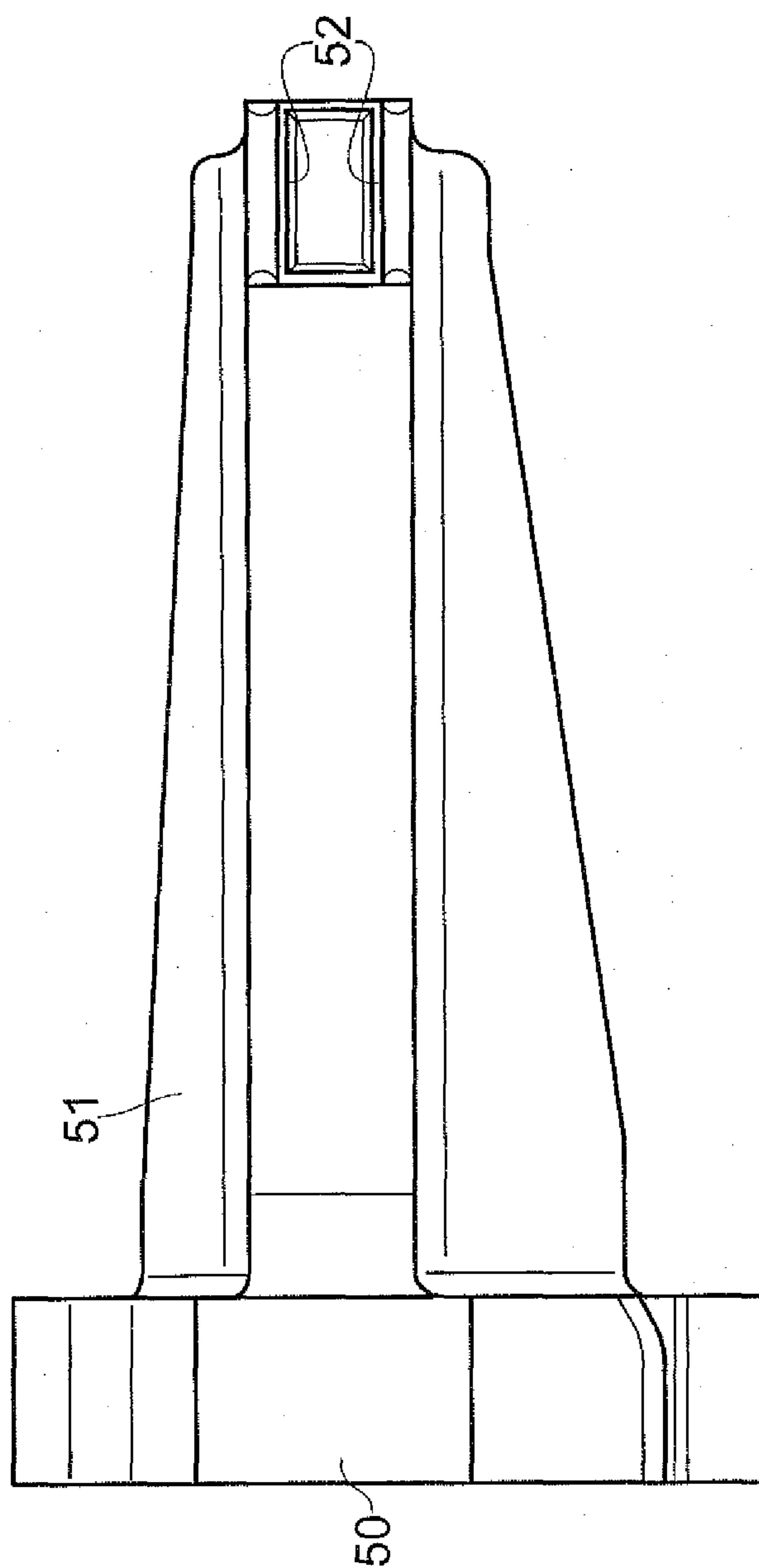


FIG. 11

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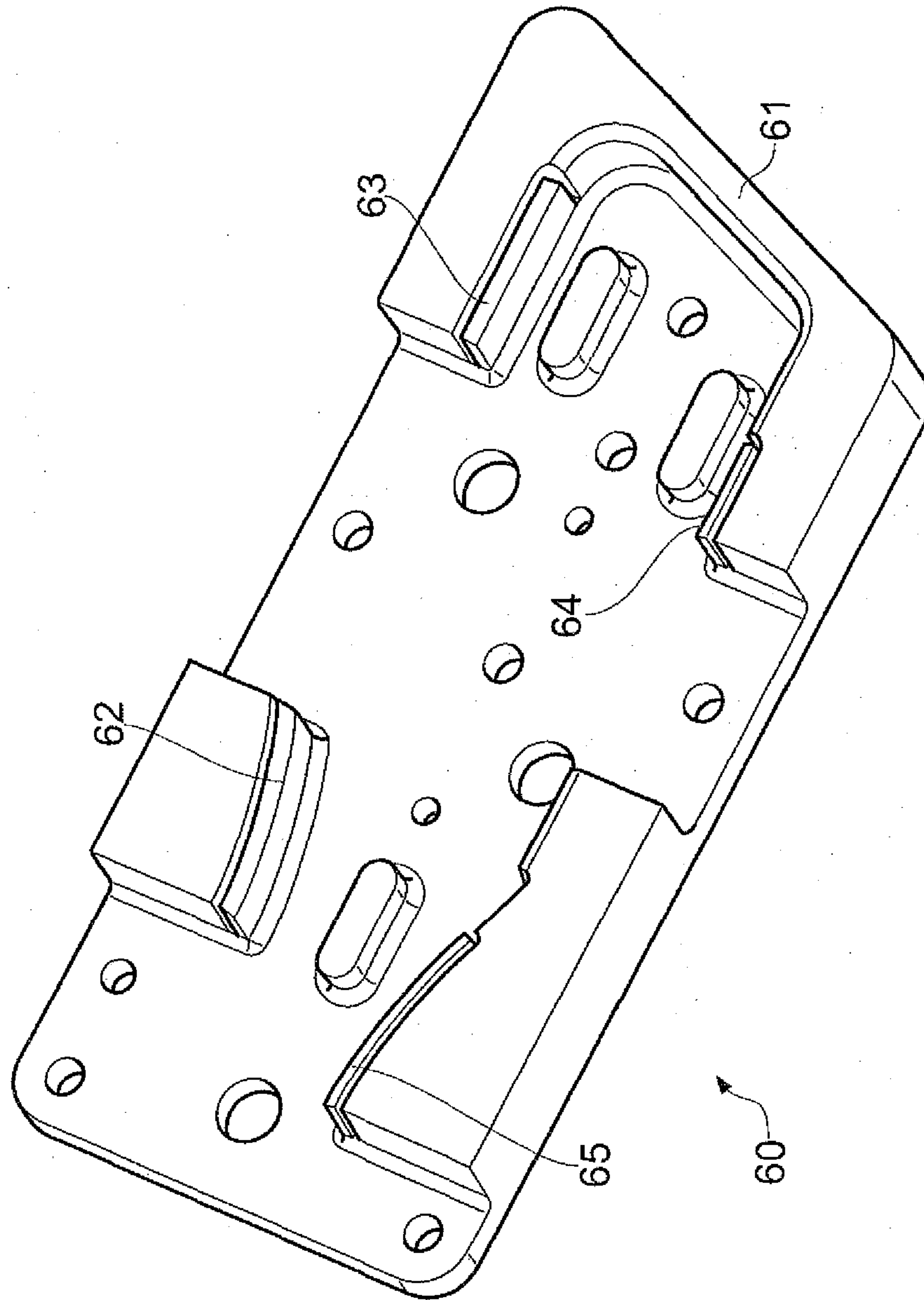


FIG. 12

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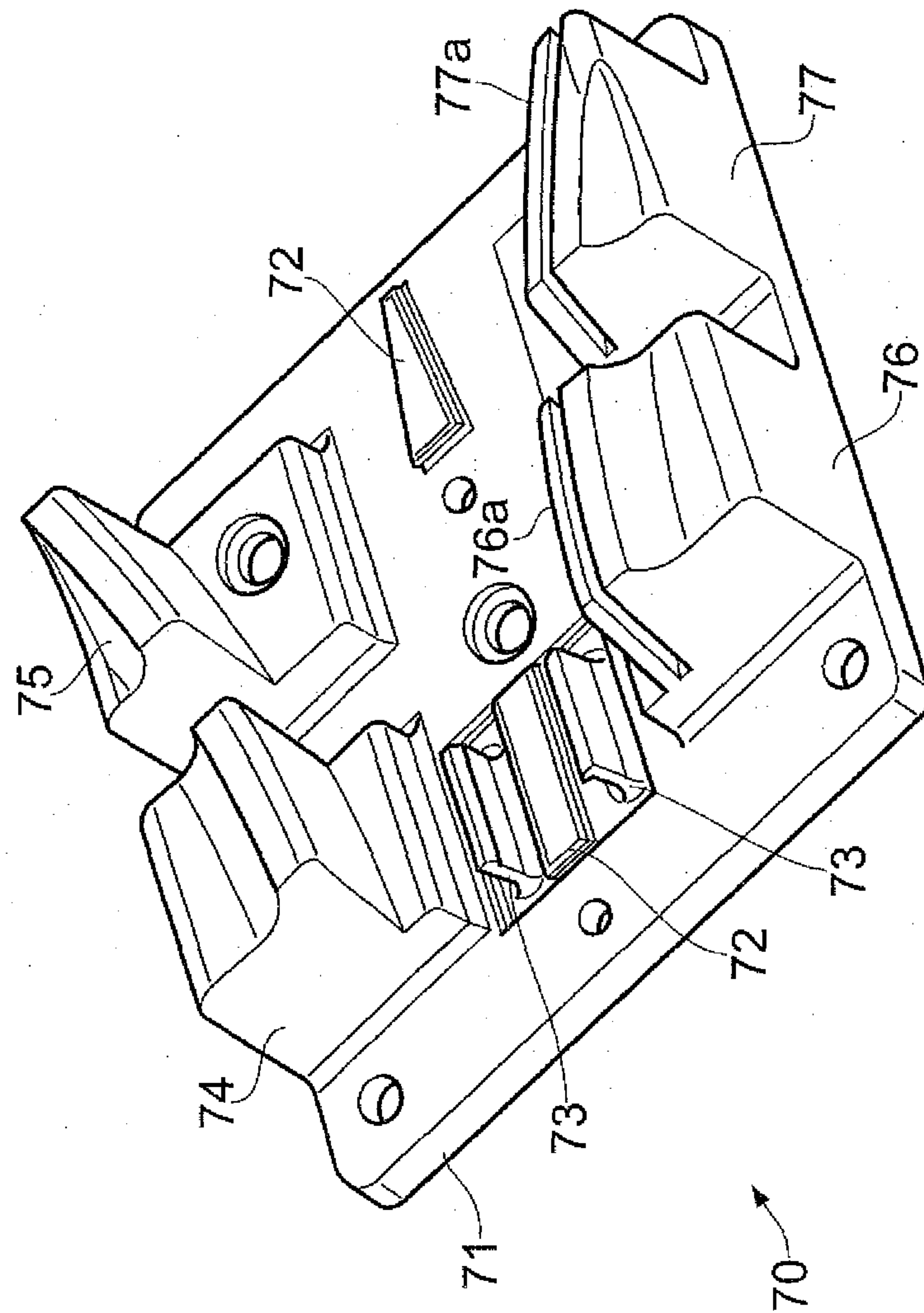


FIG. 13

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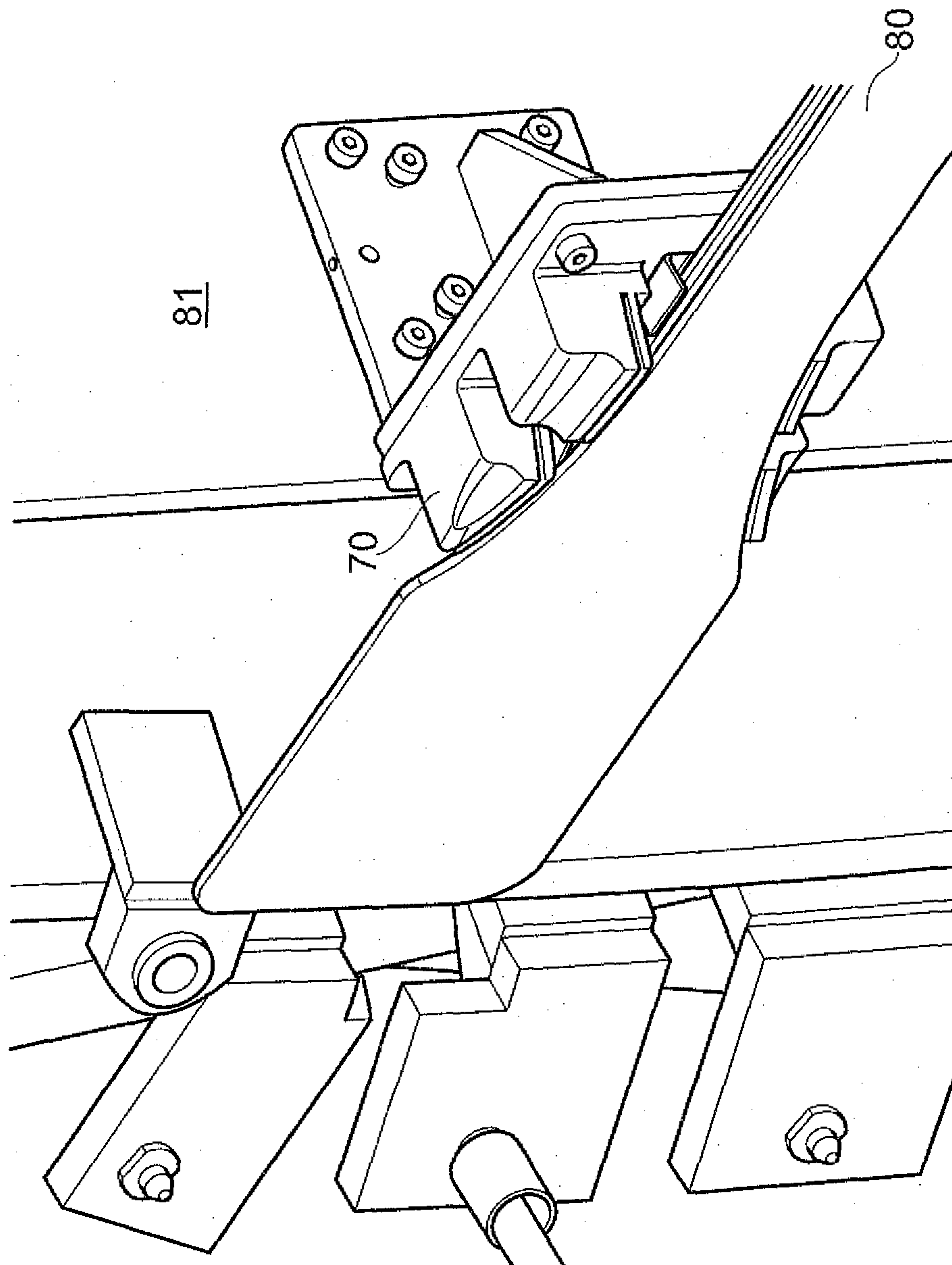


FIG. 14

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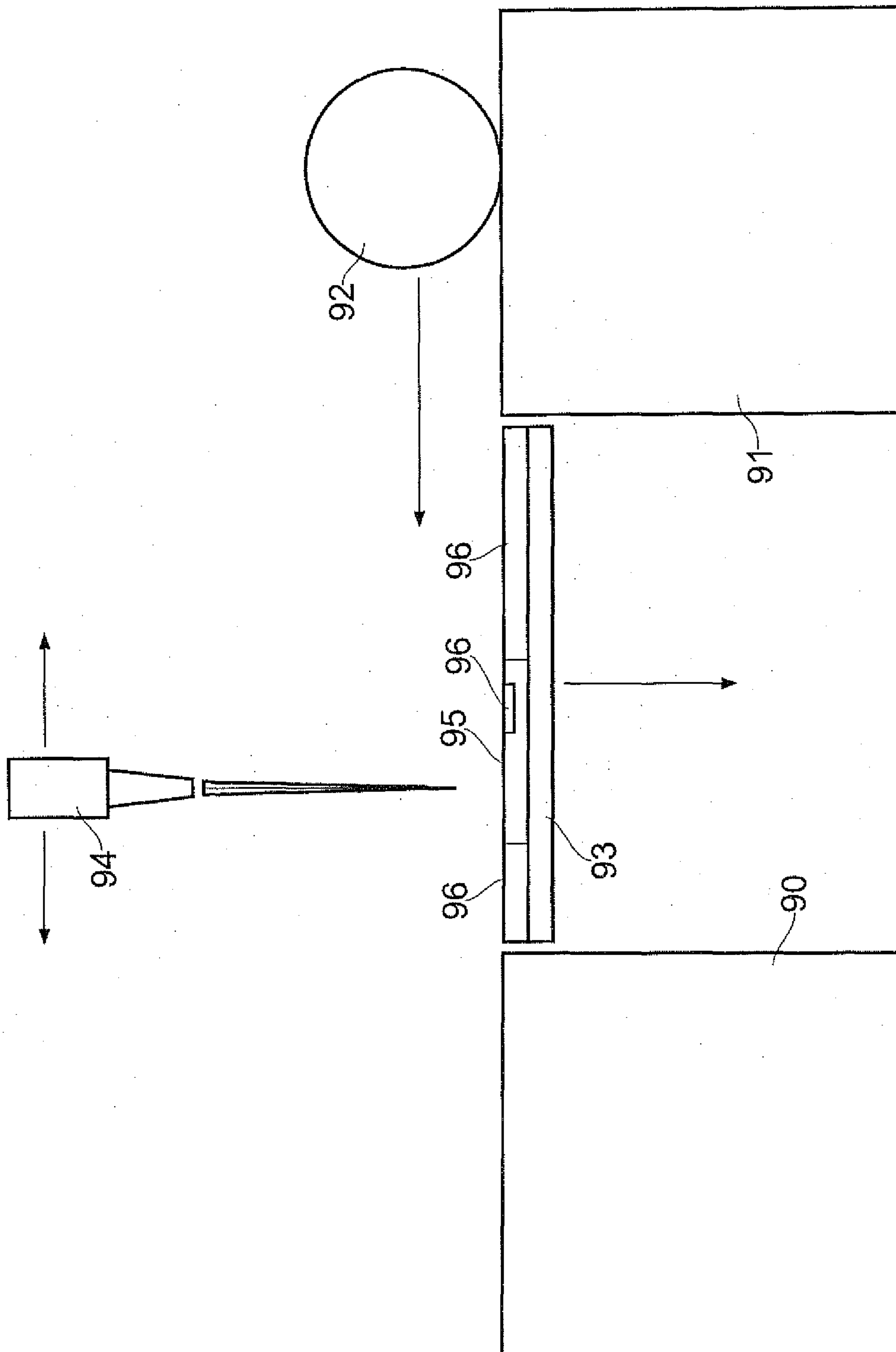


FIG. 15

