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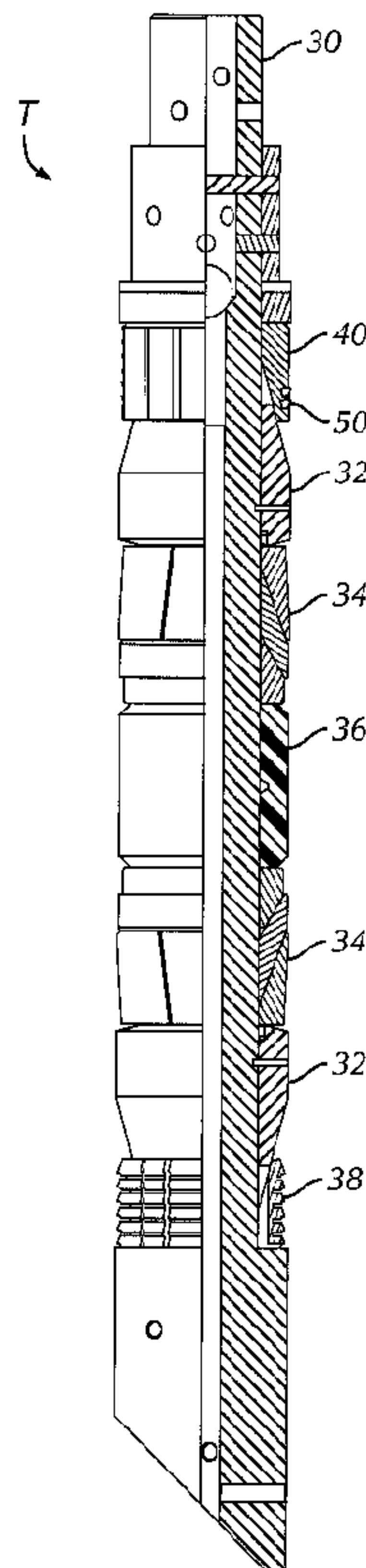
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(54) Titre : COINS DE RETENUE NON METALLIQUES DONT LES INSERTS SONT ORIENTES NORMALEMENT VERS
LA SURFACE DU CONE

(54) Title: NON-METALLIC SLIPS HAVING INSERTS ORIENTED NORMAL TO CONE FACE



(57) Abrégé/Abstract:

A slip assembly for a downhole tool, such as a composite plug, has a slip body and at least one insert. The slip body has an incline at one end that interfaces with an inclined surface of a cone. As this occurs, the slip body is pushed away from the tool's mandrel against a surrounding casing wall. The insert is disposed in the slip body with the axis of the insert angled away from the cone. In particular, the insert's axis is preferably angled normal to the slip body's incline and the inclined surface of the cone.

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ABSTRACT

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A slip assembly for a downhole tool, such as a composite plug, has a slip body and at least one insert. The slip body has an incline at one end that interfaces with an inclined surface of a cone. As this occurs, the slip body is pushed away from the tool's mandrel against a surrounding casing wall. The insert is disposed in the slip body with the axis of the insert angled away from the cone. In particular, the insert's axis is preferably angled normal to the slip body's incline and the inclined surface of the cone.

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2 NON-METALLIC SLIPS HAVING INSERTS ORIENTED NORMAL TO CONE**3 FACE**

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5 FIELD OF THE DISCLOSURE

6 The present disclosure generally relates to slips used for downhole
7 tools, and in particular, relates to slips having inserts for engaging with the casing to
8 stop the tool from moving during operation.

9

10 BACKGROUND OF THE DISCLOSURE

11 Slips are used for various downhole tools, such as composite plugs
12 and packers. The slips can have inserts or buttons to grip the inner wall of a casing
13 or tubular. Examples of downhole tools with slips and inserts are disclosed in U.S.
14 Pat. Nos. 6,976,534 and 8,047,279.

15 Inserts for slips on metallic and non-metallic tools must be able to
16 engage with the casing to stop the tool from moving during its operation. On non-
17 metallic tools, the inserts can cause the non-metallic slips to fail when increased
18 loads are applied. Of course, when the slip fails, it disengages from the casing.

19 Inserts for slips are typically made from cast or forged metal, which is
20 then machined and heat-treated to the proper engineering specifications according
21 to conventional practices. When conventional inserts are used in non-metallic slips,
22 they are arranged and oriented as shown in Figure 1A. The slip 20 is disposed
23 adjacent a mandrel 10 of a downhole tool, such as a composite plug, packer, or the

1 like. The slip 20 moves away from the mandrel 10 and engages against a
2 surrounding tubular or casing wall when the slip 20 and a cone 12 are moved toward
3 one another. Either the slip 20 is pushed against the ramped surface of the cone 12,
4 the cone 12 is pushed under the slip 20, or both.

5 Fig. 2A illustrates a side cross-section of a slip 20 having holes 22 for
6 inserts according to the prior art, and Fig. 2B illustrates a side cross-section of the
7 slip 20 with inserts 24 disposed in the holes 22. Fig. 2C illustrates a front view of the
8 slip 20 with the holes 22 for the inserts. The slip 20 can have a semi-cylindrical
9 shape. The holes 22 in the surface 21 of the slip 20 can be an array of blind
10 pockets. The slip 20 can also have annular slots 26 for a tie strap or other retaining
11 feature. The inserts 24 are anchor studs that load into the pockets 22 and can be
12 held with a press fit or adhesive.

13 As shown in both Figures 1A and 2A, the pockets 22 and the inserts 24
14 disposed in those pockets 22 intersect the slip 20 at an acute bite angle β with
15 respect to a line perpendicular to the slip's surface 21. Thus, the conventional
16 arrangement places the inserts 24 at an angle β toward the ramped surface 13 of
17 the cone 12 and the incline 23 of the slip 20. The angle β can be from 10 to 20-
18 degrees, for example, so that the top face of the insert 20 is oriented at the same
19 angle β relative to the top surface of the slip 20, as best seen in Figure 2B.

20 By providing this angle β , the inserts 24 can better engage the casing
21 wall. For example, when the slip 20 is fully extended to a set position against the
22 casing wall, the inserts 24 inclined by the acute angle β present cutting edges with
23 respect to the inside surface of the casing. With this arrangement, the inserts 24

1 can penetrate radially into the casing. Angled toward the cones 12, this penetration
2 can provide a secure hold-down against pushing and pulling forces that may be
3 applied through the tool's mandrel 10 and element system.

4 The arrangement of the inserts 24, however, can damage the slips 20
5 or the inserts 24 themselves. As shown in Figure 1B, load on the cone 12 during
6 use of the downhole tool can cause the inserts 24 to put stress on the slip 20. As a
7 result, the slip 20 can fracture at the edges of the pockets 22 toward to the top
8 surface 21 and bottom surfaces 27 and 23 of the slip 20. In another form of failure
9 shown in Figure 1B, shear forces on the inserts 24 can cause the exposed ends of
10 the inserts 24 to shear off along the slip's top surface 21.

11 The inserts 24 may also be composed of carbide, which is a dense and
12 heavy material. When the downhole tool having slips 20 with carbide inserts 24 are
13 milled out of the casing, the inserts 24 tend to collect in the casing and are hard to
14 float back to the surface. In fact, in horizontal wells, the carbide inserts may tend to
15 collect at the heel of the horizontal section and cause potential problems for
16 operations. Given that a well may have upwards of forty or fifty composite plugs
17 used during operations that are later milled out, a considerable number of carbide
18 inserts 24 may be left in the casing and difficult to remove from downhole.

19 The subject matter of the present disclosure is directed to overcoming,
20 or at least reducing the effects of, one or more of the problems set forth above.

21

1 **SUMMARY**

2 In one aspect, this disclosure discloses a downhole apparatus
3 comprising:

4 a first slip body having inner and outer surfaces, first and second ends,
5 and a body axis from the first end to the second end, the first end tapered with a first
6 incline on the inner surface, the first incline defining a first angle relative to the body
7 axis, the first slip body disposed with the inner surface adjacent the downhole
8 apparatus and movable away from the downhole apparatus through interaction of
9 the first incline with a portion of the downhole apparatus; and

10 at least one first insert having a first axis of orientation and being
11 exposed in the outer surface of the first slip body, the first axis of orientation being
12 oriented at a first obtuse angle relative to the body axis from the first end of the first
13 slip body.

14 In another aspect of this disclosure, a downhole apparatus is
15 disclosed, said downhole apparatus comprising:

16 a mandrel;

17 a body element disposed on the mandrel; and

18 a slip body having a centerline, inner and outer surfaces, and first and
19 second ends, the first end tapered with an incline on the inner surface, the incline
20 defining a first angle relative to the centerline, the slip body disposed with the inner
21 surface adjacent the mandrel and movable away from the mandrel through
22 interaction of the incline with the body element; and

1 at least one first insert having a first axis of orientation and being
2 exposed in the outer surface of the first slip body, the first axis of orientation being
3 oriented at a first obtuse angle from the first end relative to the body axis of the first
4 slip body.

5

6 **BRIEF DESCRIPTION OF THE DRAWINGS**

7 Fig. 1A illustrates inserts used in a non-metallic slip according to the
8 prior art.

9 Fig. 1B illustrates the slip of Fig. 1A during one type of failure.

10 Fig. 1C illustrates the slip of Fig. 1B during another type of failure.

11 Fig. 2A illustrates a side cross-section of a slip having holes for inserts
12 according to the prior art.

13 Fig. 2B illustrates a side cross-section of the slip with inserts disposed
14 in the holes.

15 Fig. 2C illustrates a front view of the slip with the holes for the inserts.

16 Fig. 3 illustrates a downhole tool in partial cross-section having a slip
17 assembly according to the present disclosure.

18 Fig. 4A illustrates an isolated view of a slip with inserts according to the
19 present disclosure.

20 Fig. 4B illustrates an isolated view of the slip assembly having the slip
21 with inserts disposed adjacent a mandrel and a cone.

22 Fig. 5A illustrates inserts according to the present disclosure for a slip
23 shown disengaged with a casing wall.

1 Fig. 5B illustrates the slip of Fig. 5A engaged with the casing wall.

2 Fig. 6 illustrates different aspects of an insert according to the present
3 disclosure.

4 Fig. 7 illustrates a geometric arrangement for the slip assembly of the
5 present disclosure.

6 Figs. 8A-8B illustrate different orientations of the pockets for the inserts
7 in the slip.

8 Fig. 9A illustrates variations for the faces on the top end of the inserts.

9 Fig. 9B illustrates an alternative arrangement of an insert disposed on
10 a slip according to the present disclosure.

11 Figs. 10A-10C illustrate slips having various arrangements of inserts
12 according to the present disclosure.

13 Figs. 11A-11B illustrate slips having other arrangements of inserts and
14 pads according to the present disclosure.

15 Fig. 12 illustrate various types of inserts in cross-section for the slip
16 assembly of the present disclosure.

17 Fig. 13 illustrates a front view of a slip having pockets for inserts
18 according to the present disclosure.

19 Figs. 14A-14B illustrate front and side perspective view of the slip in
20 Fig. 13 having inserts disposed in the pockets.

21 Fig. 15 illustrates a perspective view of a slip assembly having slips
22 integrated together in a ring.

1 Fig. 16A illustrates a slip, an element, and a backup ring according to
2 the present disclosure in an unset condition.

3 Fig. 16B illustrates the slip, the element, and the backup ring according
4 to the present disclosure in a set condition.

5 Figs. 17A-17B illustrate graphs of slip assemblies with a conventional
6 insert design of the prior art during failure testing.

7 Figs. 18A-18B are photographs of slip assemblies with the
8 conventional insert design of the prior art after failure testing.

9 Fig. 19 illustrates a graph of a slip assembly having an insert design of
10 the present disclosure during testing.

11 Fig. 20 is a photograph of a slip assembly having an insert design of
12 the present disclosure after testing.

13 Figs. 21A-21C illustrate cross-sectional and perspective views of a slip
14 having alternative inserts for a slip assembly according to the present disclosure.

15 Figs. 22A-22C illustrate cross-sectional view of slips having other
16 alternative inserts.

17 Fig. 23A-1 illustrates a side view of a composite plug having upper and
18 lower slip assemblies according to the present disclosure.

19 Figs. 23A-2 and 23A-3 illustrate detailed views of the upper and lower
20 slip assemblies, respectively.

21 Fig. 23B-1 illustrates a cross-sectional view of the bridge plug in Fig.
22 23A-1.

1 Figs. 23B-2 and 23B-3 illustrate detailed cross-sectional views of the
2 upper and lower slip assemblies, respectively.

3 Fig. 24A illustrates a side view of another composite plug having upper
4 and lower slip assemblies according to the present disclosure.

5 Fig. 24B illustrates a detailed view of the lower slip assembly.

6 Figs. 25A-25E illustrate various views of another slip assembly
7 according to the present disclosure.

8 Figs. 26A-26D illustrate various views of another composite plug
9 having additional embodiments of upper and lower slip assemblies according to the
10 present disclosure.

11

12 **DETAILED DESCRIPTION OF THE DISCLOSURE**

13 Figure 3 illustrates a downhole tool T in partial cross-section having a
14 slip assembly, body, or unit according to the present disclosure. The downhole tool
15 T can be a composite plug as shown, but it could also be a packer, a liner hanger,
16 an anchoring device, or other downhole tool.

17 The tool T has a mandrel 30 having cones 32 and backup rings 34
18 arranged on both sides of a packing element 36. Outside the inclined cones 32, the
19 tool T has slips 38 and 40. Together, the slip 38 and 40 along with its corresponding
20 cone 32 can be referred to as a slip assembly, unit, or body, or in other instances,
21 just the slip 38 and 40 may be referred to as a slip assembly, unit, or body. In either
22 case, either reference may be used interchangeably throughout the present
23 disclosure.

1 As shown herein, the tool T can have two types of slips 38 and 40, one
2 of which may be a conventional wicker slip 38 while the other slip 40 has inserts or
3 buttons 50 according to the present disclosure. It will be appreciated, of course, that
4 both ends of the tool T can have slips 40 with inserts or buttons 50 as proposed
5 herein. Thus, although only one slip 40 with inserts 50 is shown for the upper slip
6 assembly in Figure 3, the slip 40 can be used as an upper slip, as a lower slip, or as
7 both upper and lower slips on the downhole tool T. Moreover, rather than a wicker
8 slip 38, the tool T may have another slip with inserts with a prior art arrangement as
9 discussed previously.

10 As a composite plug, the tool T is preferably composed mostly of non-
11 metallic components according to procedures and details as disclosed, for example,
12 in U.S. Pat. No. 7,124,831. This makes the tool T easy to mill out after use.

13 When deployed downhole, the plug T is activated by a wireline setting
14 tool (not shown), which uses conventional techniques of pulling against the mandrel
15 30 while simultaneously pushing upper components against the slips 40. As a
16 result, the slips 38 and 40 ride up the cones 32, the cones 32 move along the
17 mandrel 30 toward one another, and the packing element 36 compresses and
18 extends outward to engage a surrounding casing wall. The backup elements 34
19 control the extrusion of the packing element 36. The slips 38 and 40 are pushed
20 outward in the process to engage the wall of the casing, which both maintains the
21 plug T in place in the casing and keeps the packing element 36 contained.

22 The force used to set the plug T may be as high as 30,000 lbf. and
23 could even be as high as 85,000 lbf. These values are only meant to be examples

1 and could vary for the size of the tool. In any event, once set, the plug T isolates
2 upper and lower portions of the casing so that frac and other operation can be
3 completed uphole of the plug T, while pressure is kept from downhole locations.
4 When used during frac operations, for example, the plug T may isolate pressures of
5 10,000 psi or so.

6 As will be appreciated, any slipping or loosening of the plug T can
7 compromise operations. Therefore, it is important that the slips 38 and 40
8 sufficiently grip the inside of the casing. At the same time, however, the plug T and
9 most of its components are preferably composed of millable materials because the
10 plug T is milled out of the casing once operations are done, as noted previously. As
11 many as fifty such plugs T can be used in one well and must be milled out at the end
12 of operations. Therefore, having reliable plugs T composed of entirely of (or mostly
13 of) millable material is of particular interest to operators. To that end, the slip
14 assemblies of the present disclosure are particularly suited for such composite plugs
15 T, as well as packers, and other downhole tools, and the challenges they offer.

16 Contrary to the conventional arrangement of cylindrical shaped inserts
17 disposed at an acute angle toward the inclined end of the slip, the slip 40 of the
18 present disclosure has inserts 50 in an entirely different orientation. As shown in
19 Figures 4A-4B, the slip 40 has a slip body, element, or segment 41, which can
20 comprise one of several segments of a slip assembly as shown here disposed
21 around the tool's mandrel. The slip body 41 is composed of a first material and has
22 at least one insert 50 composed of a second material exposed in the body's outer
23 surface 44. The first and second materials are preferably different, but they could be

1 the same. In general, the first material of the slip body 41 can be steel, composite,
2 or the like. Preferably, the slip body 41 is composed of a millable material, such as a
3 non-metallic material, a molded phenolic, a laminated non-metallic composite, an
4 epoxy resin polymer with a glass fiber reinforcement, thermoplastic material,
5 injection-molded plastic material, etc.

6 The second material of the inserts 50 can be can metallic or non-
7 metallic materials. For example, the inserts 50 can be composed of carbide or a
8 metallic-ceramic composite material as conventionally used in the art. Preferably,
9 the inserts 50 are composed of a cast iron, a composite, a ceramic, a cermet (*i.e.*,
10 composites composed of ceramic and metallic materials), a powdered metal, or the
11 like. Additionally, the inserts 50 preferably have a sufficient hardness, which may be
12 a hardness equivalent to about 50-60 Rc.

13 As shown, the slip body 41 is generally elongated, being longer than it
14 is wide and being relatively thin. Although this configuration is not strictly necessary,
15 the slip body 41 does generally define a body axis or line running longitudinally
16 along its length (*e.g.*, a longitudinal axis LA or centerline). (For the purposes of
17 discussion, the body axis LA of the slip body 41 is referred to herein as the
18 "longitudinal axis.") The slip's longitudinal axis LA runs parallel to a centerline CL of
19 the tool's mandrel 30, and when the slip 40 is moved for setting against surrounding
20 casing wall, the slip's longitudinal axis LA moves away from the mandrel's centerline
21 CL.

22 The slip body 41 has inner and outer surfaces 42 and 44 and has first
23 and second ends. The first end is tapered with an incline 43 on the inner surface 42,

1 which engages against the inclined surface 33 of the cone 32, as shown in Figure
2 4B. The slip's incline 43 defines a first angle θ_1 relative to the longitudinal axis LA of
3 the slip 40 (and by extension the centerline CL of the assembly (*i.e.*, of the tool T,
4 the mandrel 30, or the like)). As shown in Figure 4B, the cone's inclined surface 33
5 defines a second angle θ_2 relative to the longitudinal axis LA. In a preferred
6 arrangement, the two inclined angles θ_1 and θ_2 are the same or nearly the same.

7 When initially run in hole, the slip 40 is disposed with the inner surface
8 42 adjacent the mandrel 30 of the downhole tool T. During activation, the slip 40
9 moves away from the mandrel 30 through the interaction of the slip's incline 43 with
10 the cone's inclined surface 33. Rather than having the inserts 50 angled at an angle
11 according to the prior art, the inserts 50 have axes or orientation A angled at a third
12 angle θ_3 away from the inclined end of the slip 40. Further details of the
13 arrangement of the inserts 50 are provided below.

14 Figures 5A shows the slip 40 disengaged with a casing wall, while
15 Figure 5B shows the slip 40 pushed against the cone 32 to engage with the casing
16 wall. The inserts 50 are oriented in manner that transfers the load directly through
17 the base of the insert 50, which puts the insert 50 in compression against the casing.
18 This load arrangement reduces the stress on the non-metallic slips 40 and enhances
19 the performance of the non-metallic inserts 50, which in general preferably have
20 good compressive strength.

21 As depicted, the inserts 50 have one or more angled or conical
22 surfaces exposed on the slip 40 that allow for proper engagement and load transfer
23 to the casing. As shown in Figure 6, for example, the insert 50 has a body 52, which

1 can be cylindrical 52a, rectangular 52b, or any other suitable shape (e.g., triangular,
2 polygonal, etc.). The base or bottom end 54 of the insert 50 can be flat to evenly
3 distribute load.

4 As is typical, the insert 50 can be constructed from a long, wide bar or
5 rod that is then machined to the prior length and width and given suitable faces.
6 This technique is well suited for carbide or other hard types of materials and may
7 also be used for other disclosed materials. Alternatively, the inserts 50 can be cast
8 directly with the surfaces and size needed, if the material and tolerances allows for
9 it.

10 In contrast to the flat bottom ends 54, the top end of the insert 50 can
11 have one or more angled faces 56 and 58 on either side of the body's center axis
12 (i.e., the axis A of orientation). A lead face 56, for example, angles from the central
13 axis A at a lead angle α , which creates a wicker edge 57. When exposed in the
14 slip's outer surface, this lead face 56 faces toward the inclined end of the slip 40.

15 The sharpness of the edge 57 can be increased by a tail face 58 on
16 the insert 50, which can angle from the central axis A at a tail angle ϕ . The tail face
17 58 faces toward the butt end of the slip 40, but other arrangements of inserts 50 do
18 not necessarily have such a tail face 58.

19 These faces 56 can be circular or rectilinear depending on the outer
20 shape of the body 52. Further details of the various angles α and ϕ , faces 56 and
21 58, central axis A, and other features of the insert 50 are discussed below.

22 In the disclosed arrangement of Figures 5A-5B, stress on the non-
23 metallic slip 40 can be reduced because the normal load from the cone 32 is

1 distributed against the base 54 of the insert 50. In a conventional arrangement
2 discussed previously with reference to Figures 1A-1C, for example, the normal load
3 acting on a prior art insert 24 from the cone 32 causes a point load on the slip 20
4 against the insert 24, which leads to fracturing. Moreover, shear loads on the inserts
5 50 in the disclosed arrangement can be reduced, allowing the inserts 50 to perform
6 at higher loads—even when the inserts 50 are non-metallic. Thus, the disclosed slip
7 and insert design is believed to allow for higher loads/pressures than the
8 conventional composite slip designs.

9 Looking at the geometric arrangement for the slip assembly in more
10 detail, Figure 7 shows a slip 40 interacting with a cone 32. As noted above, the
11 inclined surface 33 of the cone defines an angle θ_2 roughly the same as the angle θ_1
12 of the slip's incline 43. In general, the angles θ_1 , θ_2 between the slip and cone can
13 be anywhere from 5 degrees to 75 degrees, but preferably the angles θ_1 , θ_2 are
14 around 15-degrees, which will be used in the examples herein.

15 As noted above, the top end of the insert 50 is exposed in the outer
16 surface 44 of the slip 40, and the axis of orientation A of the insert 50 is oriented
17 oblique (not perpendicular or parallel) to the longitudinal axis LA of the slip 40 (and
18 by extension to the centerline CL of the assembly (*i.e.*, of the mandrel 30, tool, or the
19 like)). In fact, the axis A is shown oriented at a first obtuse angle σ_1 relative to the
20 longitudinal axis LA. Moreover, as specifically shown in the present arrangement,
21 the axis A of the insert 50 is preferably oriented normal to the incline 43 on the slip
22 40 so that the bottom end 54 of the insert 50 is approximately parallel to the incline
23 43.

1 With the insert 50 disposed in the slip 40 normal to the incline 43, the
2 angle α of the lead face 56 is selected based on the angle θ_1 of the incline 43 such
3 that the face's angle α defines a second obtuse angle σ_2 relative to the longitudinal
4 axis LA. The second obtuse angle σ_2 is approximately the sum of 90 degrees, the
5 first angle θ_1 of the incline 43, and the angle α of the lead face 56. As shown here,
6 for example, the angle θ_1 of the incline 43 can be approximately 15-degrees, and the
7 angle α of the lead face 56 on the insert 50 can be approximately 55-degrees. This
8 would provide the lead face 56 with an angle μ of about 20-degrees outward from
9 the outer surface 44 of the slip 40.

10 These angles can vary depending on the implementation, the diameter
11 of the tool, the number of inserts 50 in the slip 40, the number of slips 40 used in the
12 assembly, and other factors. In general, an incline angle θ_1 of 15-degrees, plus or
13 minus 5-degrees either way may be preferred. Likewise, the angle α of the lead face
14 56 may be preferably 55-degrees, plus or minus 10 or 15-degrees either way.

15 As noted above, the axis A of the insert 50 can be normal to the incline
16 43 on the slip 40 so the axis A will be perpendicular to the cone's inclined surface 33
17 when engaged thereagainst. Because the slip 40 fits around a cylindrical tool, the
18 slip 40 can define arcuate or partial cylindrical surfaces 42 and 44 as shown in
19 Figures 8A-8B. The axis A for the inserts 50 disposed in the holes or pockets 45 in
20 the slip 40 can be normal to the curvature of the assembly, as in Figure 8A.
21 Alternatively, the axes A of the inserts 50 can be parallel to one another, as in Figure
22 8B, and hence not normal to the curvature. These and other orientations can be
23 used.

1 As noted above, the top end of the insert 50 can have lead and tails
2 faces 56 and 58. Figure 9A illustrates variations for the faces 56 and 58 on the top
3 end of the inserts 50. On the first insert 50₁, for example, the lead and tail faces 56
4 and 58 can be symmetrically arranged so that the angles α , ϕ can be about the
5 same and the wicker edge 57 can lie roughly on the insert's axis A. On the second
6 insert 50₂, for example, the lead and tail faces 56 and 58 can be asymmetrically
7 arranged so that the angles α , ϕ can be the same or different, but the wicker edge
8 57 can lie off of the insert's axis A. Moving the tip of the wicker edge 57 will not
9 necessarily change the preferred angles of the faces 56 and 58. Instead, the angles
10 of the faces 56 and 58 are more generally determined by the initial angle of the cone
11 and slip interface between surfaces 33 and 43 and are not as dependent upon the
12 location of the axis A of the insert 50.

13 The third insert 50₃ shows an example lacking a tail face so that the
14 back edge of the insert 50₃ forms the wicker edge 57 with the lead face 56. Finally,
15 the fourth insert 50₄ has an angled lead face 56 and a flat tail face 58 that still forms
16 a wicker edge 57. As will be appreciated, the insert 50 of the present disclosure can
17 have these and other configurations.

18 In fact, Figure 9B illustrates an alternative arrangement of inserts 50
19 disposed on a slip 40 according to the present disclosure. Here, the inserts 50 are
20 cylindrical in shape as with conventional arrangements, but they are disposed in
21 angled pockets 47 in the slip 40 that direct the inserts 50 away from the inclined end
22 of the slip 40. In other words, the axes of orientation A of the inserts 50 can be

1 angled at an obtuse angle σ relative to the assembly's longitudinal axis LA. This
2 angle σ in one implementation can be about 160-degrees.

3 As noted above, various configurations of inserts 50 can be used for
4 the slips 40. To that end, Figures 10A-10C illustrate examples of slips 40 having
5 various arrangements of inserts 50a, 50b, 50c, and 50d according to the present
6 disclosure, which are also separately depicted in cross-section in Figure 12 for
7 reference. In Figure 10A, the slip 40 has a first type of insert 50a toward the slip's
8 inclined end and has a second type of insert 50b toward the slip's back end. The
9 first type of insert 50a has a chamfered lead face 56 with a flat top for the tail face
10 58, while the second type of insert 50b has a chamfered lead face 56 only.

11 In Figure 10B, the slip 40 has an insert 50c with a stepped base end
12 55, which can facilitate load distribution. The lead and tails faces 56 and 58 may or
13 may not be symmetrical. In Figure 10C, the inserts 50d having widened bases 57
14 that are pyramid or conical in shape for load distribution. Here in Figure 10C, the
15 two inserts 50d can have different heights h_1 , h_2 , widths, or sizes as well. This can
16 be true for these as well as any other inserts 50 disclosed herein. Moreover, as
17 shown in Figures 10A-10C, the inserts 50 can be molded into the material of the slip
18 40 so that the inserts 50 are shown encapsulated in the slip 40.

19 Alternate components can also be incorporated into the arrangement
20 to distribute the load uniformly. Figures 11A-11B illustrate embodiments of the slip
21 assembly having inserts 50e and 50f and pads 60 and 62 according to the present
22 disclosure. In Figure 11A, a pad 60 is incorporated into the inclined surface 33 of the
23 cone 30 against which the incline 43 of the slip 40 engages. The inserts 50e in this

1 arrangement may pass all the way through the slip 40 to the incline 43, although
2 other embodiments may not necessarily extend that far. In any event, when the slip
3 40 engages the cone 32, the bases of the inserts 50e engage either directly or
4 indirectly against the pad 60, which supports the compressive loads.

5 In Figure 11B, a different pad 62 is disposed on a portion of the slip's
6 incline 43. The bases of the inserts 50f may or may not reach to the surface of the
7 pad 62. Either way, the pad 62 supports the compressive forces of the inserts 50f.
8 Although not shown, yet another arrangement may have both pads 60 and 62 for
9 supporting the compressive loads of the inserts 50f.

10 The pads 60 and 62 are composed of a third material, which may be
11 different than the materials of the inserts 50 and the slip 40. In general, the third
12 material of the pad 60 and 62 can be a thermoplastic, composite, or any other
13 suitable material. In general, the pad 60 and 62 is preferably a higher strength,
14 denser material than the slip material, which can be a more brittle, injection molded
15 composite. Also, the material of the pads 60 and 62 is preferably millable. As will
16 be appreciated, anywhere from two to five different materials can be utilized for the
17 arrangements of Figures 11A-11B. Two materials may be present if the slip 40 and
18 the cone 32 are of the same material, and the pad 60 or 62 and the insert 50 are of
19 the same material. Four materials may be present if the cone 32, the pad 60 or 62,
20 the slip 40, and the insert 50 have different materials from one another. Up to five
21 materials can be present for the embodiment having a pad 60 in the cone 32 and
22 having another pad 62 in the slip 40.

1 As shown in the various views of Figures 13 and 14A-14B, the slip 40
2 can have preconfigured holes or pockets 45 in the outer surface 44 in which the
3 inserts 50 affix using adhesive or the like. The slip 40 can be molded without the
4 pockets 45, which can then be machined, or the slip 40 can be molded with the
5 pockets 45. Alternative forms of constructions can be used, such as molding the
6 inserts 50 directly in the material of the slip 40. Upper and lower slots 48 can also
7 be provided for retaining rings (not shown) typically used to hold the slip 40 against
8 the mandrel of the tool.

9 As shown in Figures 14A-14B, the slip 40 can have a plurality of
10 inserts 50 (*e.g.*, four inserts 50) exposed in the outer surface 44, but any other
11 acceptable number of inserts 50 can be used in symmetrical or asymmetrical
12 arrangements. Preferably, the inserts 50 are arranged so that the wicker edges 57
13 are parallel to evenly distribute forces. As shown, each of the inserts 50 used on a
14 given slip 40 may be the same, but as detailed previously, different types of inserts
15 50 as disclosed herein can be used on the same slip 40.

16 Although all of the inserts 50 are shown symmetrically arranged with
17 their axes angled away from the slip's inclined end, this is not strictly necessary.
18 Instead, some of the inserts (not shown) can be arranged in a conventional manner
19 with the insert's axis angled in an acute angle toward the slip's inclined end, while
20 other inserts 50 can be angled in the manner disclosed herein.

21 As shown in Figures 14A-14B, the slip body 41 can be one of a
22 plurality of independent slip bodies, elements, or segments of a slip assembly that
23 fits around the mandrel of a downhole tool. A number (*e.g.*, six or eight) of the slip

1 bodies 41 can encircle the mandrel to form a slip ring to secure the tool in the
2 surrounding casing. As shown in Figure 15, however, the slip body 41 may
3 comprises one of several integrated slips or segments 40 of a slip assembly. The
4 slip bodies 41 have inserts 50 exposed on their outer surfaces and have ends
5 connected together at a ring structure 49 of the assembly. These and other
6 arrangements can be used.

7 In previous arrangements, the slip 40 with inserts 50 is used with a
8 cone 32 on a mandrel of a tool T. As noted previously, the tool T can be a
9 composite plug that can have a packing element for engaging a casing wall. In
10 another arrangement, Figures 16A-16B show embodiments of an assembly having
11 an inclined surface 73 integrated into a packing element 70. An intermediate
12 element or backup ring 80 disposes between the incline 43 of the slip 40 and the
13 inclined surface 73 of the packing element 70. The slip 40 also has inserts 50 as
14 disclosed herein.

15 In an unset condition shown in Figure 16A, the backup ring 80
16 separates the slip 40 from the packing element 70. During compression as shown in
17 Figure 16B, the slip 40 rides up on the backup ring 80, which rides up together with
18 the slip 40 onto the packing element 70. As also shown, the packing element 70
19 extends outward from the mandrel 30 toward the casing wall as it is compressed.
20 The element 70 can be composed of elastomer, and the backup ring 80 can be
21 composed of composite, thermoplastic, or the like. The slip 40 and inserts 50 can
22 be composed of materials as disclosed herein.

1 Figures 17A-17B illustrates graphs of slip assemblies with conventional
2 insert or button designs of the prior art during failure testing. Pressures in the top
3 annulus and bottom annulus that are acting on the plug are labeled as TA and BA,
4 respectively. The temperature for the TA and BA are shown as TOP TEM and BOT
5 TEM, respectively. Figures 18A-18B are photographs of slip assemblies with
6 conventional insert designs of the prior art after failure testing. As typically seen, the
7 inserts have rotated in the slips.

8 By contrast, Figure 19 illustrates a graph of a slip assembly having an
9 insert design of the present disclosure during testing. Pressures in the top annulus
10 and bottom annulus that are acting on the plug are labeled as TA and BA,
11 respectively. The temperature for the TA and BA are shown as TOP TEM and BOT
12 TEM, respectively. Figure 20 is a photograph of a slip assembly having an insert
13 design of the present disclosure after testing. The tested assembly on a composite
14 plug has been sectioned after testing. As can be seen, the inserts arranged normal
15 to the inclined surface of the cone have not caused catastrophic slip failure, and the
16 edges of the inserts remain biting in the casing wall.

17 In previous arrangements, the inserts 50 have been discrete elements
18 either disposed and adhered in holes or pockets in the slip body 41 or molded
19 therein. Rather than using singular discrete elements for inserts, Figures 21A
20 through 22C show alternative inserts 150 according to the present disclosure.
21 These inserts 150 are elongated strips of wire or cut segments of rings affixed or
22 embedded in the slip and exposed on the top surface 44.

1 For example, Figures 21A-21C illustrate cross-sectional and
2 perspective views of a slip 40 having three of these alternative inserts 150 for a slip
3 assembly according to the present disclosure. The inserts 150 are strips or
4 segments of wire having angled sides, much like a V-wire. The inserts 150 affix in or
5 are molded into lateral grooves 47' along the slip's top surface 44. A bottom surface
6 or face 154 of the inserts 150 situates parallel to the slip's incline 43. Thus, as
7 shown in the example angles here, if the incline 43 defines an angle of 15-degrees,
8 then the inserts' bottom faces 154 dispose at a 15-degree angle in the lateral
9 grooves 47'. This arrangement places the bottom faces 154 of the inserts 150
10 parallel to the incline 43 to that force applied against the axis A of the insert A tends
11 to be normal to the incline 43 and the inclined surface (33) of the cone (not shown).

12 Lead faces 156 of the inserts 150 are angled to lie at a preferred angle
13 relative to the slip's top surface 44, which in this example has the faces 156 angled
14 up from the top surface by an angle of 20-degrees. Thus, the lead faces 156 define
15 an obtuse angle with the inclined end of the slip 40 that is about 160-degrees.
16 Meanwhile, tail faces 158 of the inserts 150 are at any other acceptable angle to
17 create a wicker edge 157.

18 Figs. 22A-22C illustrate cross-sectional view of slips 40 having other
19 alternative inserts 150. In Figures 22A and 22C, four inserts 150 are disposed in
20 lateral grooves 47', while Figure 22B shows three inserts 150 as with Figure 21A. In
21 general, any acceptable number of inserts 150 can be used.

22 In Figures 21A and 22A, the bottom surfaces 154 that are parallel to
23 the incline 43 also includes flat portions parallel to the inner surfaces 42 of the slip

1 40. Other arrangements are possible. In Figure 22B, for example, the bottom
2 surfaces 154 also include front edges angled upward toward the inclined end of the
3 slip 40. In Figure 22C, the inserts 150 essentially have a triangular cross-section.
4 As will be appreciated, these and other arrangements can be used.

5 As already hinted to above, the inserts 150 can be manufactured and
6 affixed to the slip 40 in a number of ways. For example, wires of suitable material
7 can be formed having a desired curvature and the appropriate faces using
8 conventional practices. Then, strips of this wire can be affixed as the inserts 150 in
9 pre-machined lateral grooves 47' in the top surface 44 of the slip using adhesive or
10 the like. Alternatively, the strips of the wire can be molded as the inserts 150 into
11 the top surface 44 of the slip 40 during a molding process.

12 Rather than using strips of wire, rings of suitable material can be
13 manufactured with an appropriate diameter for the curvature of the slip assembly.
14 Cut segments of the ring can then be affixed or molded to the slip 40 as the inserts
15 150. This process may be more suited for some harder materials.

16 Moreover, rather than being entirely continuous and curved across the
17 outer surface 44 of the slip 40, the inserts 150 can include several, straight sections
18 that are placed about the lateral curvature of the slip 40.

19 Additional arrangements of slip assemblies having inserts are provided
20 in Figures 23A-1 through 25E. As shown in the side view of Figure 23A-1 and the
21 cross-sectional view of Figure 23B-1, a composite plug T has a mandrel 30 with
22 cones 32 and backup rings 34 arranged on both sides of a packing element 36.
23 Outside the inclined cones 32, the tool T has slip assemblies 40U and 40D, each

1 having one or more slip elements or segments 41 for engaging a wellbore tubular
2 when activated. Together, the slip elements 41 along with the corresponding cones
3 32 can be referred to as a slip assembly, unit, or body, or in other instances, just the
4 slip elements 41 may be referred to as a slip assembly, unit, or body. In either case,
5 either reference may be used interchangeably throughout the present disclosure.

6 The cones 32 have inclined surfaces 33 that face outward and away
7 from the centrally located backup rings 34 and packing element 36. In some
8 embodiments, the inclined surfaces 33 are conical, while the inclined surfaces 33 in
9 other embodiments may be flats as shown. Either type of inclined surfaces 33 can
10 be used.

11 The upper slip assembly 40U (shown in detail in Figs. 23A-2 & 23B-2)
12 has slip elements 41, and the lower slip assembly 40D (shown in detail in Figs. 23A-
13 3 & 23B-3) has slip elements 41 also connected at their ends by an interconnected
14 ring portion 49. Each of the slip elements 41 has inner and outer surfaces 42 and 44
15 and has distal and proximal ends.

16 As shown, the distal ends of the slip elements 41 are tapered with an
17 incline 43 on the inner surface 42 for engaging against and riding up on the inclined
18 surfaces 33 of the corresponding cone 32. As with the cone's inclined surfaces 33,
19 the inclines 43 on the slip elements 41 can be conical or flats. Either type of inclines
20 43 can be used.

21 As also shown, the proximal ends of the slip elements 41 are
22 connected by an interconnected ring portion 49, although this is not strictly

1 necessary on either assembly 40U and 40D as other retention techniques, bands,
2 retainers, or the like can be used.

3 During setting, the slip elements 41 are movable away from the
4 mandrel 30 through interaction of the elements' inclines 43 with the inclined surfaces
5 33 of the cones 32. Beyond these similarities, the upper and lower slip assemblies
6 40U and 40D are different from one another. In particular, each of these upper slip
7 elements 41 has conventional, cylindrical-shaped inserts 24 disposed in the outer
8 surface 44 in a conventional manner. Namely, as best shown in Figs. 23A-2 and
9 23B-2, each of these inserts 24 has its axis A disposed at an acute angle to the
10 inclined surfaces 33 (and comparably to the incline 43 on the element's distal end).
11 By contrast, each of the lower slip elements 41 has inserts 50 disposed in the outer
12 surface 44 with axes A of orientation normal to the inclined surfaces 33 of the cone
13 32 (and comparably to the incline 43) in the manner disclosed herein. Moreover,
14 these inserts 50 can have exposed surfaces at angles disclosed herein and need not
15 be strictly cylindrical.

16 As will be appreciated, the plug T disposed in a wellbore tubular holds
17 pressure during operations, such as a fracturing treatment. The upper and lower
18 assemblies 40U and 40D may experience different setting movements when the
19 plug T is set and when the assemblies 40U and 40D engage the surrounding tubular
20 wall. Additionally, the upper and lower assemblies 40U and 40D may be subjected
21 to different pressures from above and below the plug T once set and used during
22 operations.

1 Having the different arrangement of slip inserts 24 and 50 on the upper
2 and lower assemblies 40U and 40D allows operators to tailor the setting and
3 operation of the plug T to meet the needs of a particular implementation. For
4 example, having the normal-oriented inserts 50 on the downhole assembly 40D can
5 be beneficial in some implementations based on the temperatures encountered and
6 the stress on the slip elements 41 and the inserts 50 of the downhole assembly 40D.
7 In one example, a fracture plug may be expected to hold the fracture treatment
8 pressure from above and little to no pressure from below. Such a fracture plug can
9 utilize this embodiment because the stress exerted on the lower assembly 40D is
10 expected to be much greater than the upper assembly 40A. Another benefit is that
11 the conventional inserts on the upper assembly 40U may be a lower cost alternative
12 when compared to normal-oriented inserts on the lower assembly 40D.

13 As shown in the side view of Figure 24A, another composite plug T
14 again has a mandrel 30 with cones 32 and backup rings 34 arranged on both sides
15 of a packing element 36. Outside the inclined cones 32, the tool T has slip
16 assemblies 40U and 40D. In this embodiment, the assemblies 40U and 40D are the
17 same as one another. A detailed view of the lower slip assembly 40D is shown in
18 Figure 24B. Each of the assemblies 40U and 40D has first inserts 24 disposed in
19 the slip elements 41 in the conventional manner. Each of the assemblies 40U and
20 40D also has second inserts 50 disposed normal to the inclined surfaces 33 of the
21 cone 32 in the manner disclosed herein. The second inserts 50 are disposed
22 towards the distal ends of the slip elements 41, while the first inserts 24 are

1 disposed towards the elements' proximal ends, although other arrangements are
2 possible.

3 As can be seen by the above embodiments, the slip assemblies 40U
4 and 40D on the composite plug T can have different inserts from one another (Fig.
5 23A-1) or can have the same inserts as one another (Fig. 24A). Also, each of the
6 elements 41 on the upper and lower slip assemblies 40U and 40D can have the
7 same configurations of inserts. As an alternative, however, each of the elements 41
8 on the upper and lower slip assemblies 40U and 40D can have different
9 configurations of inserts.

10 For example, all the elements of a slip assembly can have normal-
11 oriented inserts 50 disposed in one row and can have conventional inserts 24
12 disposed in another row. Other alternates may include: various arrangements and
13 quantities of conventional inserts 24 and normal-oriented inserts 50 on the slip
14 elements 41, differing combinations of normal and conventional inserts 24 and 50 on
15 the upper slip assembly 40U versus the lower slip assembly 40D, or alternating
16 elements 41 of the slip assembly 40 with various arrangements of normal and
17 conventional inserts 24 and 50.

18 As shown in Figures 25A-25E, example, a slip assembly 40 according
19 to the present disclosure can have alternating arrangements of inserts on the
20 various slip elements 41 of the assembly 40. First alternating ones of the slip
21 elements 41 have four inserts 50 arranged normal to the inclined surfaces 43.
22 Second alternating ones of the slip elements 41, however, have three inserts 24 and
23 50. One of these inserts 24 is disposed towards the proximal end of the element 41

1 and is disposed in the conventional manner. The other inserts 50 are disposed
2 toward the distal end of the slip element 41 and are arranged normal to the inclined
3 surfaces 43.

4 As depicted here, alternating elements 41 of the slip assembly 40 have
5 various arrangements of normal and conventional inserts 24 and 50—*i.e.*, one
6 element 41 has all normal inserts 50, the next element 41 has all conventional
7 inserts 24 or some combination of the two inserts 24 and 50, or two adjacent
8 elements 41 have different arrangements of the two types of inserts 24 and 50. The
9 same types of normal-oriented inserts 50 can be used throughout the assembly 40,
10 but this is not strictly necessary. Instead, different types of the normal-oriented
11 inserts 50 disclosed herein can be used on the various elements 41. Moreover,
12 although the arrangement can be symmetrical as shown, this may not be strictly
13 necessary in practice either.

14 Having the different arrangement of slip inserts 24 and 50 on the
15 assemblies 40 of Figures 24A to 25E allows operators to tailor the setting and
16 operation of the plug T to meet the needs of a particular implementation. For some
17 plug geometries, for example, the embodiments shown Figures 24A to 25E can be
18 utilized because the stress on the slip assemblies 40 may not require as many
19 normal-oriented inserts 50 to be utilized. One or more normal-oriented inserts 50
20 can prevent slip fracture and the conventional (similar or dissimilar material) inserts
21 24 can be utilized to maintain casing bite. Another benefit is the conventional inserts
22 24 may be a lower cost alternative when compared normal-oriented inserts 50.

1 In yet another example, Figures 26A-26D illustrate various views of
2 another composite plug T having additional embodiments of upper and lower slip
3 assemblies 40U and 40D according to the present disclosure. As shown in the side
4 view of Figure 26A and the cross-sectional view of Figure 26B, the composite plug T
5 has a mandrel 30 with cones 32 and backup rings 34 arranged on both sides of a
6 packing element 36. Outside the inclined cones 32, the tool T has slip assemblies
7 40U and 40D, each having one or more slip elements or segments 41 for engaging a
8 wellbore tubular when activated. Together, the slip elements 41 along with the
9 corresponding cones 32 can be referred to as a slip assembly, unit, or body, or in
10 other instances, just the slip elements 41 may be referred to as a slip assembly, unit,
11 or body. In either case, either reference may be used interchangeably throughout
12 the present disclosure.

13 The cones 32 have inclined surfaces 33 that face outward and away
14 from the centrally located backup rings 34 and packing element 36. The slip
15 assemblies 40U and 40D each has slip elements 41 connected at their ends by an
16 interconnected ring portion 49. As shown, the slip elements 41 have conventional,
17 cylindrical-shaped inserts 24 and has normal-oriented inserts 50, and these can be
18 arranged in various different ways, rows, numbers, and/or combinations on the
19 assemblies 40U, 40D to achieve desired purposes.

20 In the present disclosure, terms such as body, element, and segment
21 may be used for a slip assembly as a whole, for an individual slip, or for one slip of
22 several slips on a slip assembly. Likewise, terms such as assembly, unit, or body
23 may be used interchangeably herein.

1 In the present disclosure, reference to the tool can refer to a number of
2 downhole tools, such as a plug, a packer, a liner hanger, an anchoring device, or
3 other downhole tool. For example, a composite plug as discussed herein can
4 include a bridge plug, a fracture plug, or a two ball fracture plug. A bridge plug has
5 an integral sealing device completely isolating upper and lower annuluses from
6 either direction when set in casing. A fracture plug typically has one ball that is
7 integral or is dropped on the top of the plug to provide a one way seal from above.
8 Finally, a two ball fracture plug can also be deployed with a lower integral ball that
9 acts to seal pressure from below, but provide bypass from above. A second ball can
10 be dropped or pumped down on top of the plug to seal off pressure above the plug
11 from the lower annulus.

12 The foregoing description of preferred and other embodiments is not
13 intended to limit or restrict the scope or applicability of the inventive concepts
14 conceived of by the Applicants. It will be appreciated with the benefit of the present
15 disclosure that features described above in accordance with any embodiment or
16 aspect of the disclosed subject matter can be utilized, either alone or in combination,
17 with any other described feature, in any other embodiment or aspect of the disclosed
18 subject matter.

19 In exchange for disclosing the inventive concepts contained herein, the
20 Applicants desire all patent rights afforded by the appended claims. Therefore, it is
21 intended that the appended claims include all modifications and alterations to the full
22 extent that they come within the scope of the following claims or the equivalents
23 thereof.

1 **WHAT IS CLAIMED IS:**

2

3 1. A downhole apparatus, comprising:

4 a first slip body having inner and outer surfaces, first and second ends,
5 and a body axis from the first end to the second end, the first end tapered with a first
6 incline on the inner surface, the first incline defining a first angle relative to the body
7 axis, the first slip body disposed with the inner surface adjacent the downhole
8 apparatus and movable away from the downhole apparatus through interaction of
9 the first incline with a portion of the downhole apparatus; and

10 at least one first insert having a first axis of orientation and being
11 exposed in the outer surface of the first slip body, the first axis of orientation being
12 oriented at a first obtuse angle relative to the body axis from the first end of the first
13 slip body.

14

15 2. The apparatus of claim 1, wherein the first slip body comprises
16 one of a plurality of segments of a slip assembly, one of a plurality of independent
17 segments of a slip assembly, one of a plurality of integrated segments of a slip
18 assembly, or at least a portion of a cylindrical slip assembly.

19

20 3. The apparatus of claim 1 or 2, wherein the at least one first
21 insert comprises a cylindrical shape disposed endwise in the first slip body, a
22 cylindrical shape disposed lengthwise in the first slip body, a rectilinear shape

1 disposed endwise in the first slip body, or a strip shape disposed laterally across the
2 outer surface of the first slip body.

3

4 4. The apparatus of any one of claims 1 to 3, wherein the first slip
5 body further comprises a second insert exposed in the outer surface of the first slip
6 body and disposed with a second axis of orientation being at an acute angle relative
7 to body axis from the first end.

8

9 5. The apparatus of any one of claims 1 to 4, wherein the inner
10 surface of the first slip body defines a curvature laterally across the first slip body,
11 and wherein the first axis of orientation of the at least one first insert is substantially
12 perpendicular to the curvature.

13

14 6. The apparatus of any one of claims 1 to 5, wherein the first slip
15 body is composed of a first material; and wherein the at least one first insert is
16 composed of a second material.

17

18 7. The apparatus of claim 6, wherein the first material comprises a
19 cast iron, a metallic material, a non-metallic material, a composite, a millable
20 material, a molded phenolic, a laminated non-metallic composite, an epoxy resin
21 polymer with a glass fiber reinforcement, thermoplastic material, injection-molded
22 plastic material, or a combination thereof.

23

1 8. The apparatus of claim 6 or 7, wherein the second material
2 comprises a metallic material, a non-metallic material, a composite, a millable
3 material, a carbide, a metallic-ceramic composite material, a cast iron, a ceramic, a
4 cermet, a composite composed of ceramic and metallic materials, a powdered
5 metal, or a combination thereof.

6
7 9. The apparatus of any one of claims 1 to 8, wherein the at least
8 one first insert has a top end exposed in the outer surface, the top end defining a
9 lead face toward the first end of the first slip body, the lead face defining a second
10 angle relative to the first axis of orientation.

11
12 10. The apparatus of claim 9, wherein the top end comprises a tail
13 face toward the second end of the first slip body, the tail face defining a third angle
14 relative to the first axis of orientation.

15
16 11. The apparatus of claim 9 or 10, wherein the second angle of the
17 lead face is selected based on the first angle of the first incline such that the second
18 angle defines a second obtuse angle relative to the body axis from the first end.

19
20 12. The apparatus of claim 11, wherein the second obtuse angle is
21 approximately a sum of 90-degrees plus the first angle of the first incline plus the
22 second angle of the lead face.

23

1 13. The apparatus of any one of claims 1 to 12, wherein the first slip
2 body comprises a plurality of the at least one first insert exposed in the outer
3 surface.

4

5 14. The apparatus of claim 13, wherein at least two of the first
6 inserts are disposed along the body axis of the first slip body and have different axial
7 lengths.

8

9 15. The apparatus of any one of claims 1 to 8, wherein the at least
10 one first insert comprises a top end exposed at the outer surface of the first slip body
11 and comprises a bottom end embedded in the first slip body or adhered in a hole in
12 the first slip body.

13

14 16. The apparatus of any one of claims 1 to 8, wherein the at least
15 one first insert comprises a top end exposed at the outer surface of the first slip body
16 and comprises a bottom end exposed at the first incline of the inner surface.

17

18 17. The apparatus of any one of claims 1 to 16, wherein the first
19 axis is substantially normal to the first incline.

20

21 18. The apparatus of any one of claims 1 to 14, wherein the at least
22 one first insert has a bottom end disposed in the first slip body, the bottom end being
23 substantially parallel to the first incline.

1

2 19. The apparatus of any one of claims 1 to 18, wherein the
3 apparatus comprises a cone disposed on the apparatus as the portion of the
4 downhole apparatus, the cone having a first surface adapted to interface with the
5 first incline of the first slip body.

6

7 20. The apparatus of any one of claims 1 to 18, wherein the
8 apparatus comprises:

9 a mandrel adjacent which the inner surface of the first slip body is
10 disposed;

11 a packing element disposed on the mandrel; and

12 a cone disposed on the mandrel, the cone being the portion of the
13 downhole tool interacting with the first incline of the first slip body.

14

15 21. The apparatus of claim 20, wherein the apparatus comprises a
16 composite plug, a bridge plug, a fracture plug, a packer, a liner hanger, or an
17 anchoring device.

18

19 22. The apparatus of claim 1, wherein the first slip body comprises
20 a plurality of first slip segments of a slip assembly; and wherein one or more of the
21 first slip segments comprises one or more of the at least one first insert.

22

1 23. The apparatus of claim 1, wherein the first slip body comprises
2 a plurality of first slip segments of a slip assembly having at least proximal ends
3 connected to one another.

4
5 24. The apparatus of any one of claims 1 to 23, further comprising:
6 a second slip body having inner and outer surfaces and having third
7 and fourth ends, the third end tapered with a second incline on the inner surface, the
8 second slip body disposed with the inner surface adjacent the downhole apparatus
9 and movable away from the downhole apparatus through interaction of the second
10 incline with another portion of the downhole tool.

11
12 25. The apparatus of claim 24, wherein the first and second slip
13 bodies are arranged opposite one another on the downhole apparatus.

14
15 26. The apparatus of claim 24 or 25, further comprising at least one
16 second insert exposed in the outer surface of the second slip body.

17
18 27. The apparatus of claim 26, wherein the at least one second
19 insert is disposed with a second axis of orientation being substantially normal to the
20 second incline.

21

1 28. The apparatus of claim 26 or 27, wherein the first and second
2 slip bodies are different with respect to an arrangement of the first and second
3 inserts.

4

5 29. The apparatus of any one of claims 1 to 5, further comprising:
6 an intermediate element disposed at least partially between the first
7 incline and the portion of the downhole apparatus.

8

9 30. The apparatus of any one of claims 7 to 28, further comprising:
10 an intermediate element disposed at least partially between the first
11 incline and the portion of the downhole apparatus.

12

13 31. The apparatus of claim 29, wherein the slip body is composed
14 of a first material; wherein the at least one insert is composed of a second material;
15 and wherein the intermediate element is composed of a third material.

16

17 32. The apparatus of claim 30, wherein the intermediate element is
18 composed of a third material.

19

20 33. The apparatus of claim 32, wherein the third material is different
21 than the first and second materials.

22

1 34. The apparatus of any one of claims 29 to 33, wherein the
2 intermediate element comprises a pad disposed on a portion of the incline of the
3 inner surface, the pad positioning at least partially between the portion of the
4 downhole apparatus and a bottom end of the at least one insert.

5

6 35. The apparatus of any one of claims 29 to 33, wherein the
7 apparatus comprises a packing element as the portion of the downhole tool
8 interacting with the incline; and wherein the intermediate element comprises a
9 backup ring disposed at least partially between the packing element and the incline.

10

11 36. The apparatus of any one of claims 29 to 33, wherein the
12 apparatus comprises a cone as the portion of the downhole tool interacting with the
13 incline, and wherein the intermediate element comprises a pad disposed on a
14 portion of the cone.

15

16 37. A downhole apparatus, comprising:

17 a mandrel;

18 a body element disposed on the mandrel; and

19 a slip body having a centerline, inner and outer surfaces, and first and
20 second ends, the first end tapered with an incline on the inner surface, the incline
21 defining a first angle relative to the centerline, the slip body disposed with the inner
22 surface adjacent the mandrel and movable away from the mandrel through
23 interaction of the incline with the body element; and

1 at least one first insert having a first axis of orientation and being
2 exposed in the outer surface of the first slip body, the first axis of orientation being
3 oriented at a first obtuse angle, the first obtuse angle measured from the first end
4 relative to the centerline of the first slip body toward the first axis of orientation.

5

6 38. The apparatus of claim 37, wherein the body element comprises
7 a cone disposed on the mandrel and having an inclined surface adapted to interact
8 with the incline of the slip body.

9

10 39. The apparatus of claim 37 or 38, further comprising:
11 an intermediate element disposed at least partially between the incline
12 and the body element.

13

14 40. The apparatus of claim 39, wherein the intermediate element
15 comprises a pad disposed on a portion of the incline of the inner surface, the pad
16 positioning at least partially between the body element and a bottom end of the at
17 least one insert.

18

19 41. The apparatus of claim 39, wherein the body element comprises
20 a packing element disposed on the mandrel; and wherein the intermediate element
21 comprises a backup ring disposed at least partially between the packing element
22 and the incline.

1 42. The apparatus of claim 37, wherein the body element comprises
2 a cone disposed on the mandrel and having an inclined surface, and an intermediate
3 element disposed at least partially between the incline and the body element, and
4 wherein the intermediate element comprises a pad disposed on a portion of the
5 inclined surface.

6

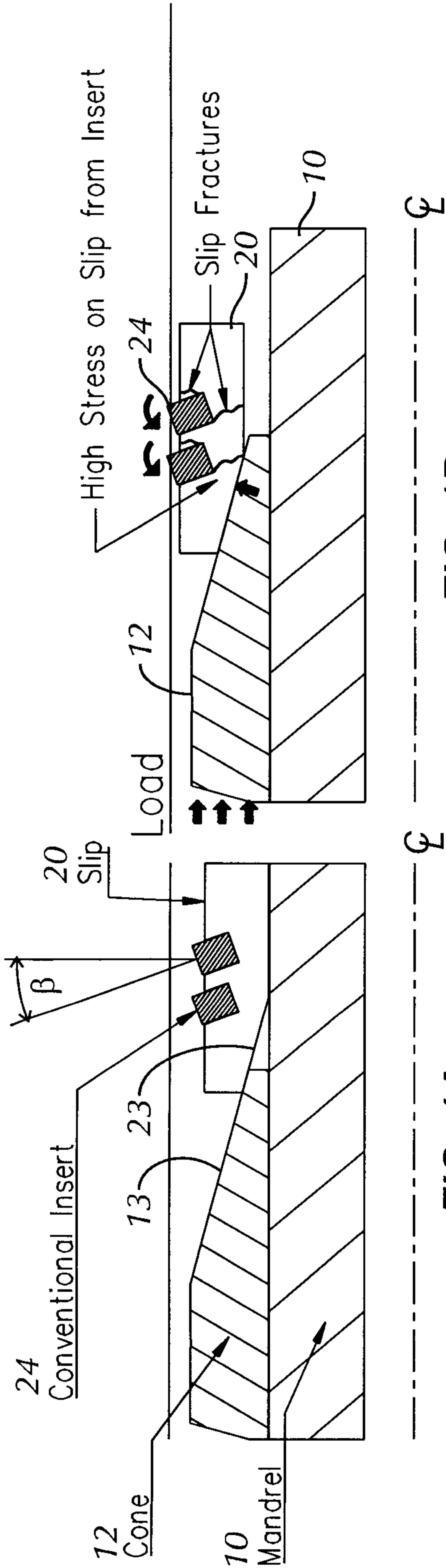


FIG. 1A
(Prior Art)

FIG. 1B
(Prior Art)

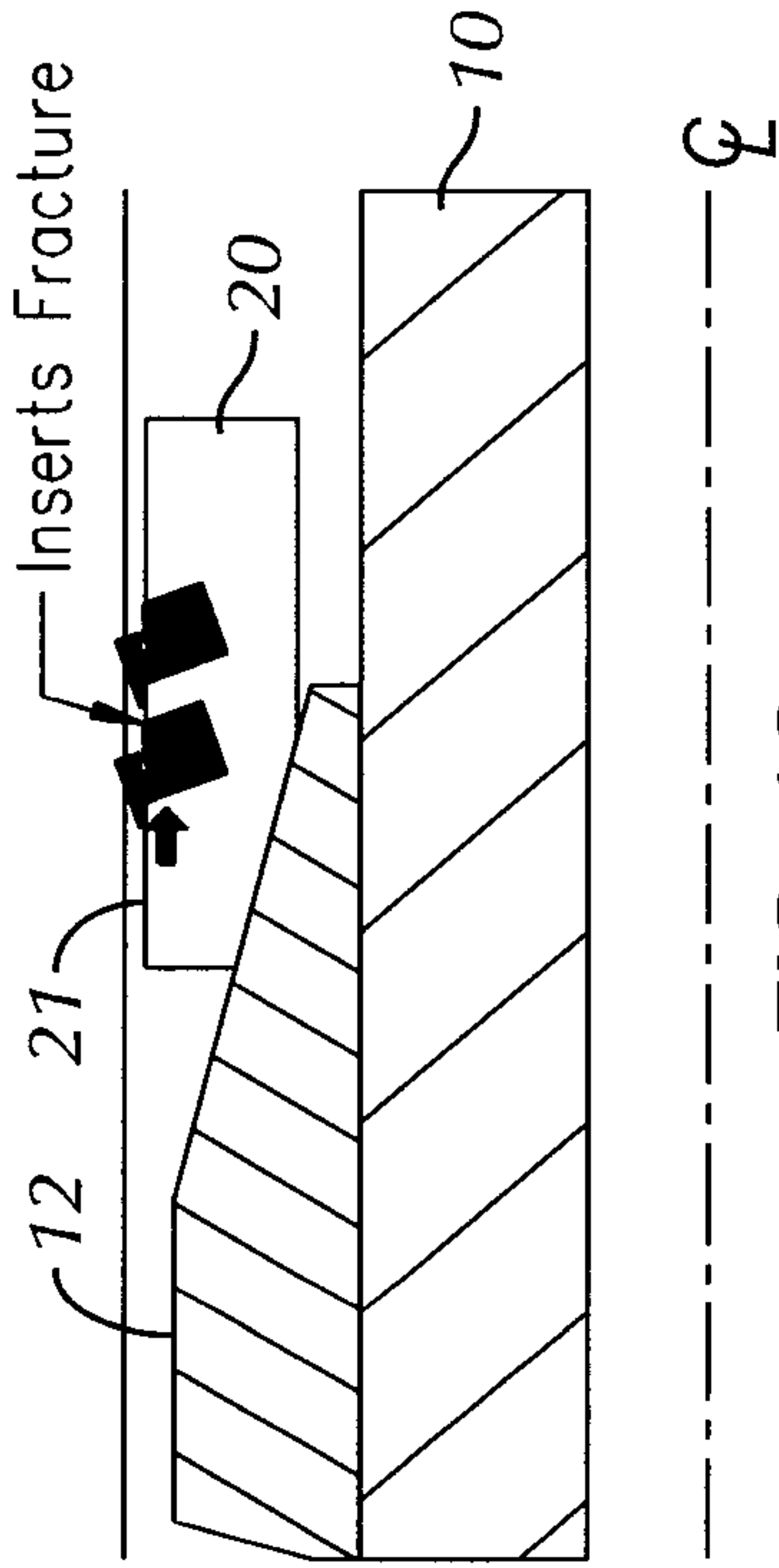


FIG. 1C
(Prior Art)

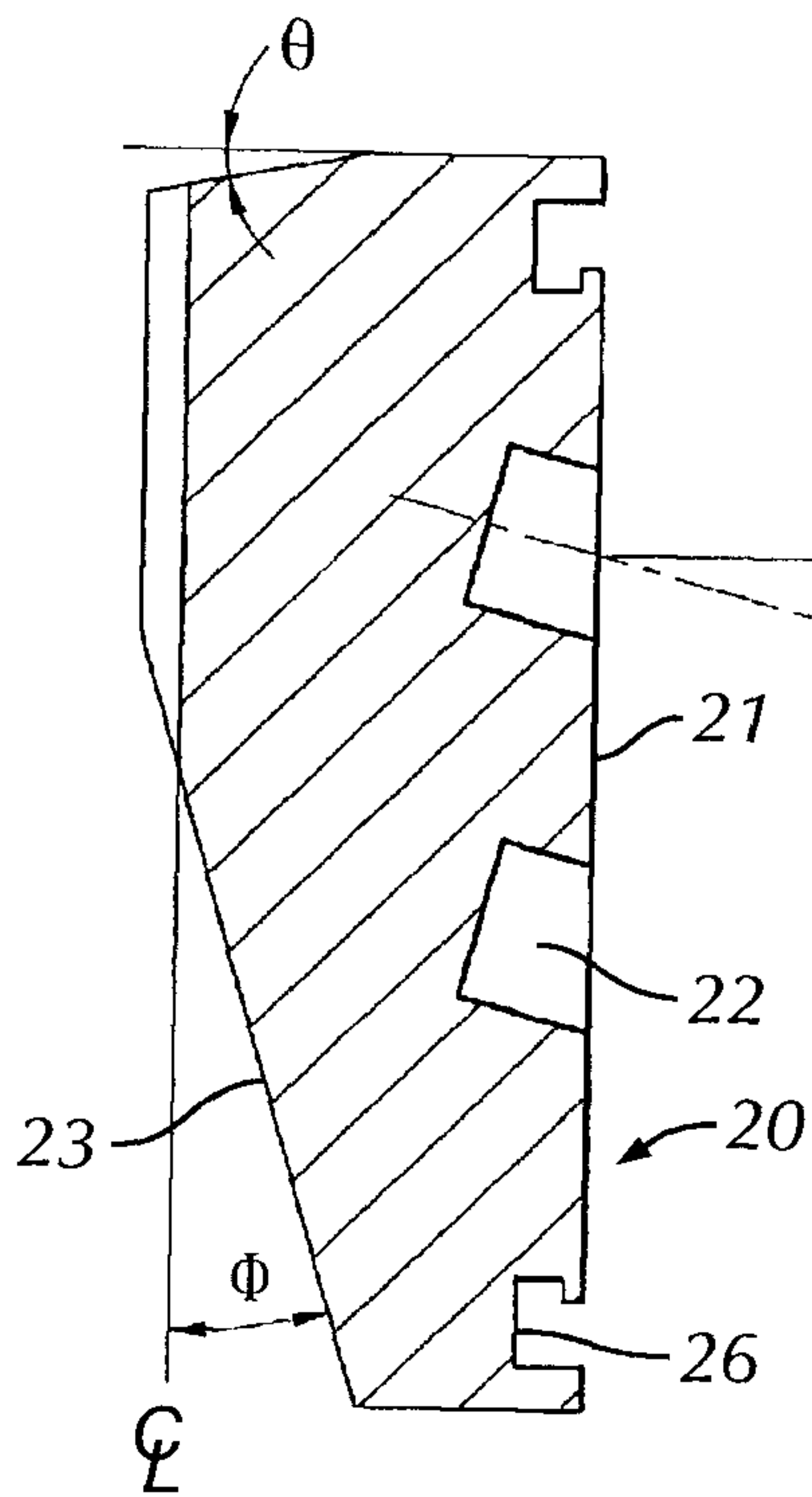


FIG. 2A
(Prior Art)

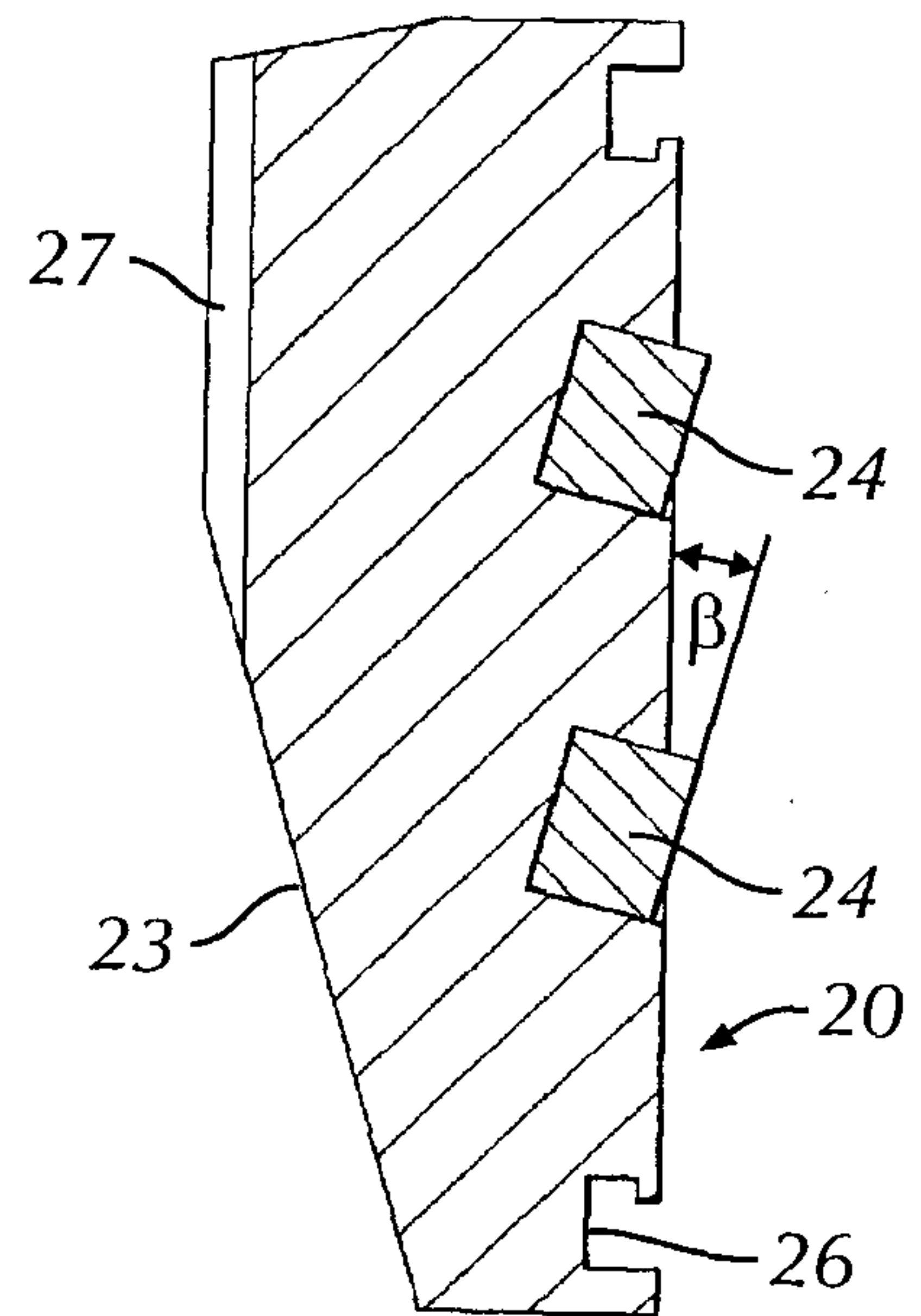


FIG. 2B
(Prior Art)

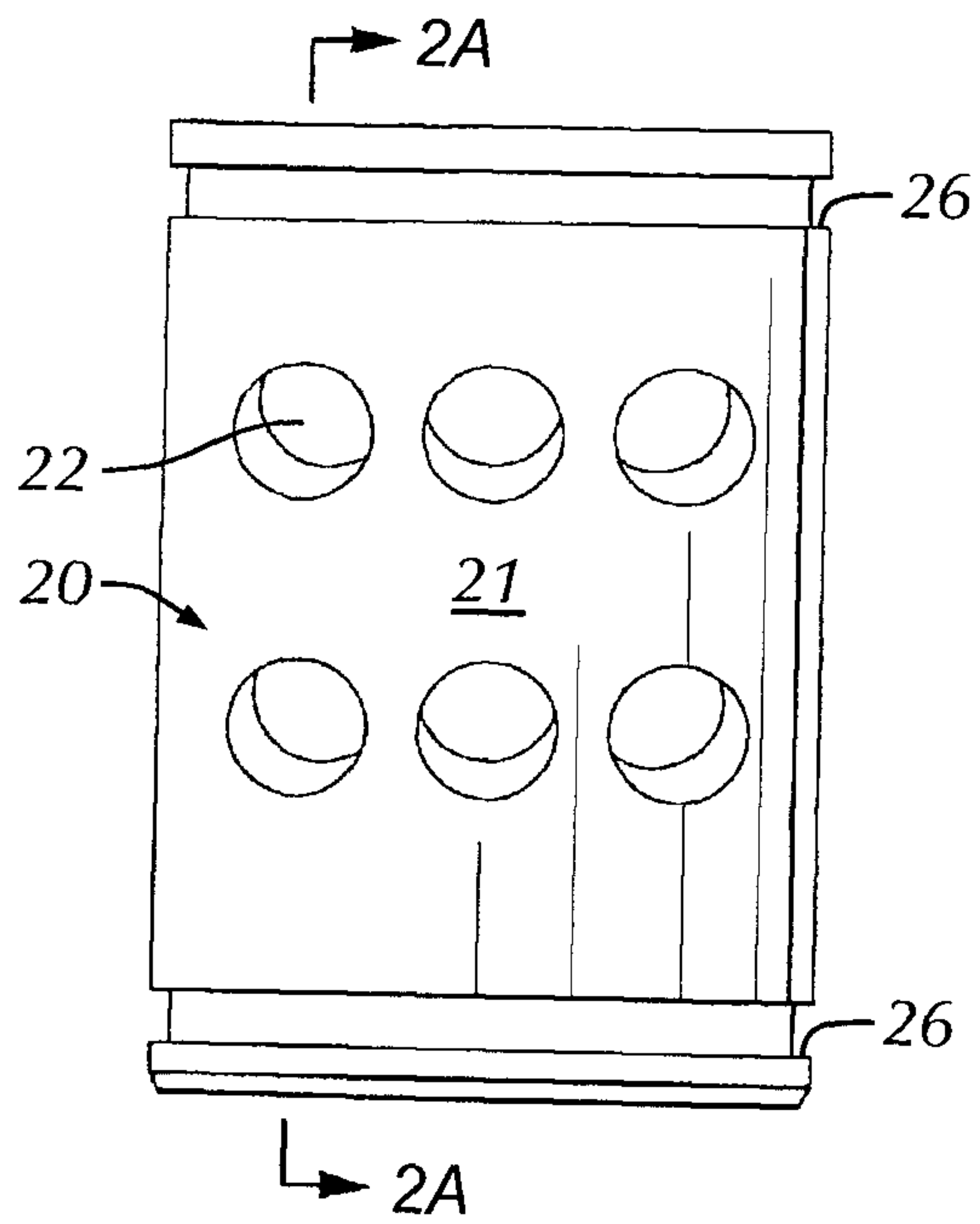
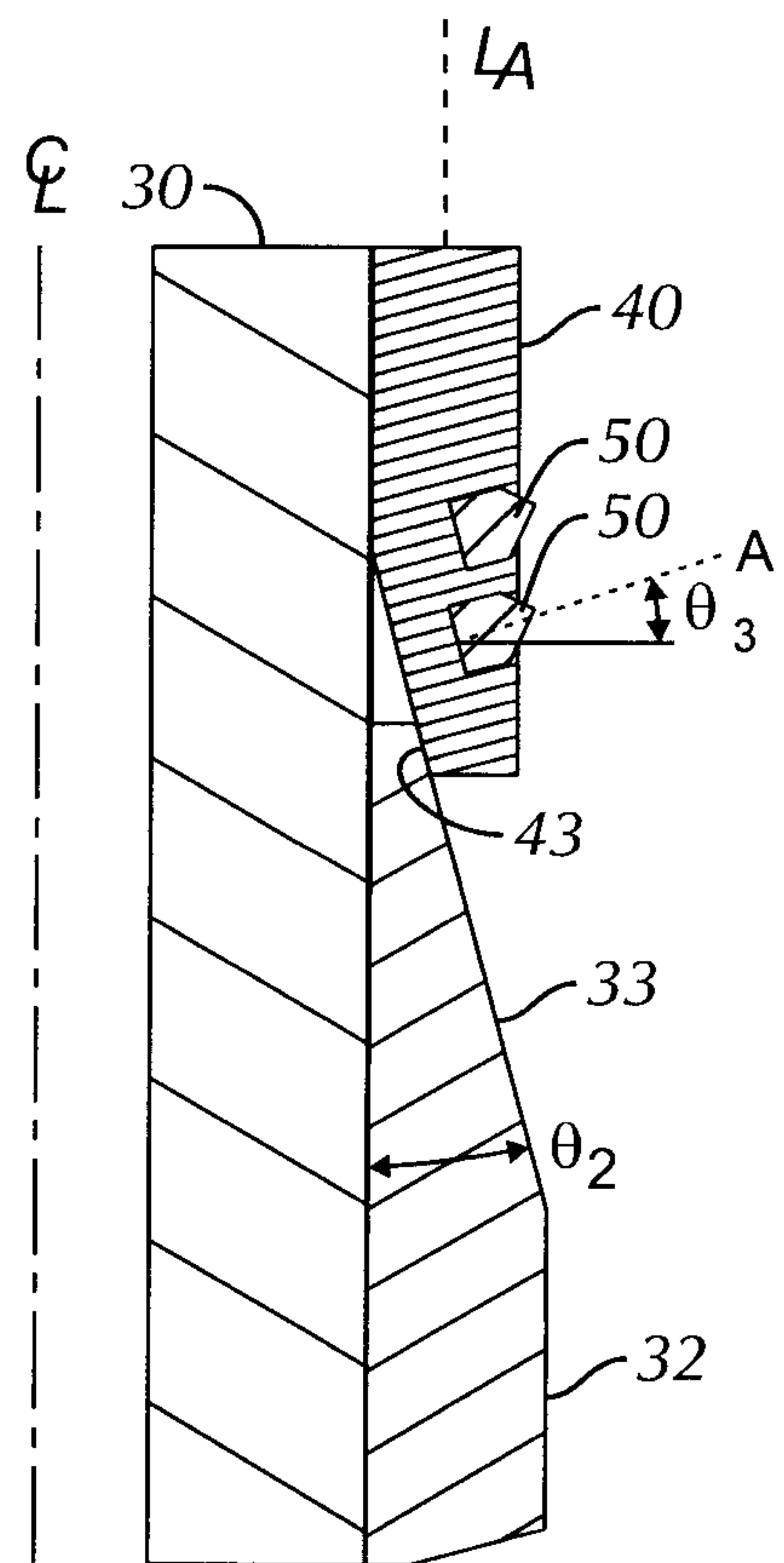
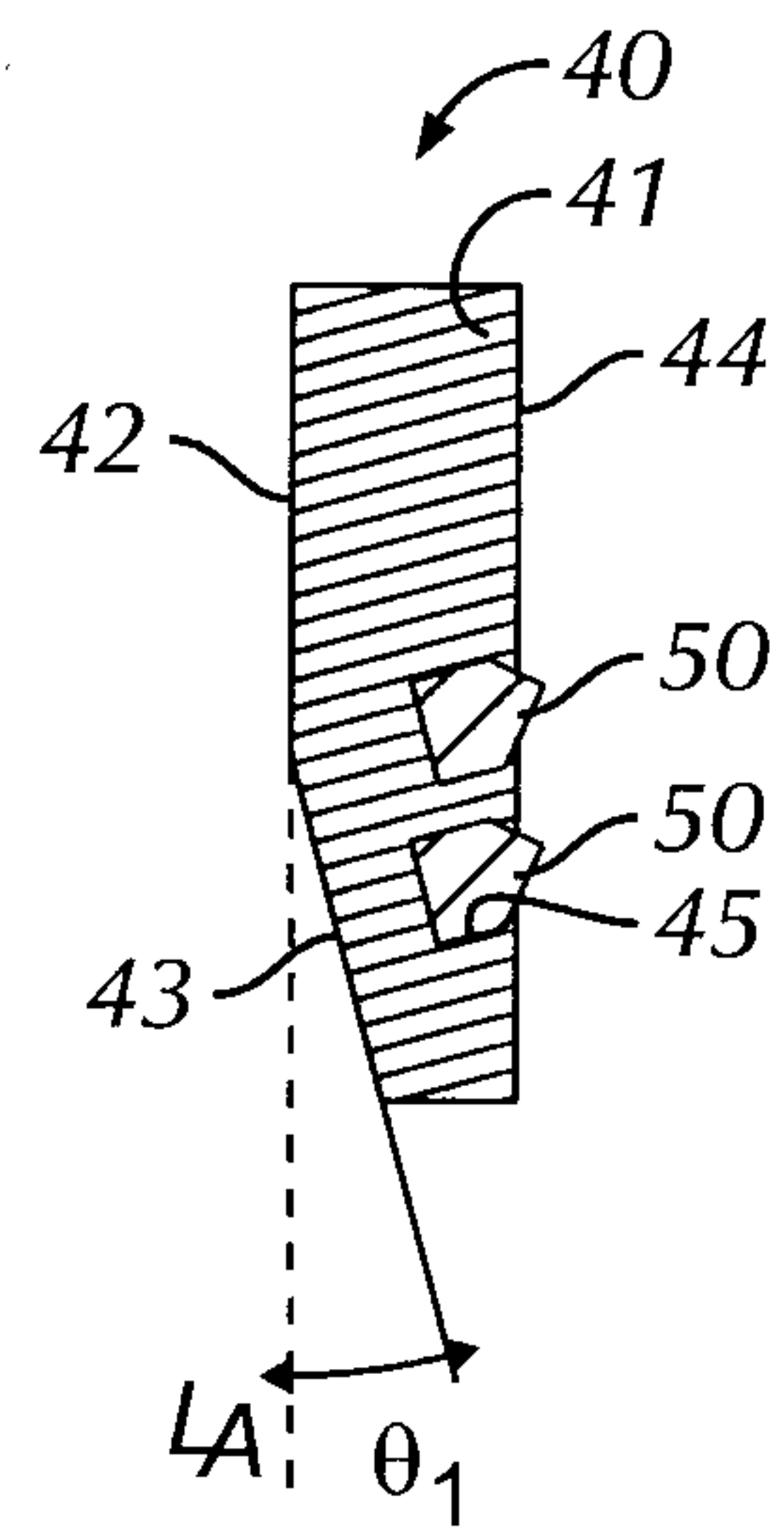
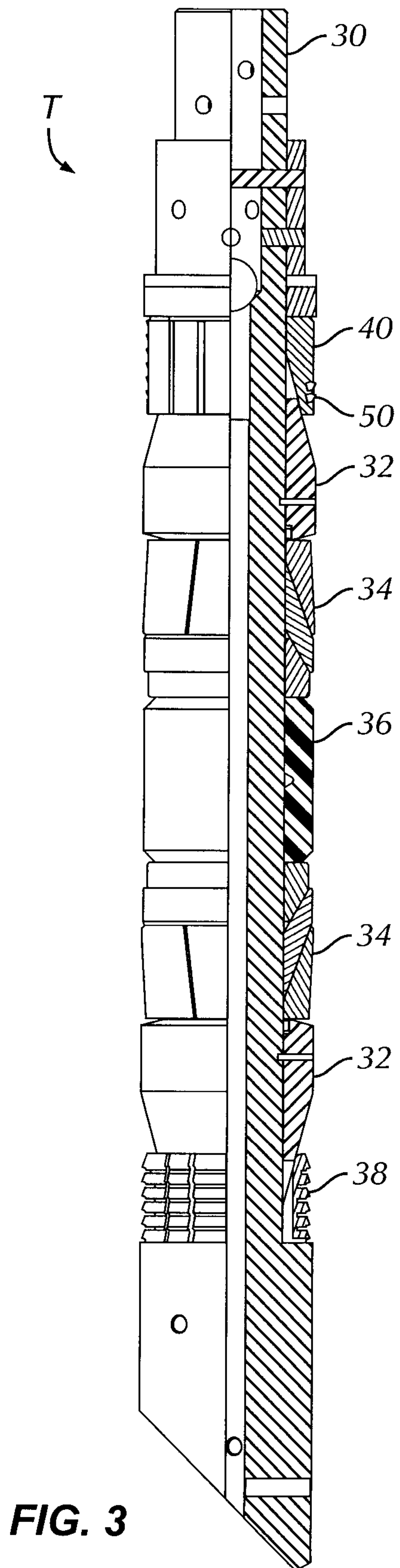
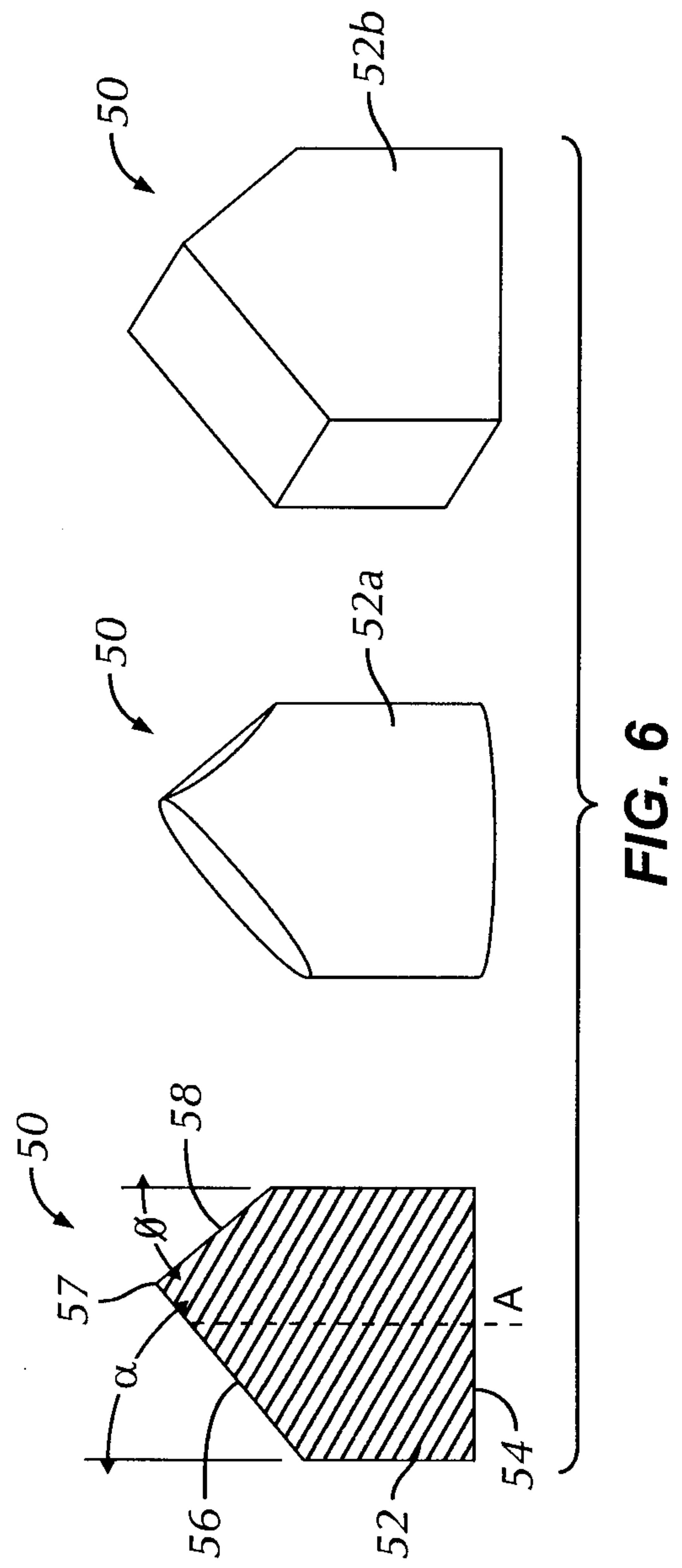
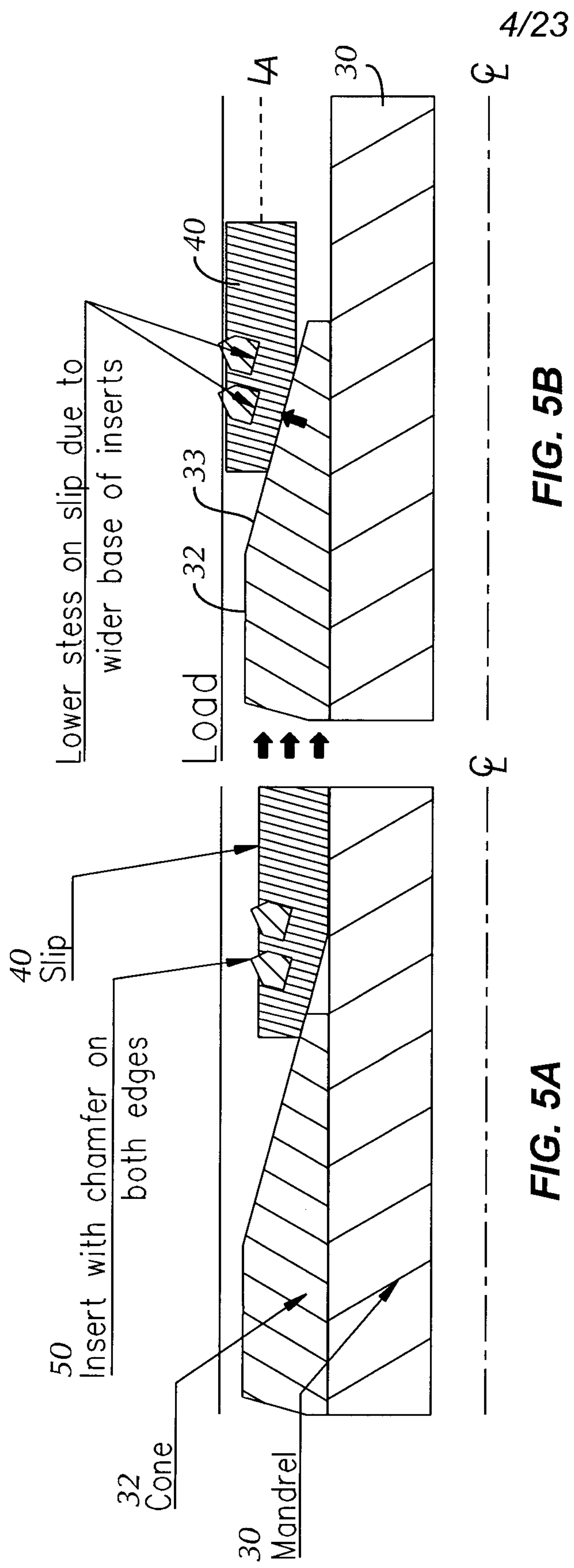


FIG. 2C
(Prior Art)

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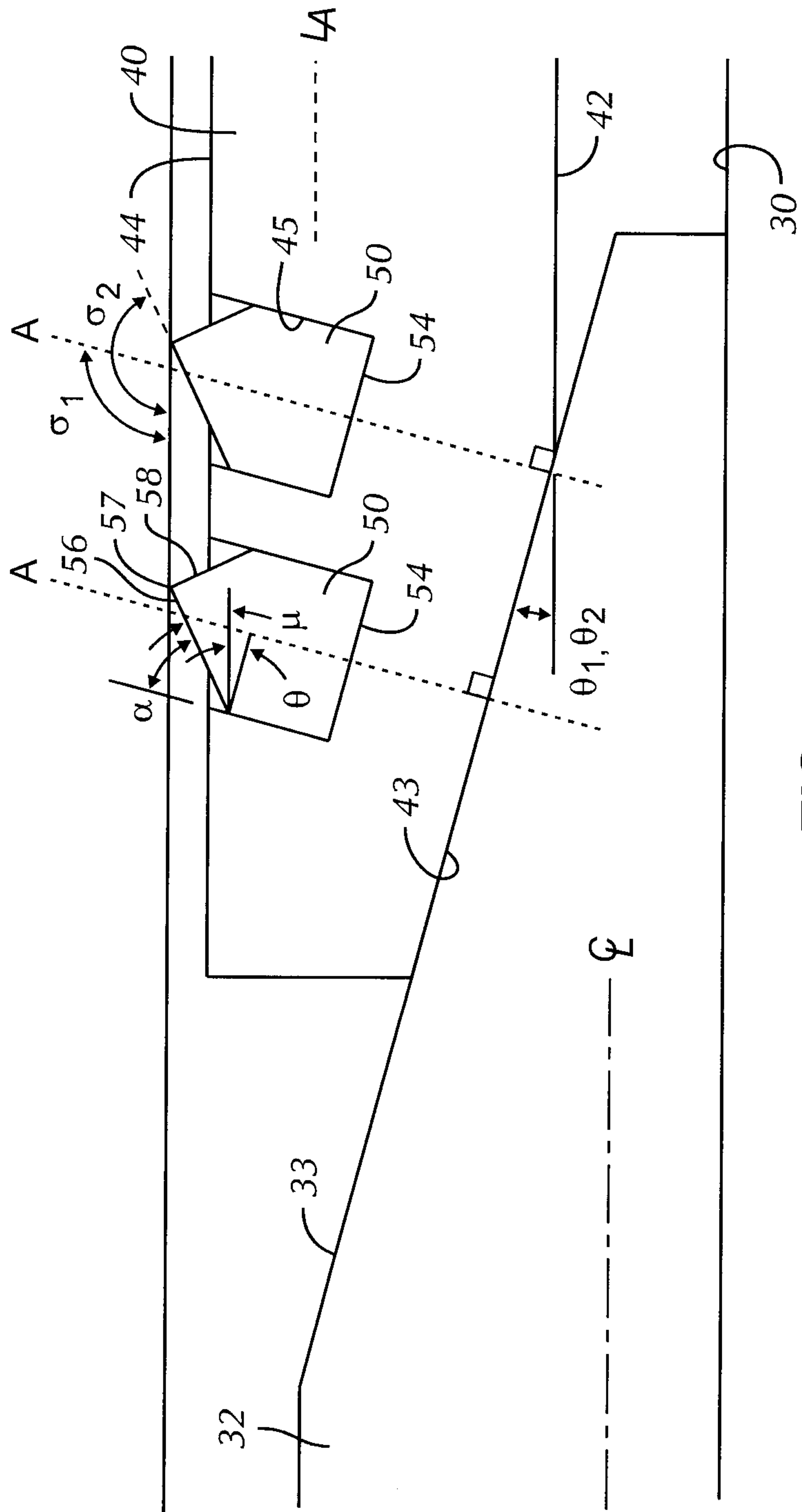
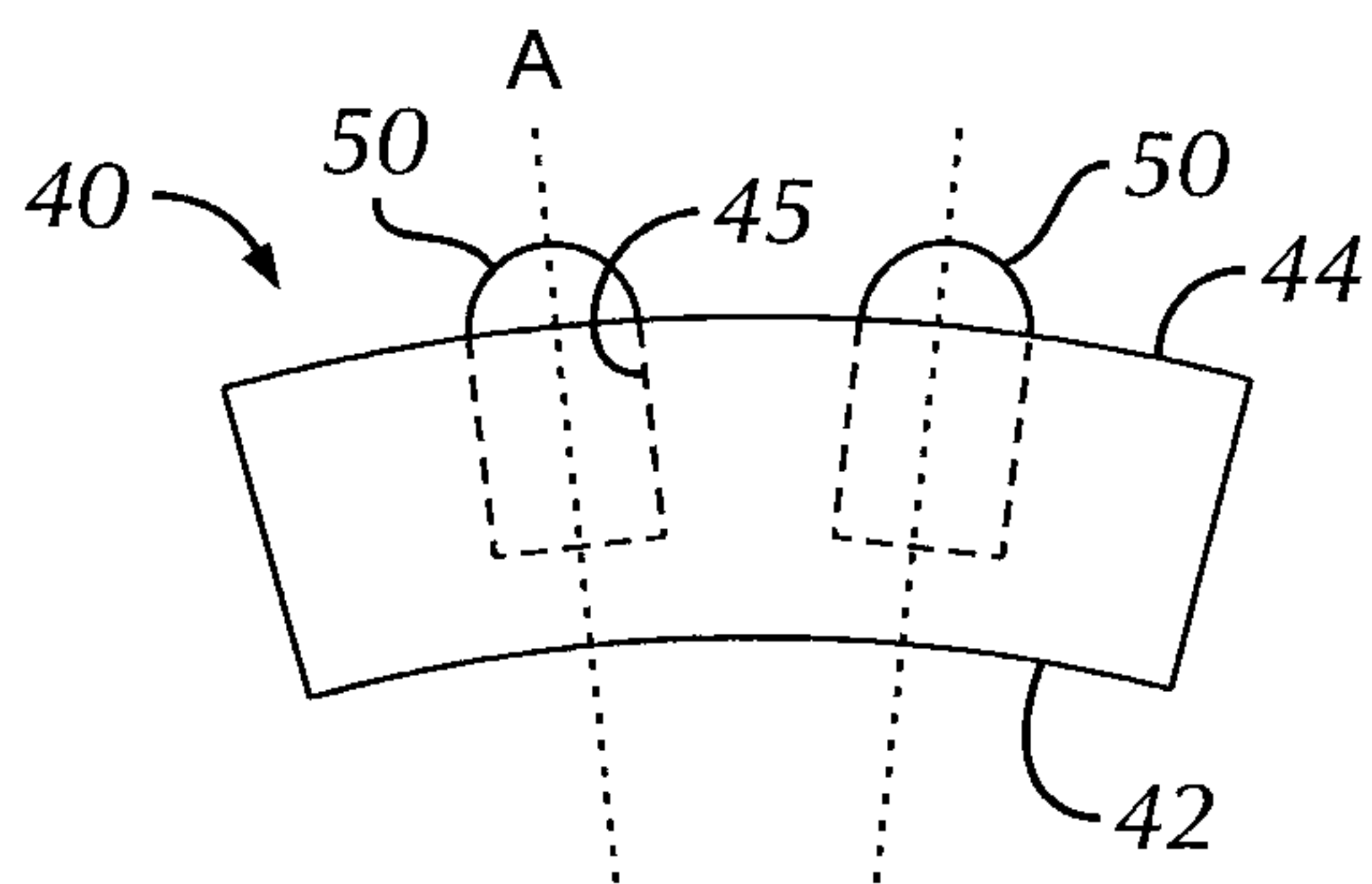
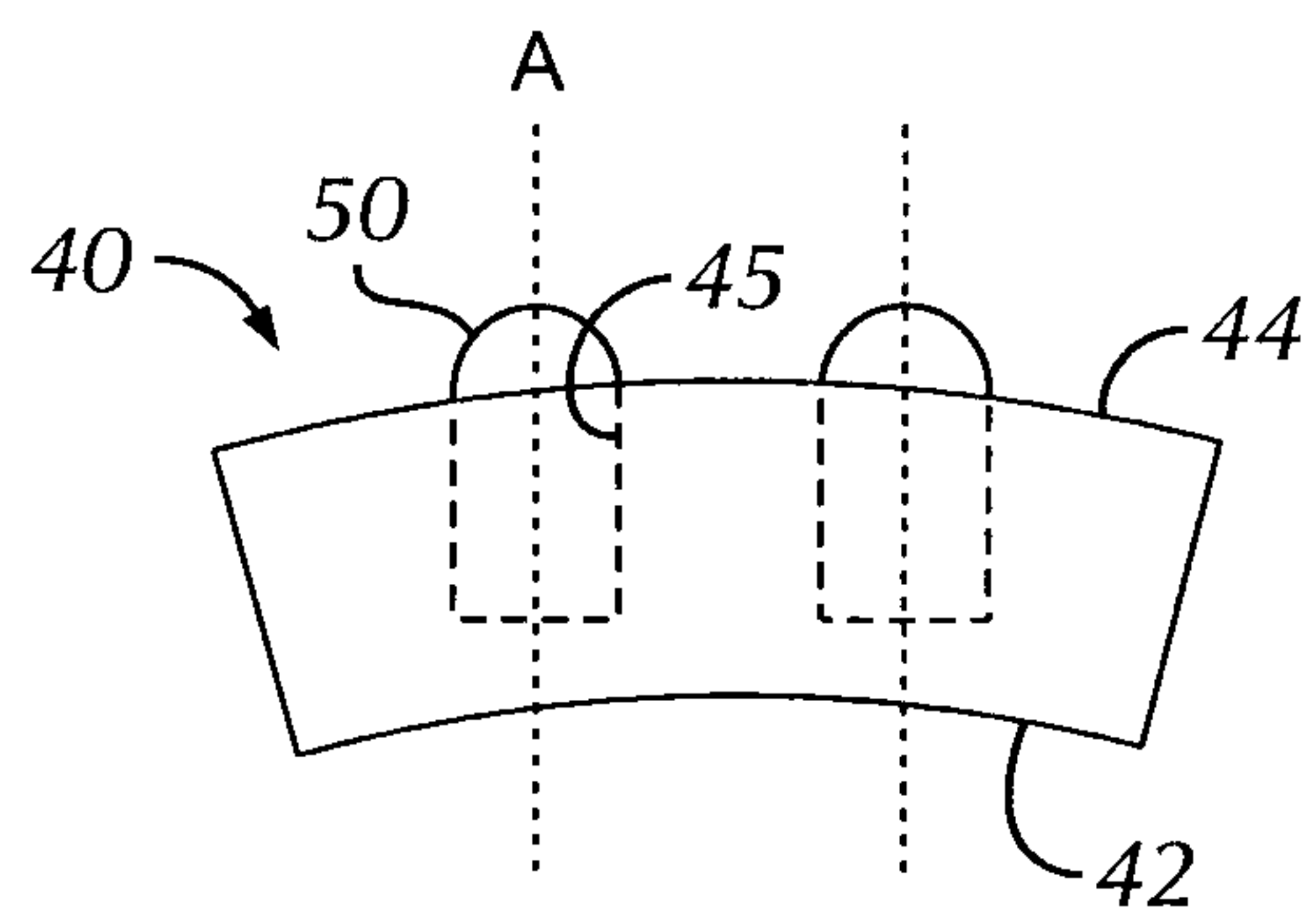
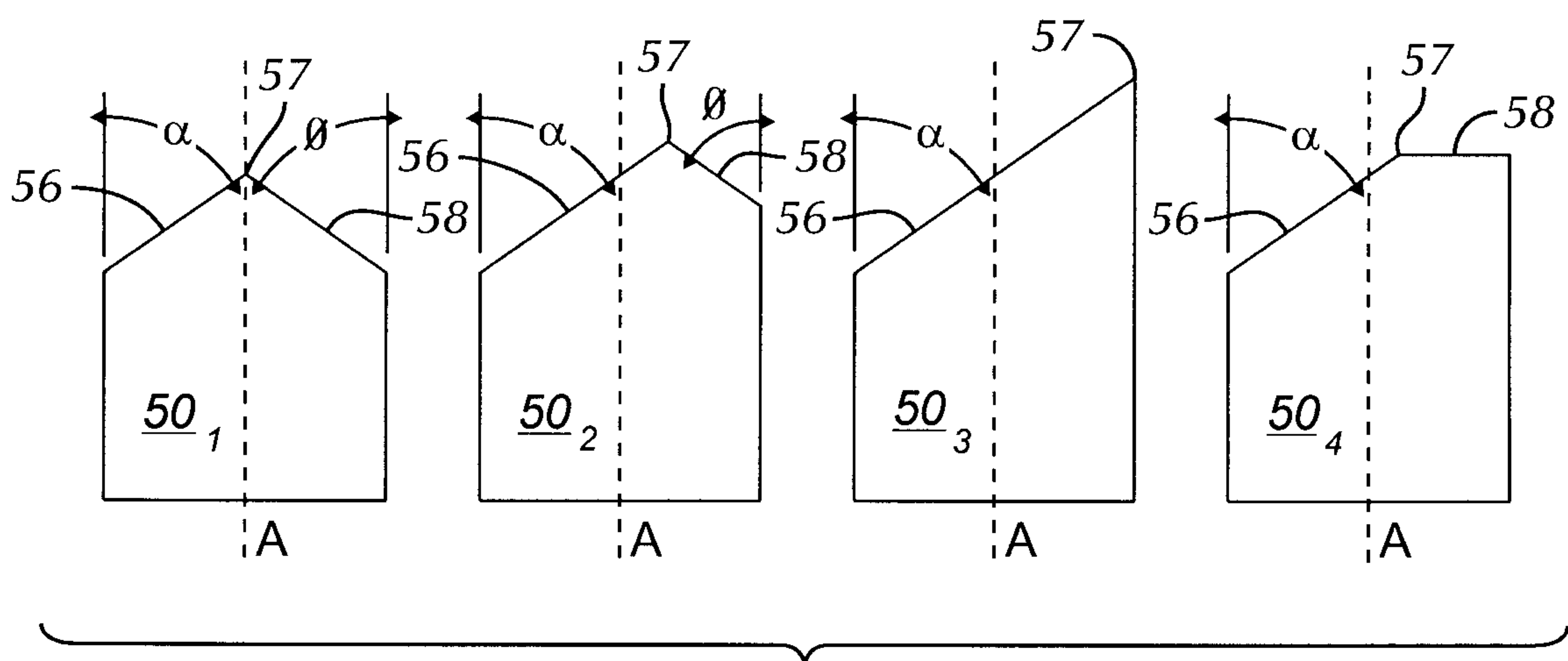
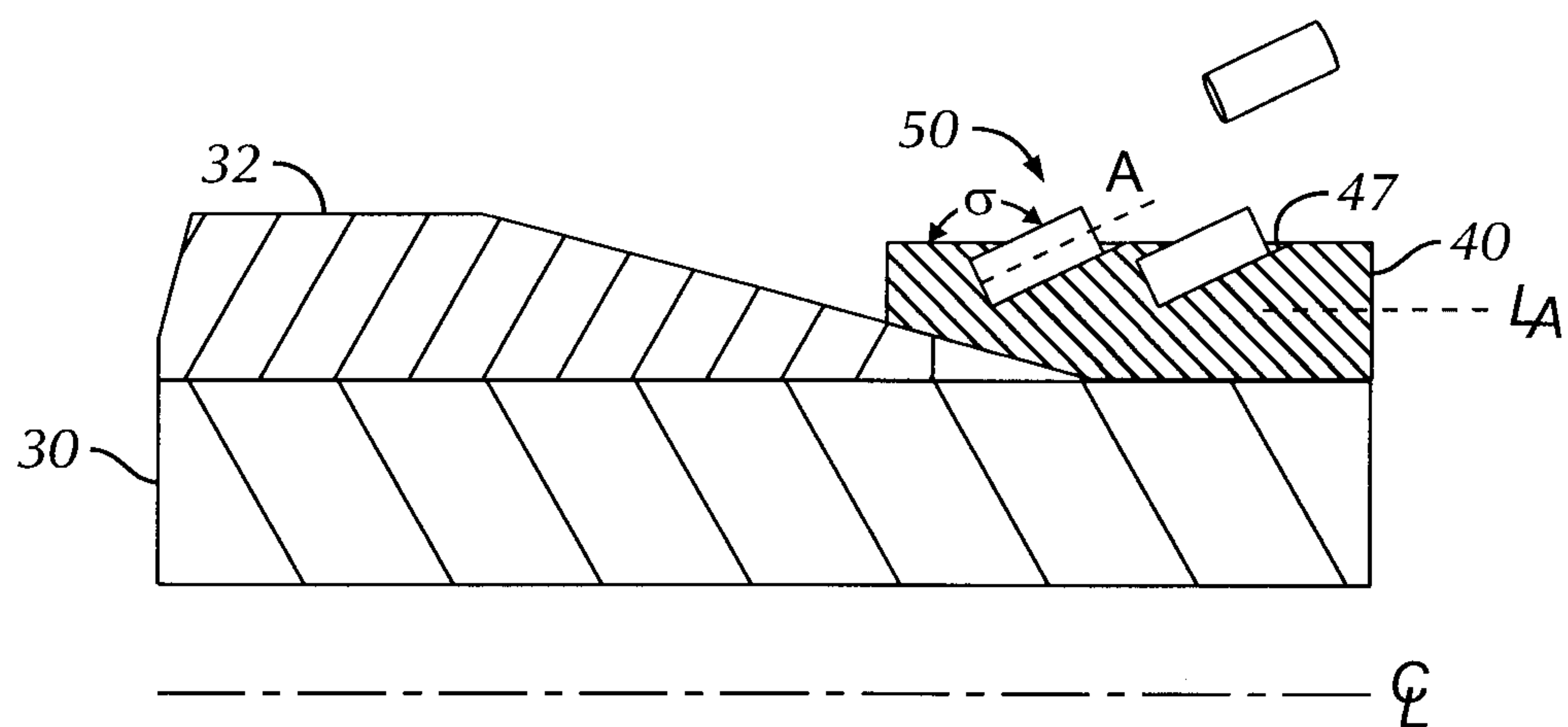
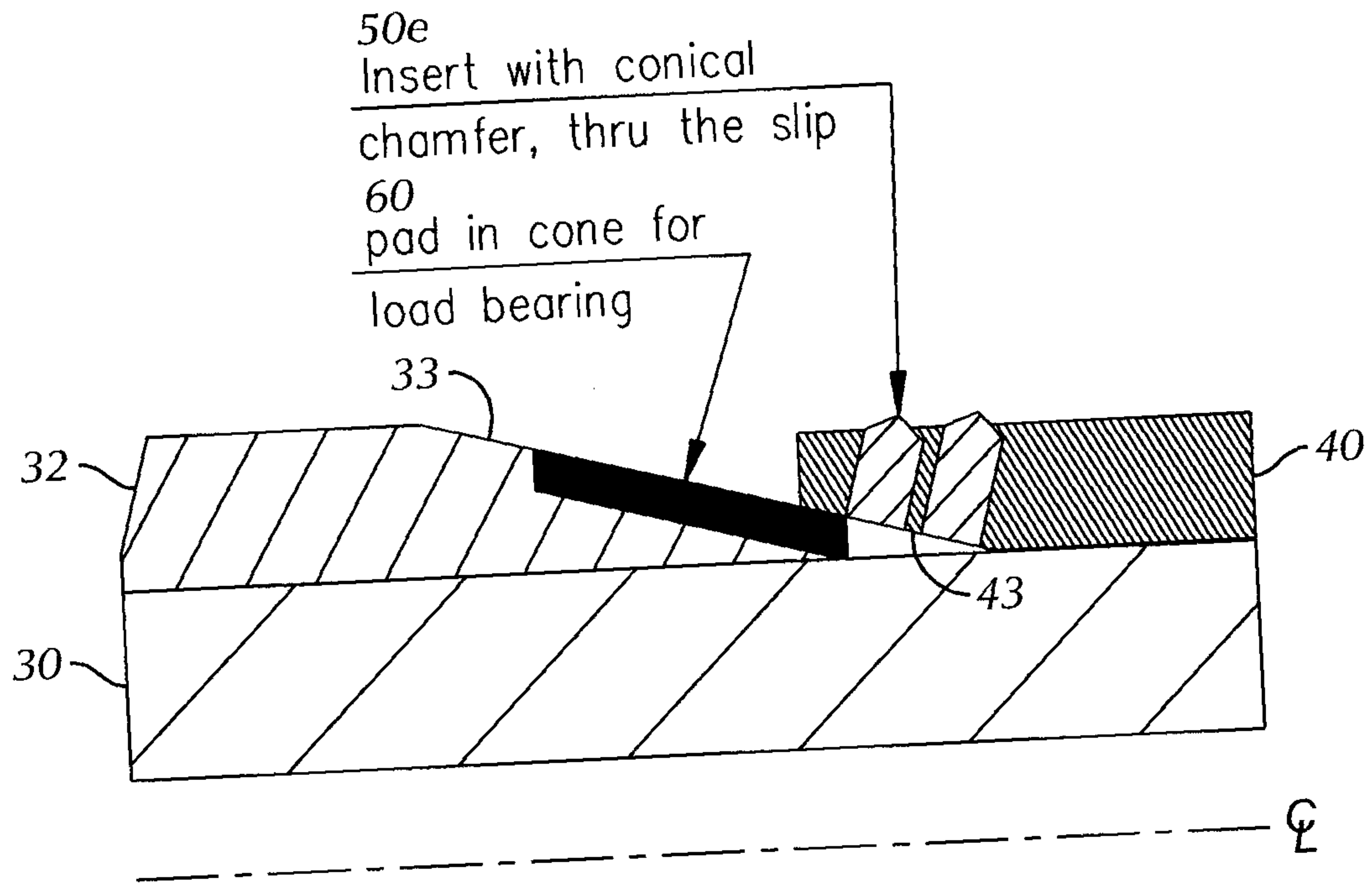
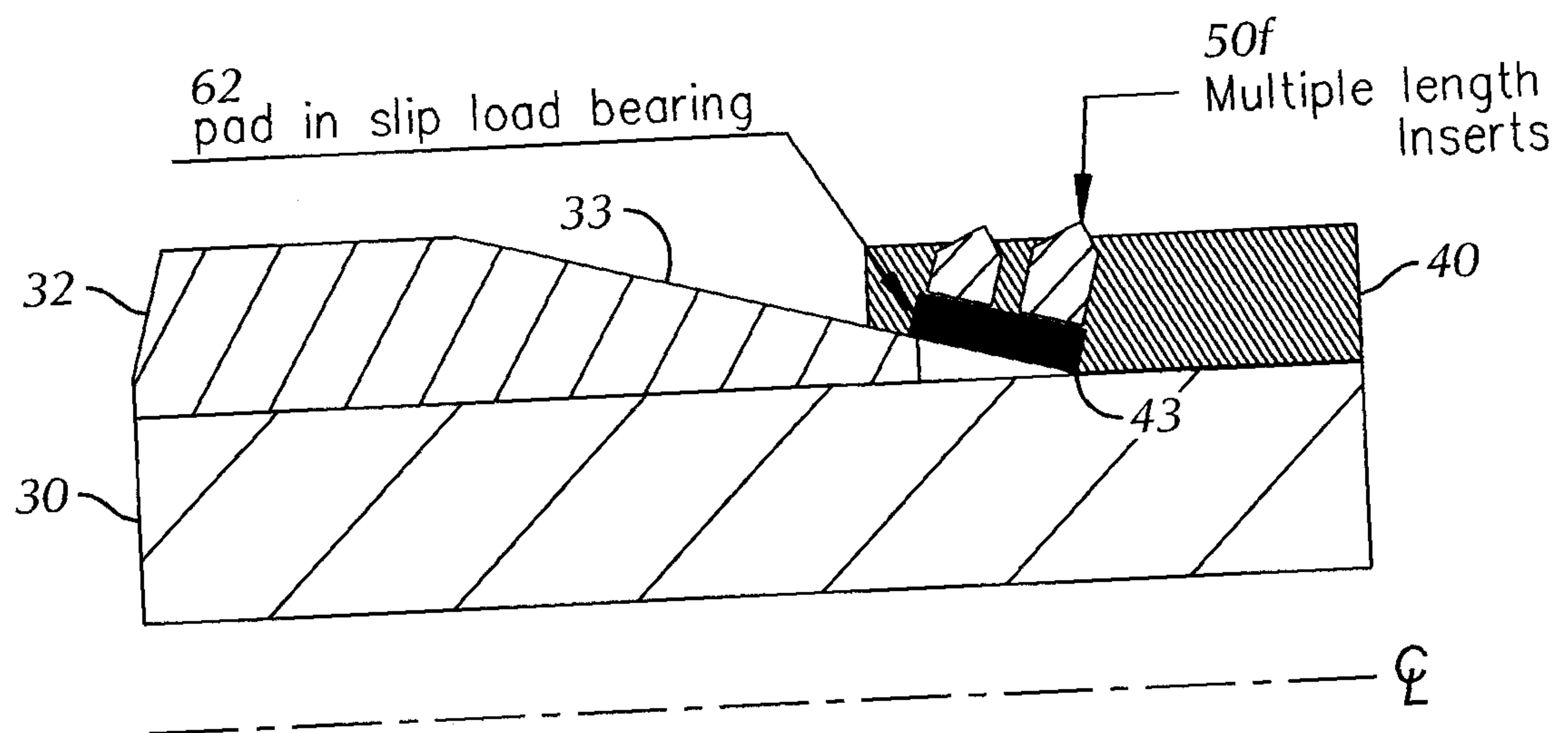


FIG. 7

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**FIG. 8A****FIG. 8B****FIG. 9A****FIG. 9B**

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**FIG. 11A****FIG. 11B**

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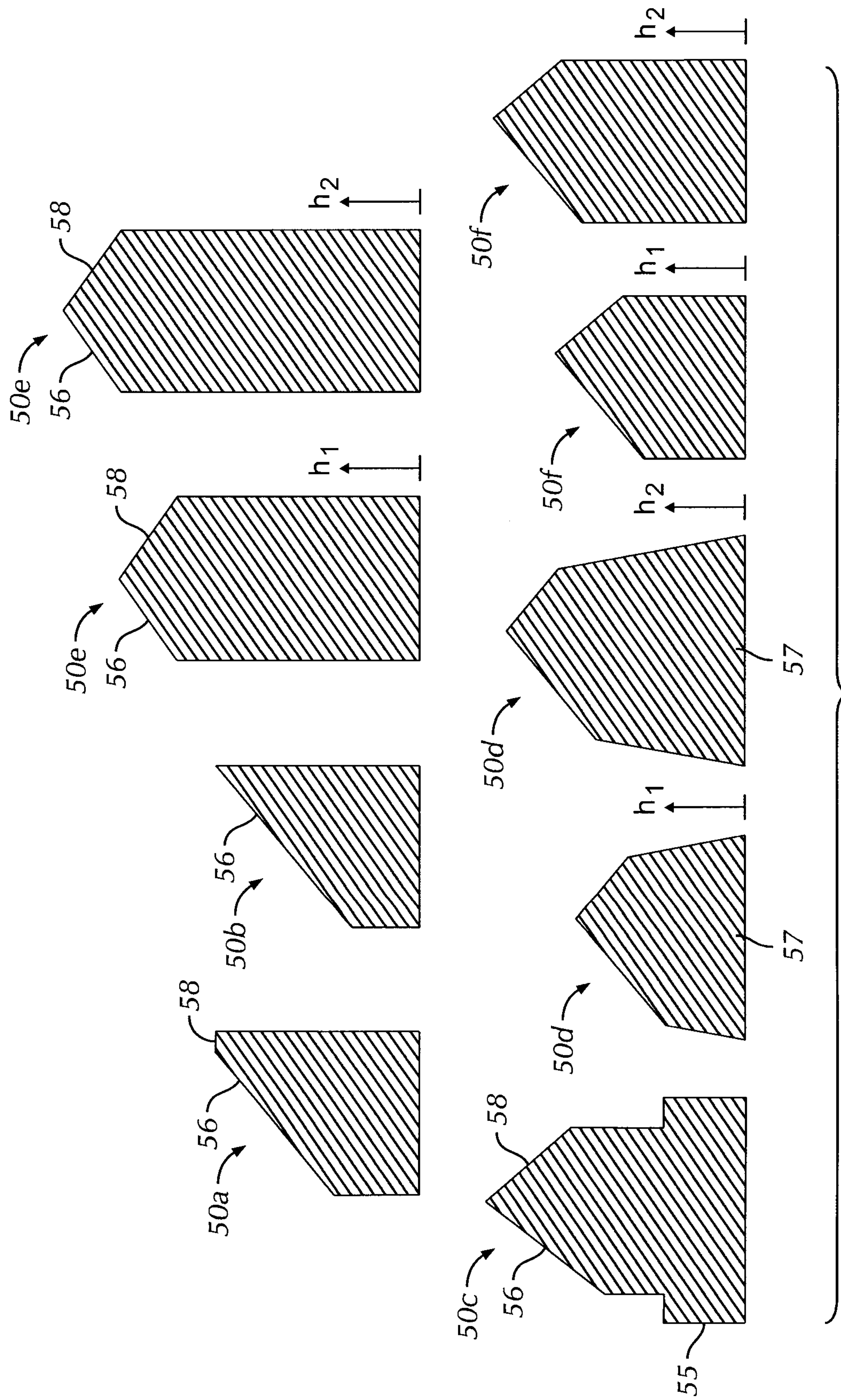
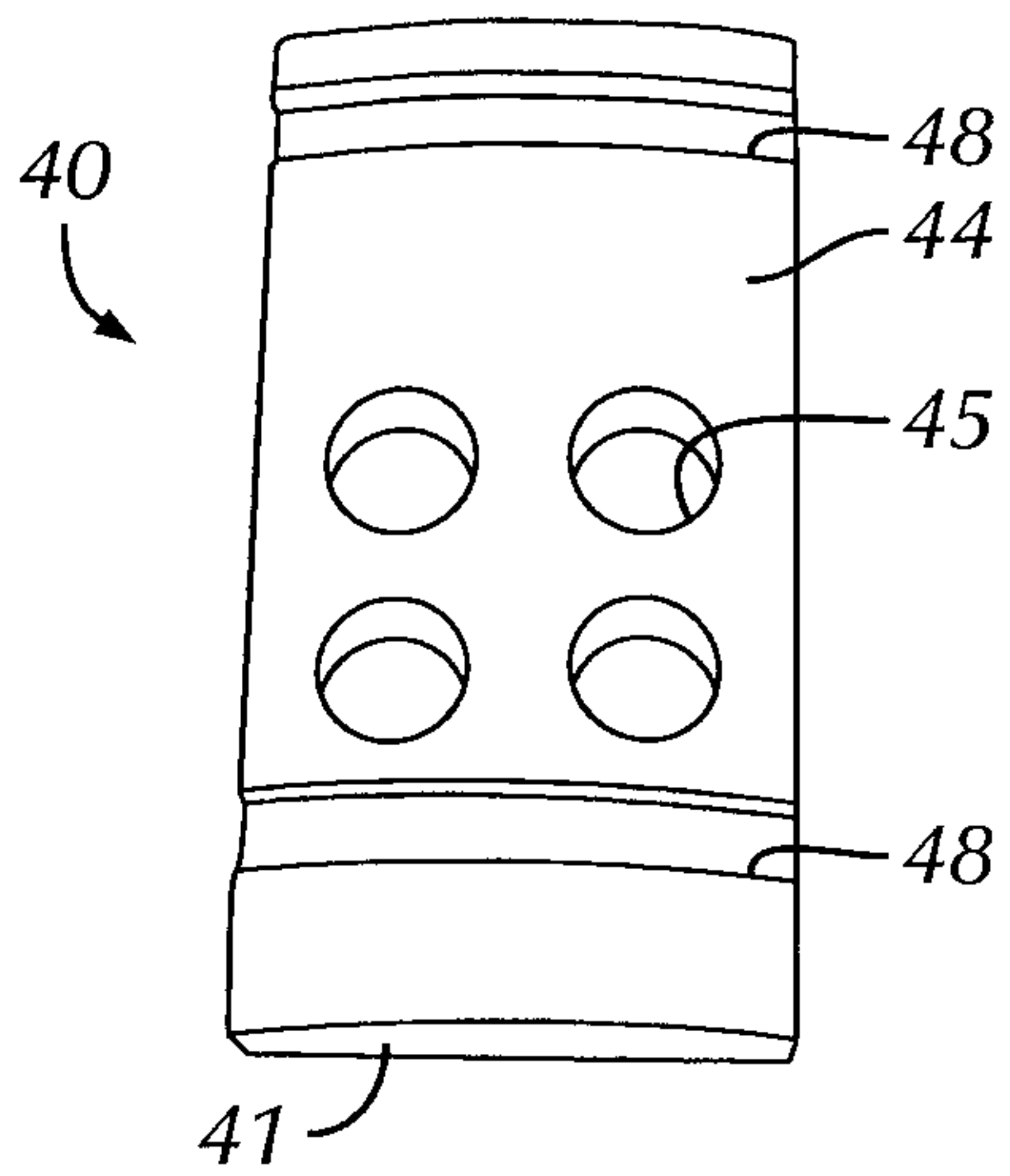
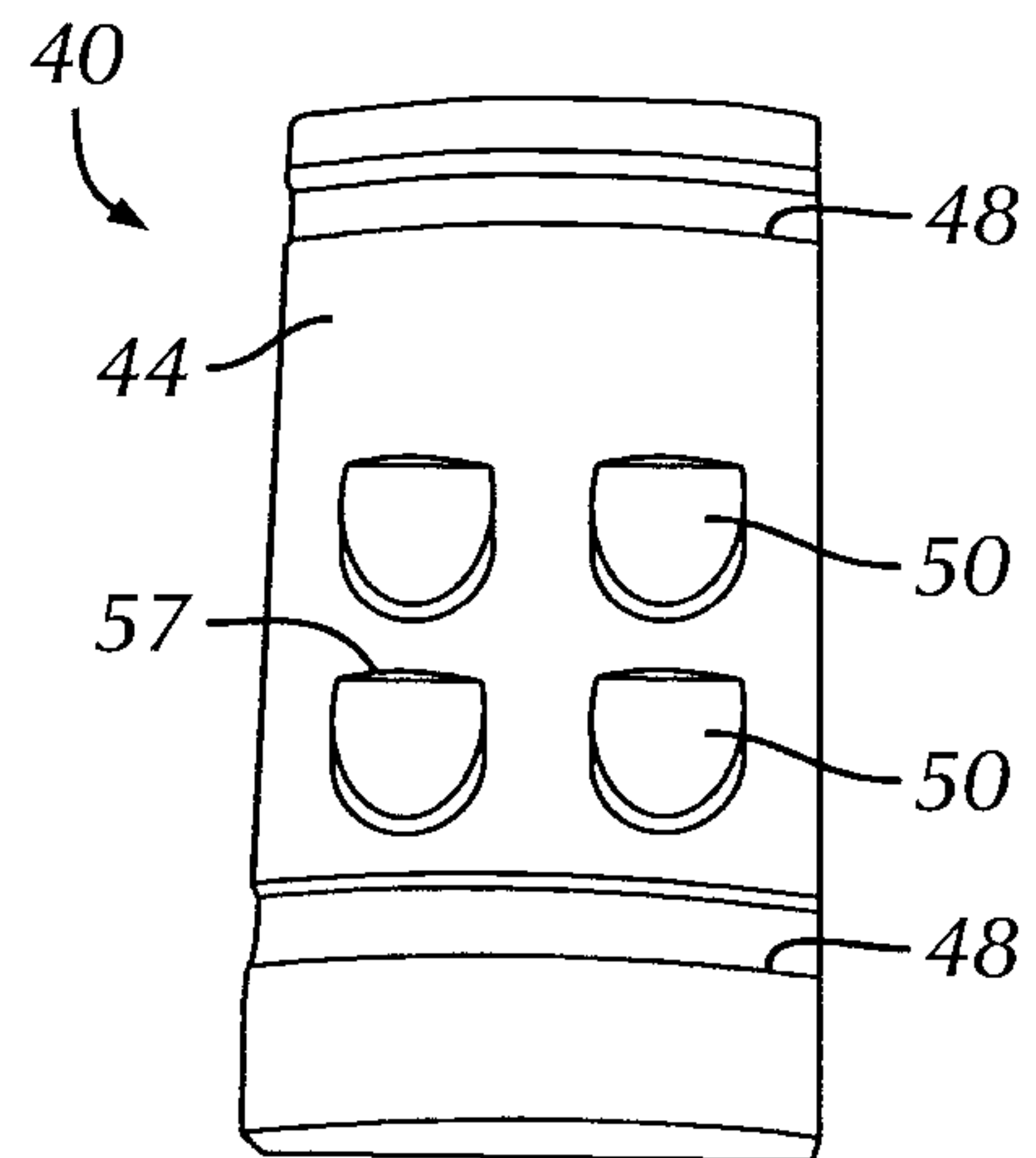
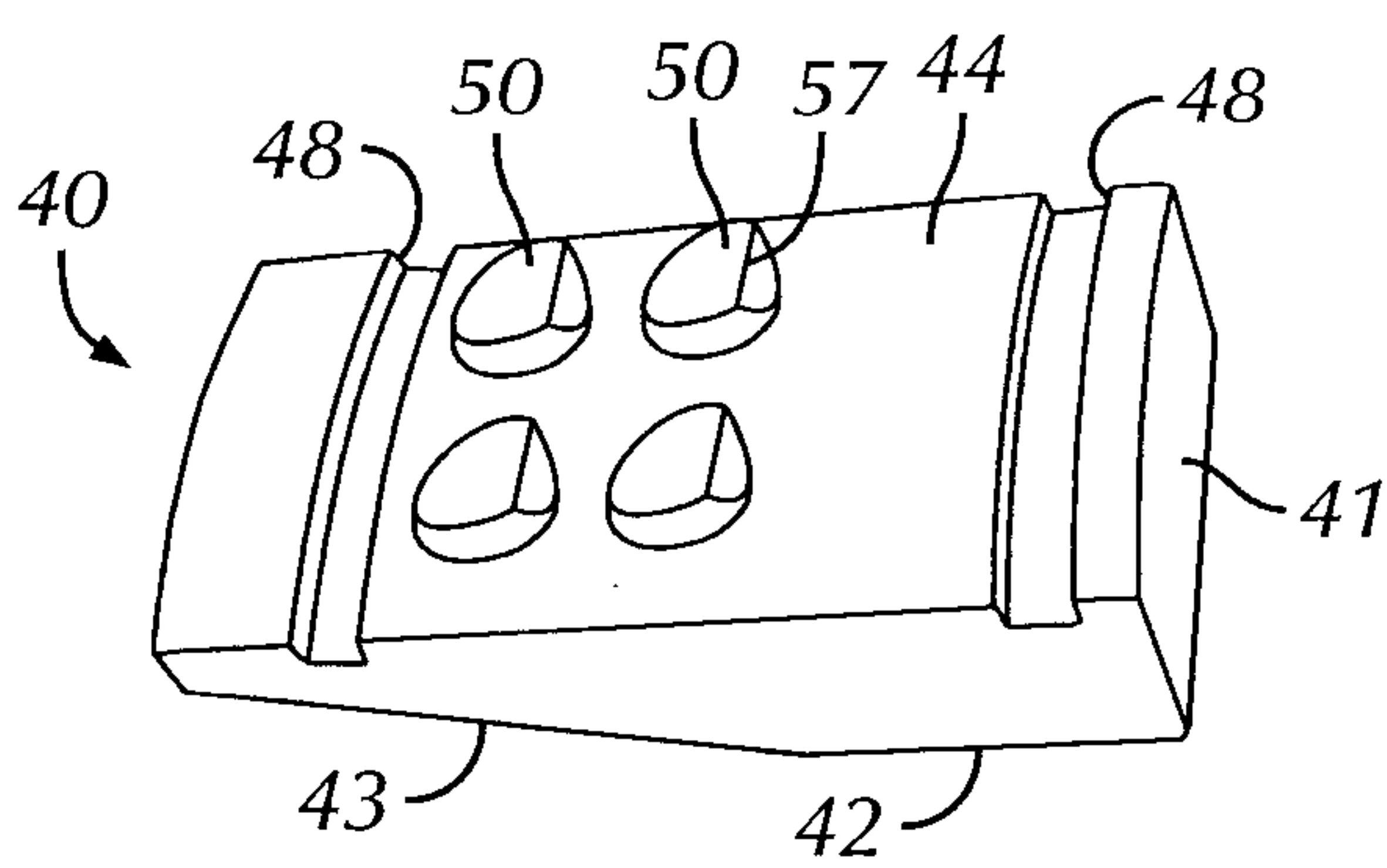
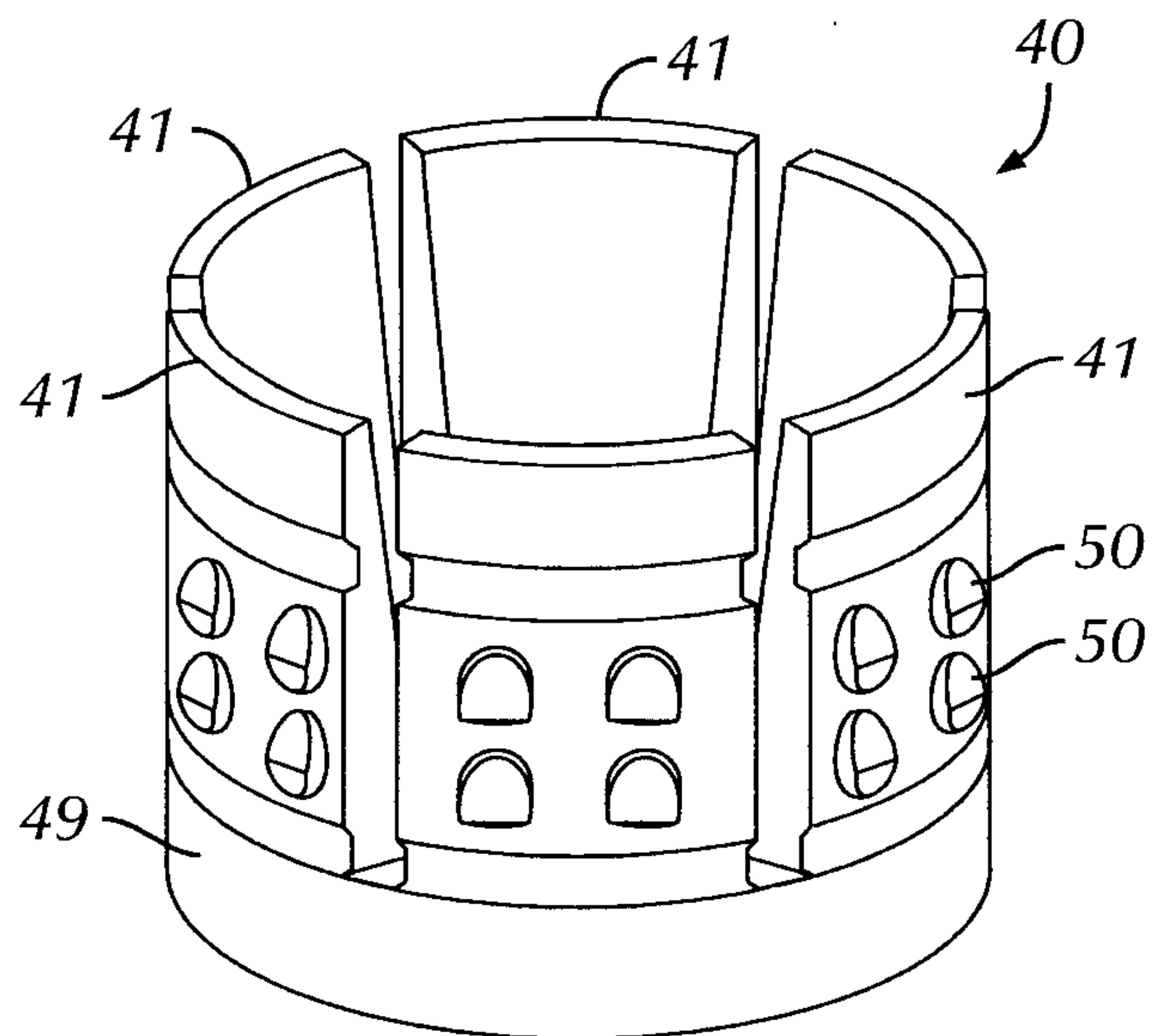


FIG. 12

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**FIG. 13****FIG. 14A****FIG. 14B****FIG. 15**

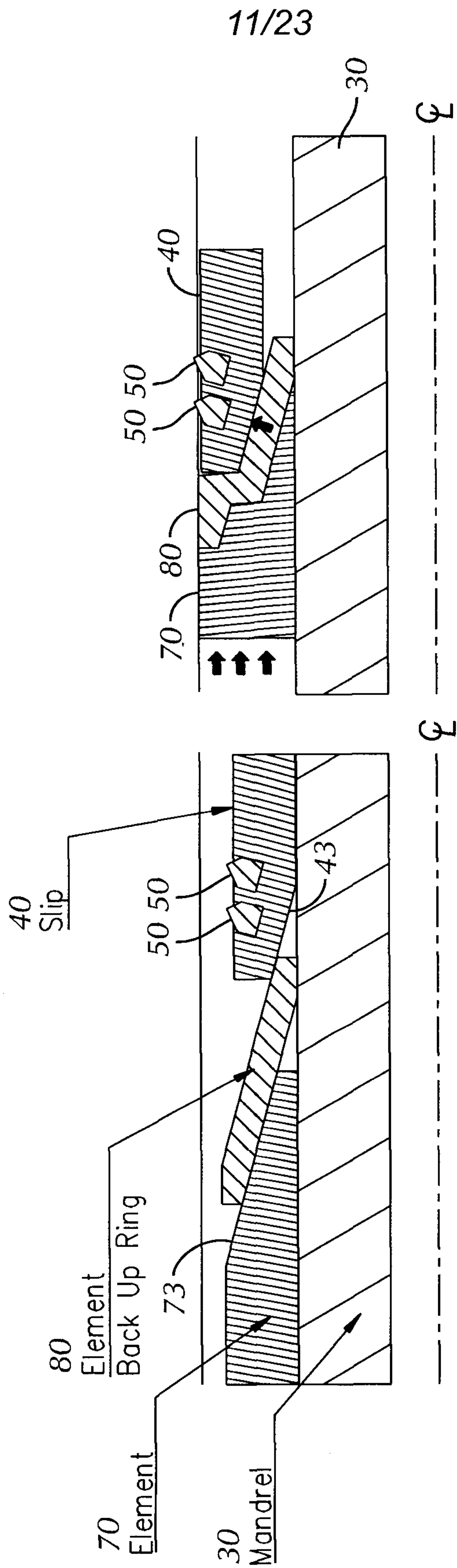


FIG. 16A

FIG. 16B

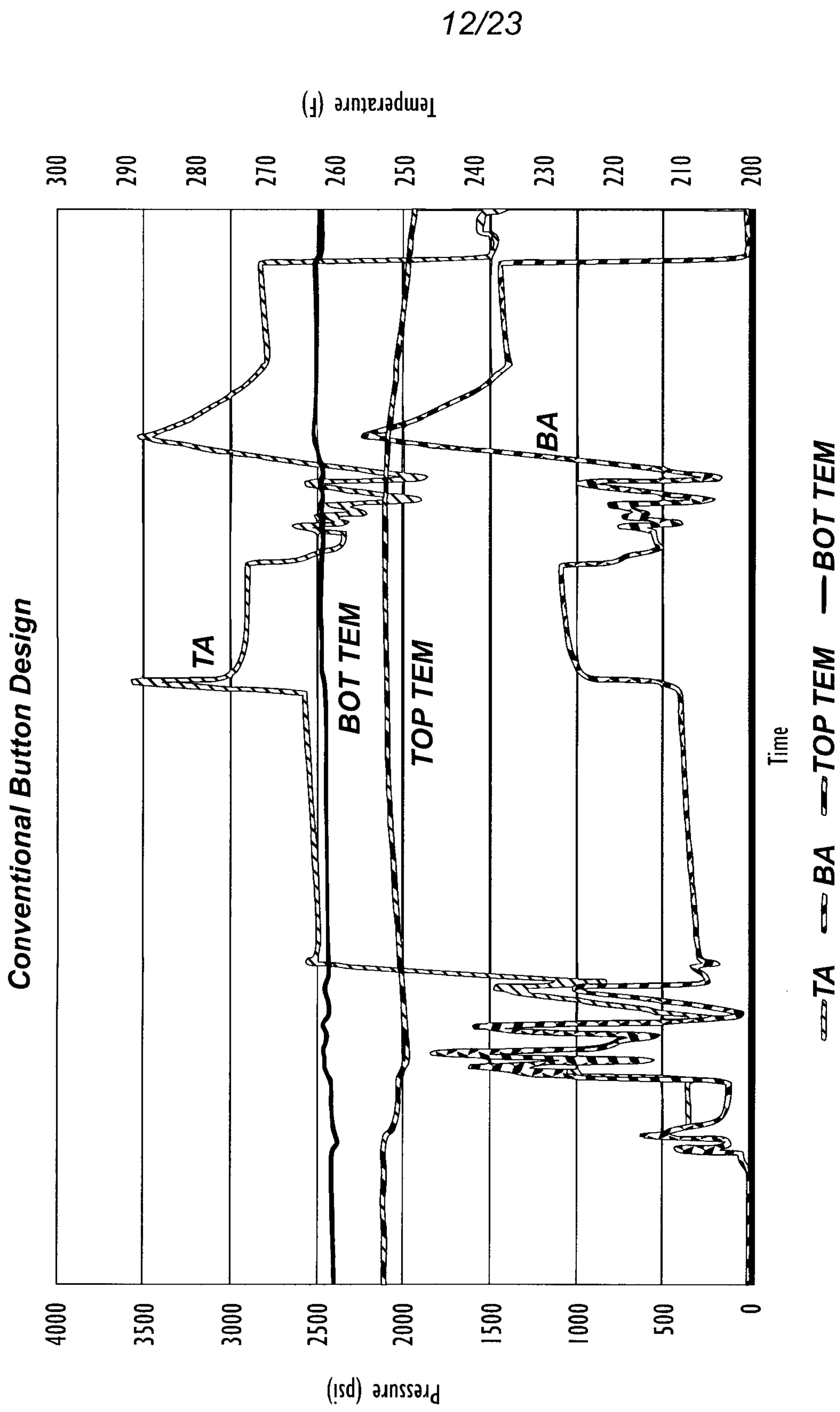


FIG. 17A
(Prior Art)

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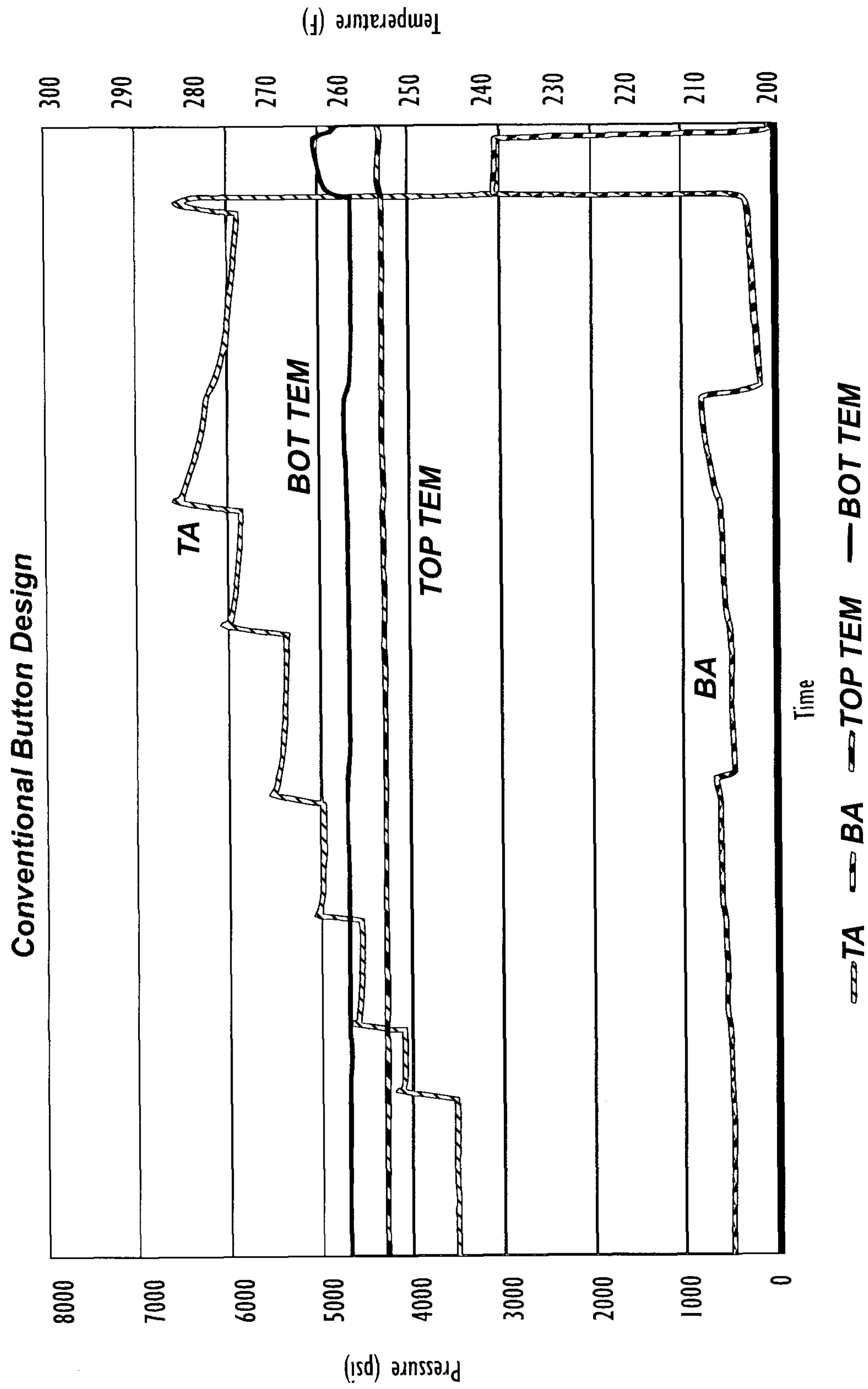


FIG. 17B
(Prior Art)

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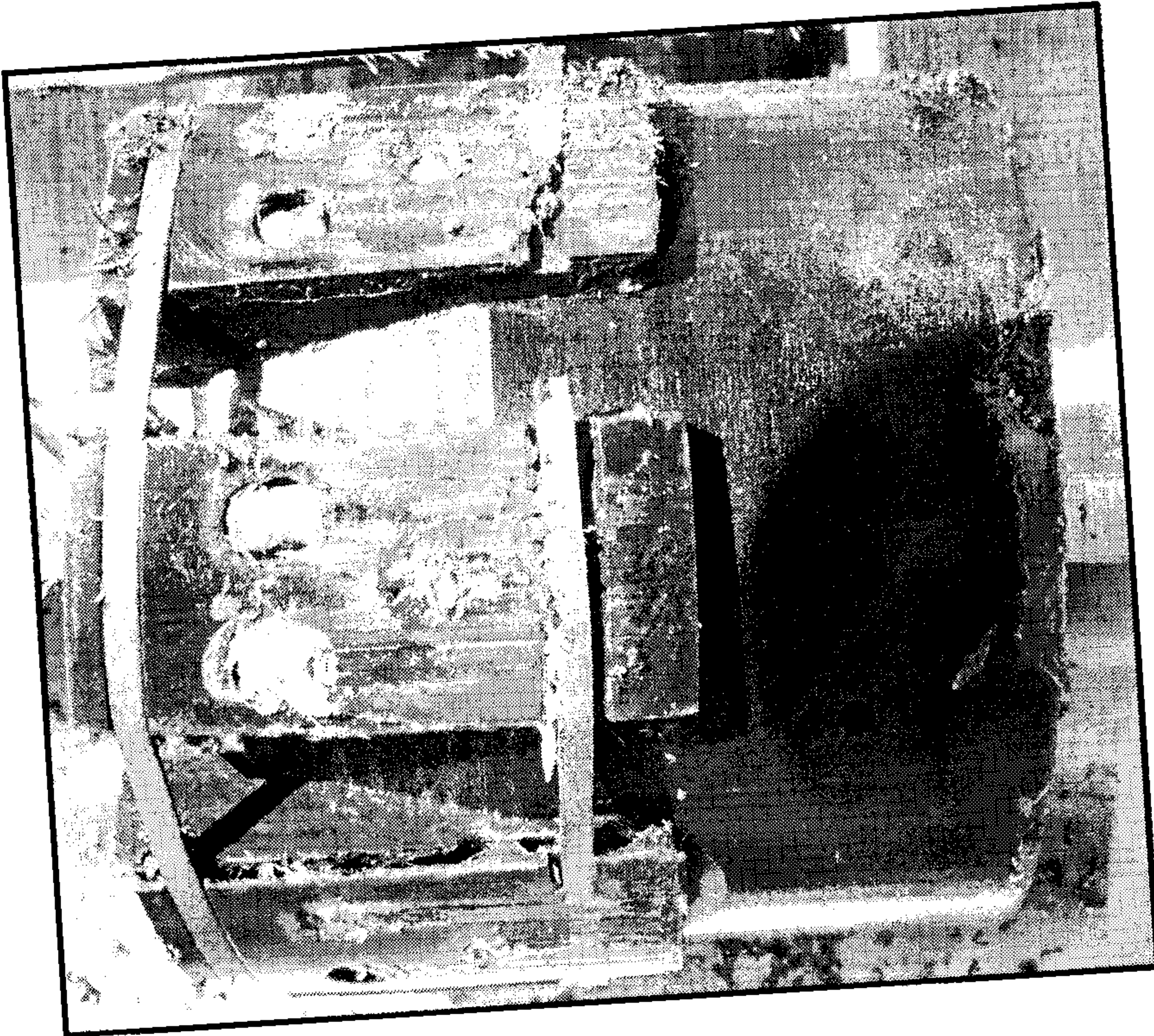


FIG. 18A
(Prior Art)

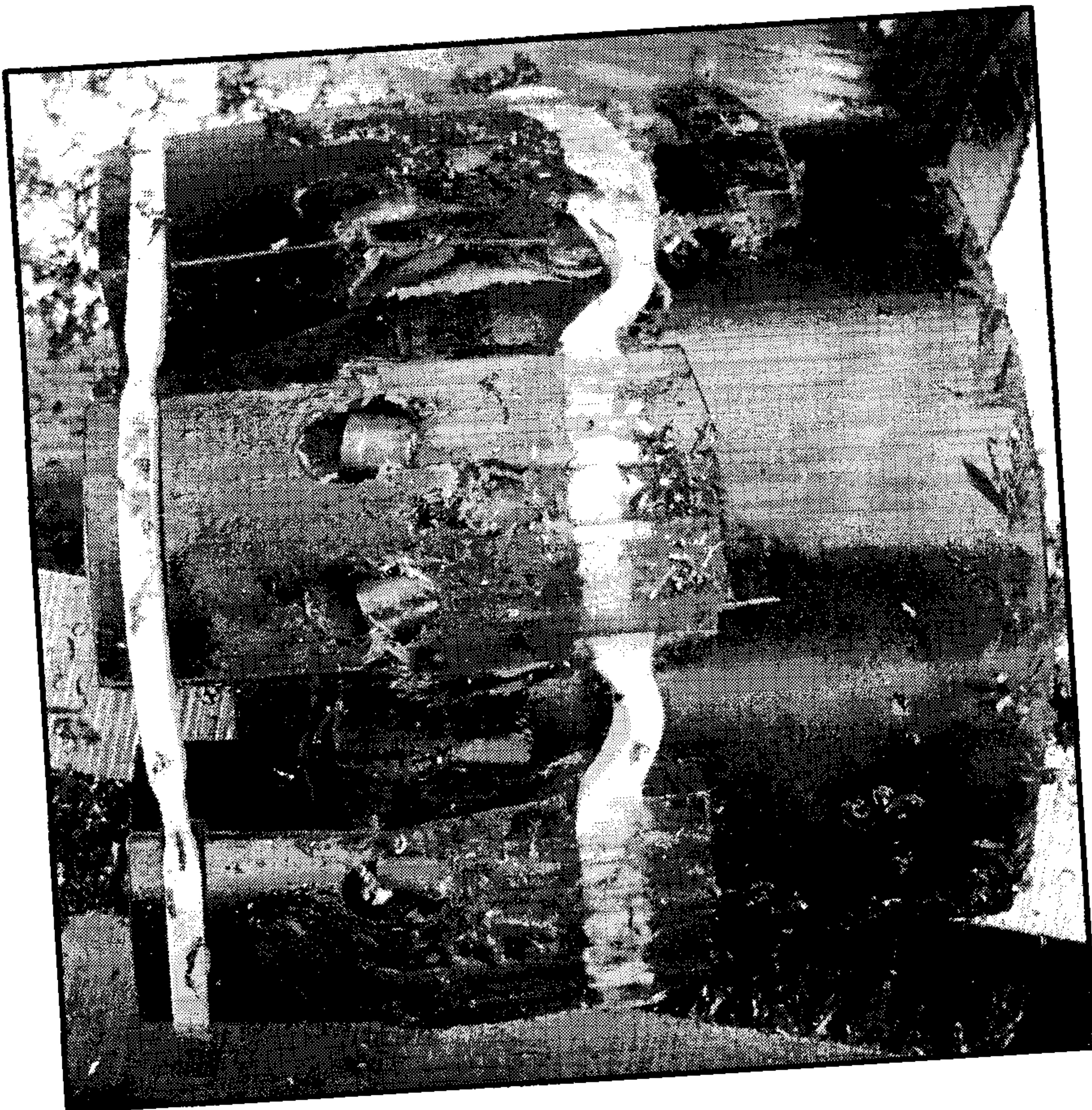


FIG. 18B
(Prior Art)

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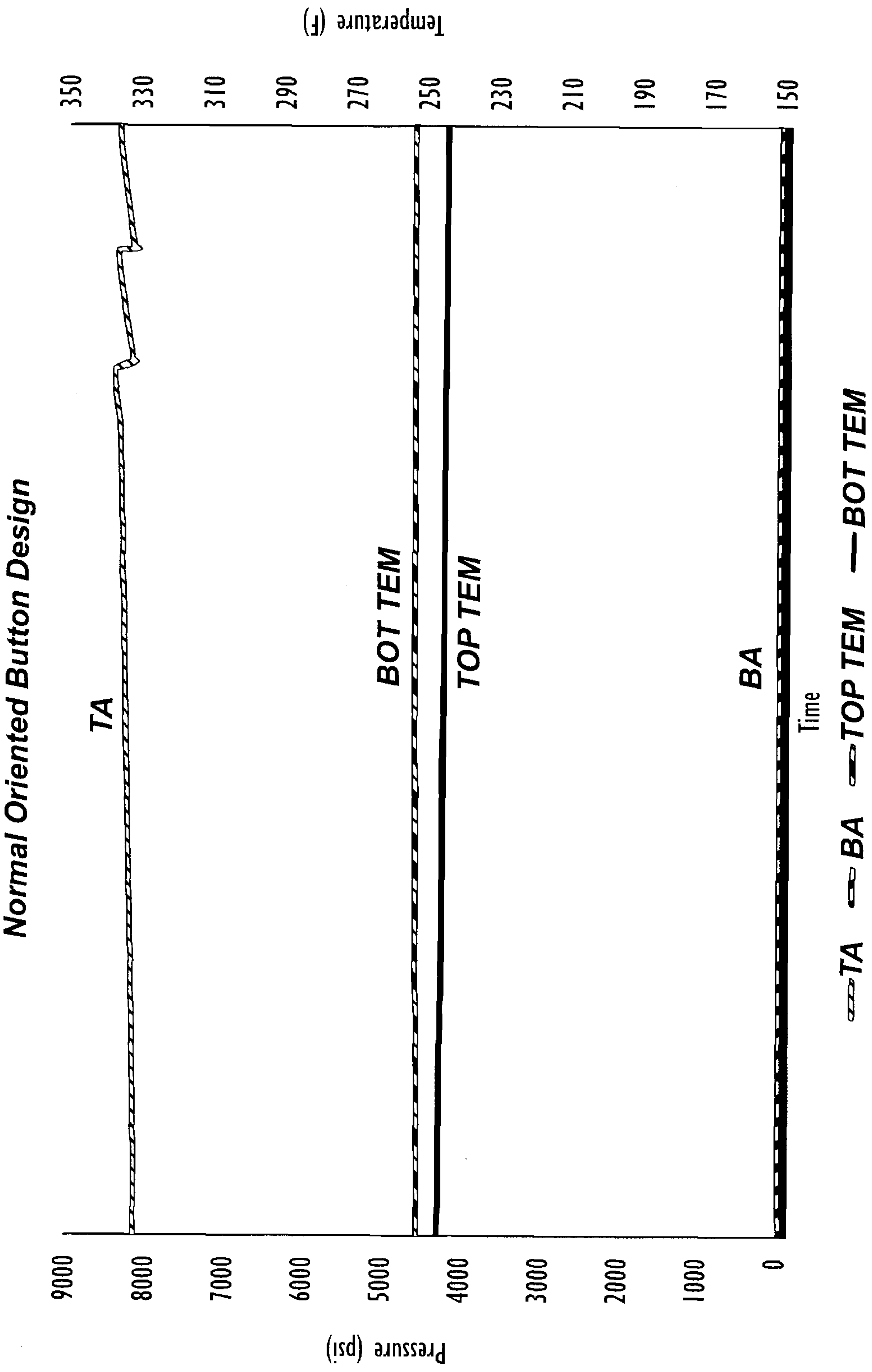


FIG. 19

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FIG. 20

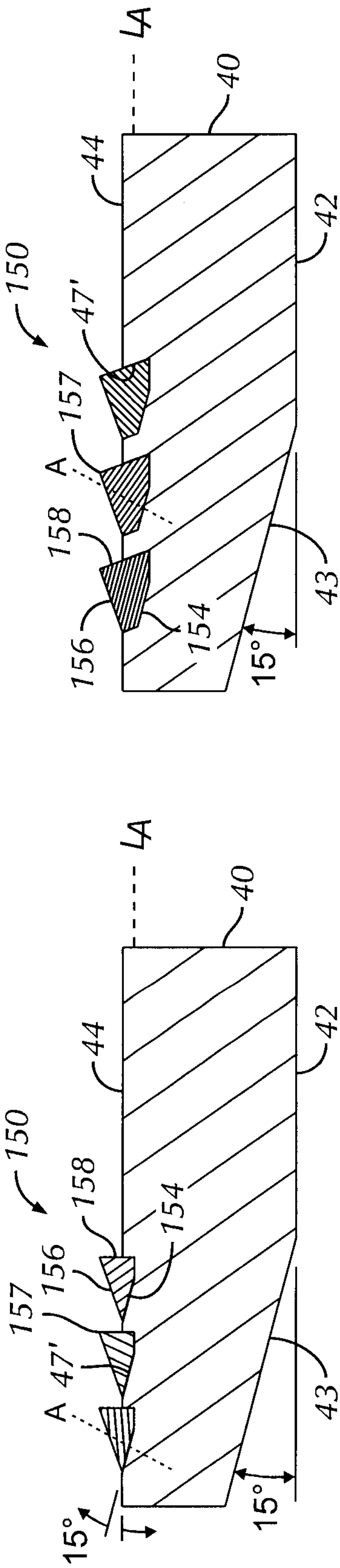


FIG. 21A

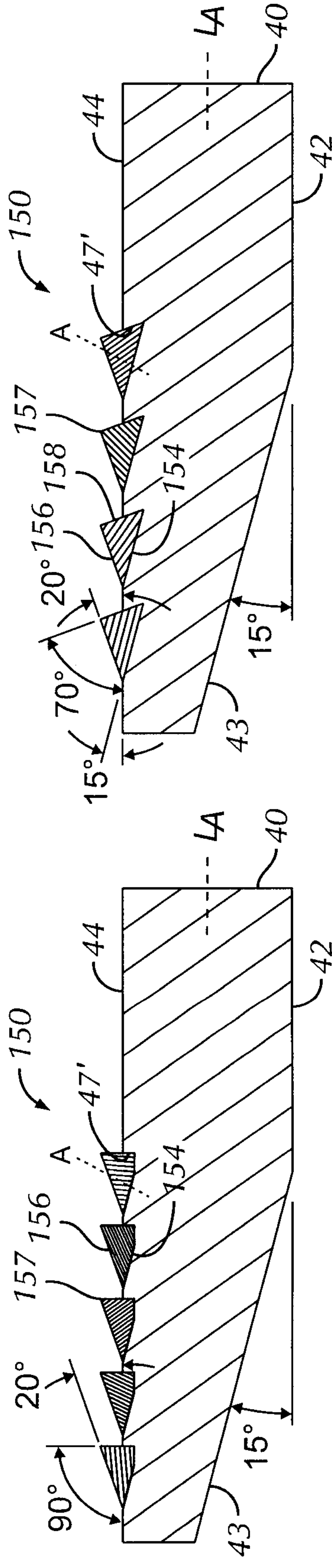


FIG. 21B

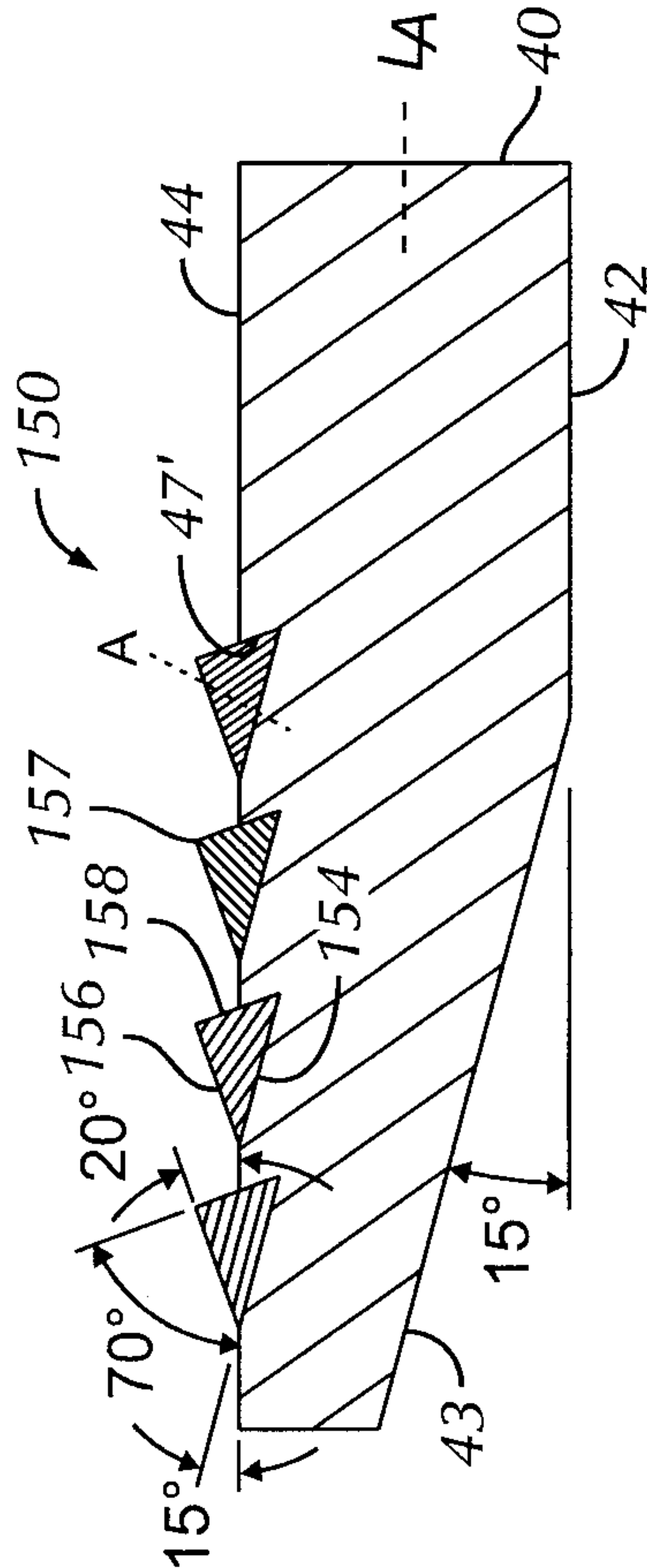


FIG. 22A

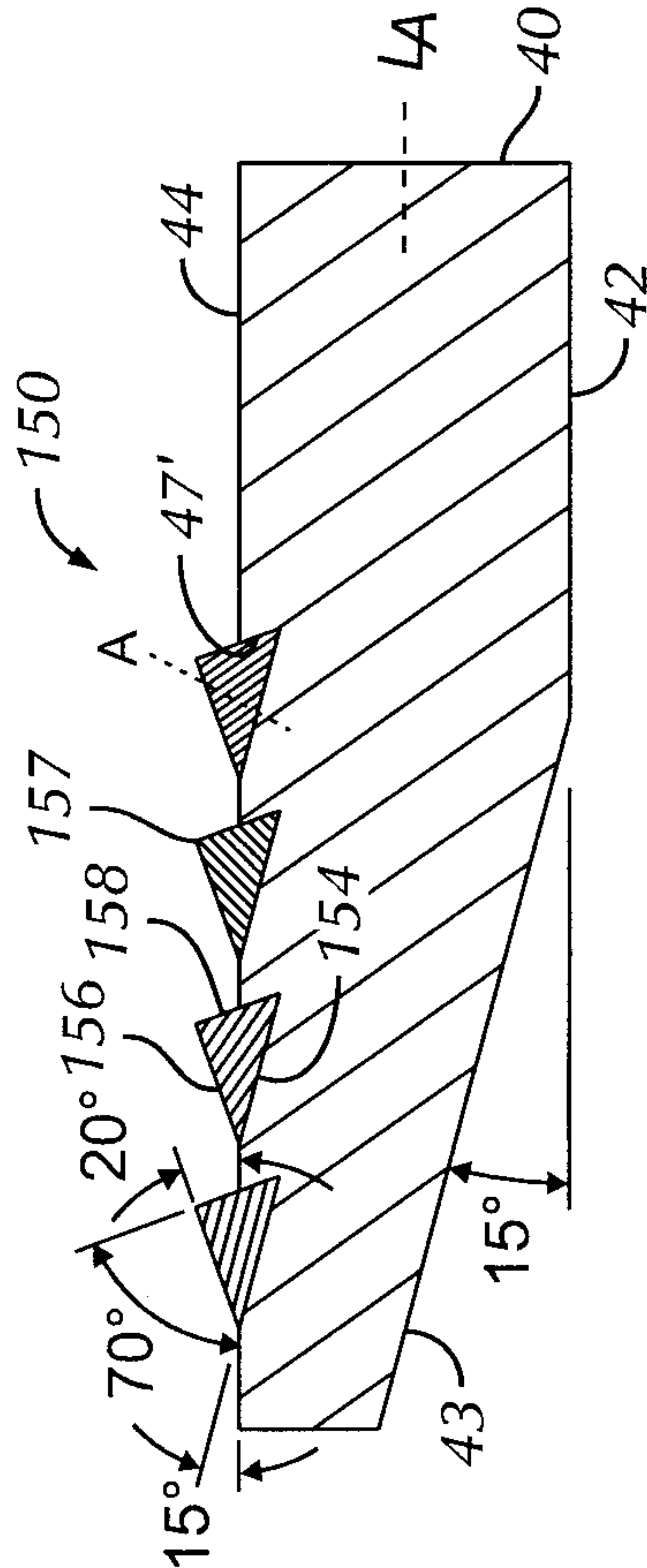


FIG. 22B

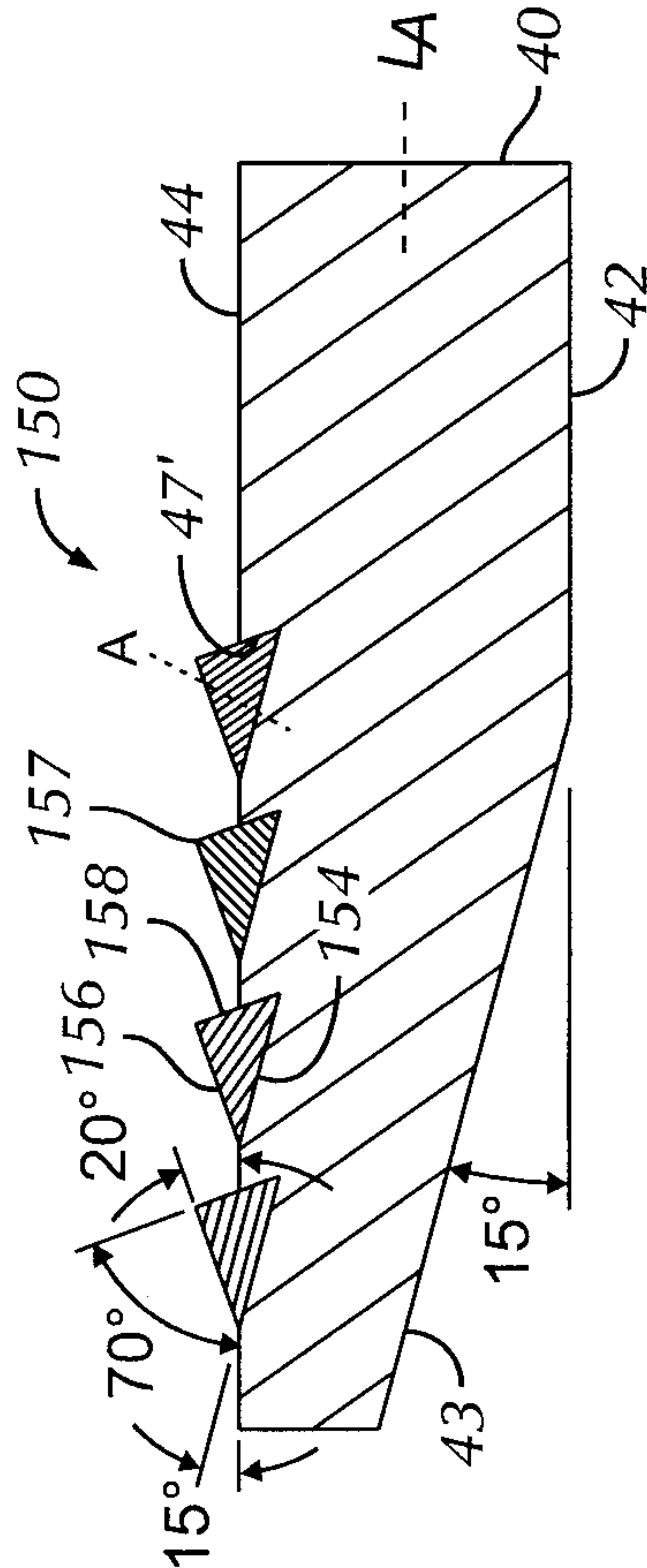
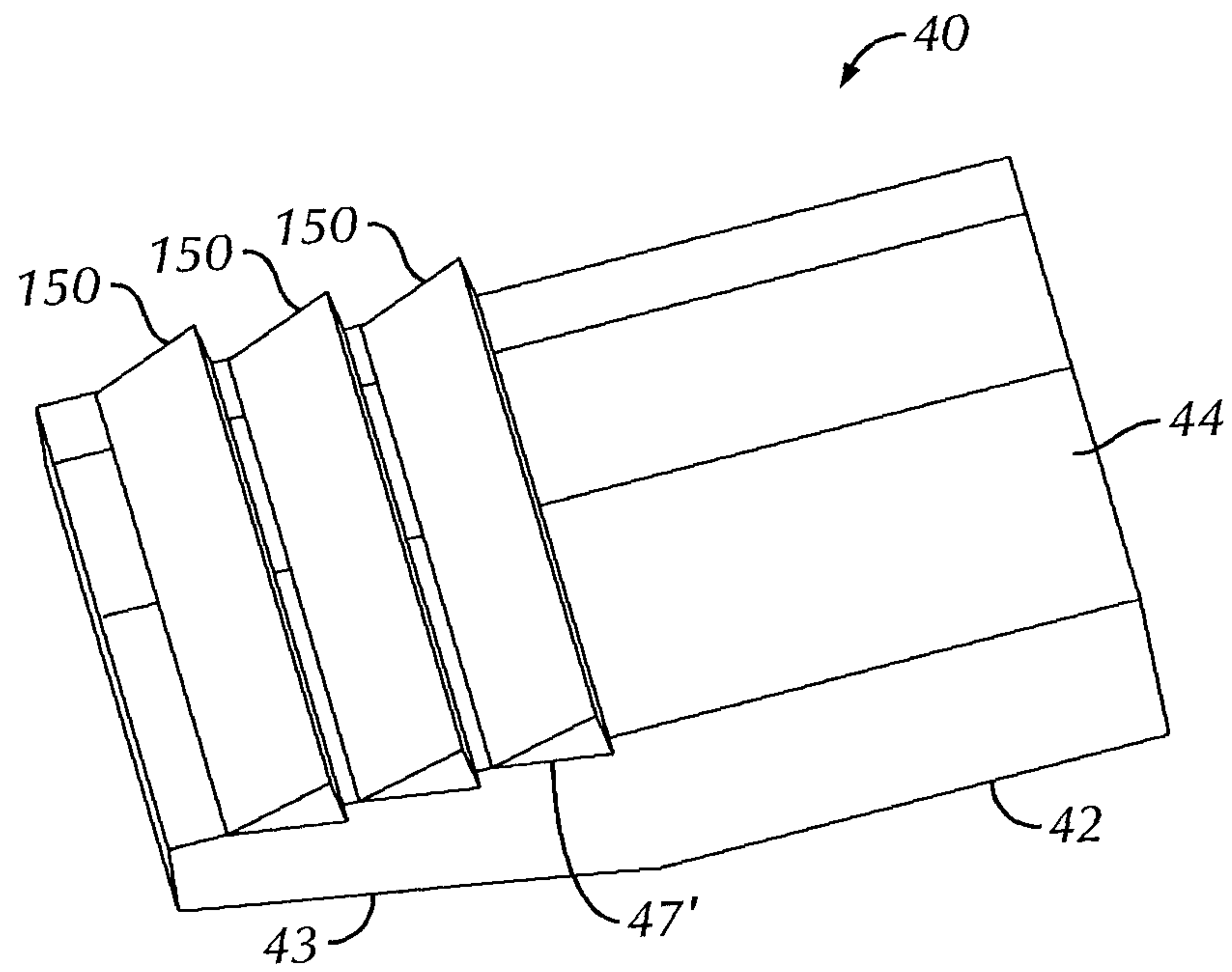
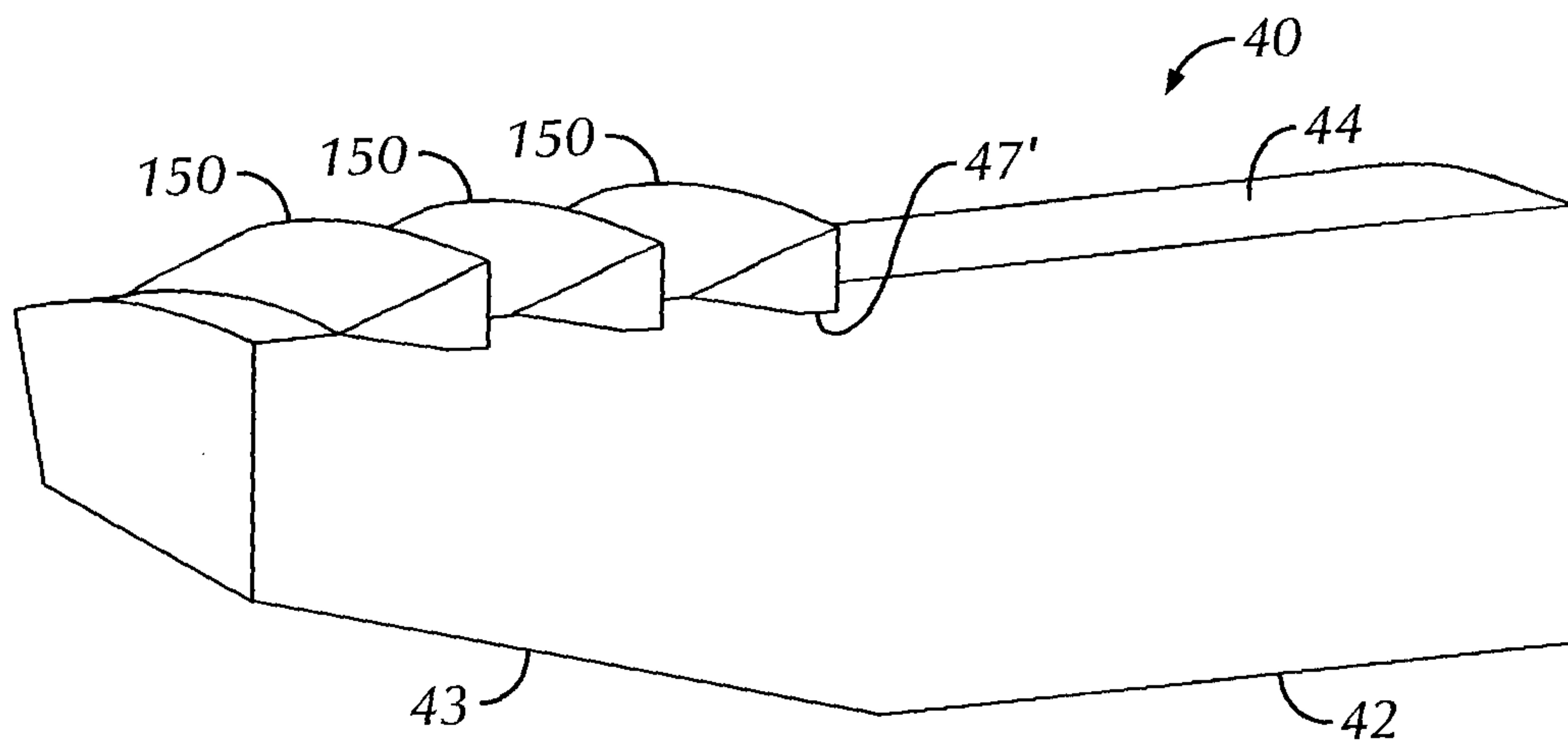


FIG. 22C

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**FIG. 21B****FIG. 21C**

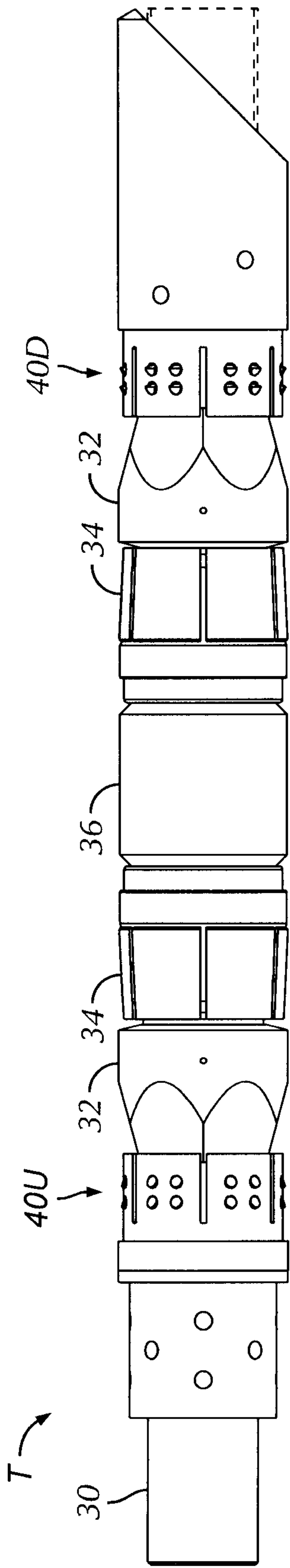


FIG. 23A-1

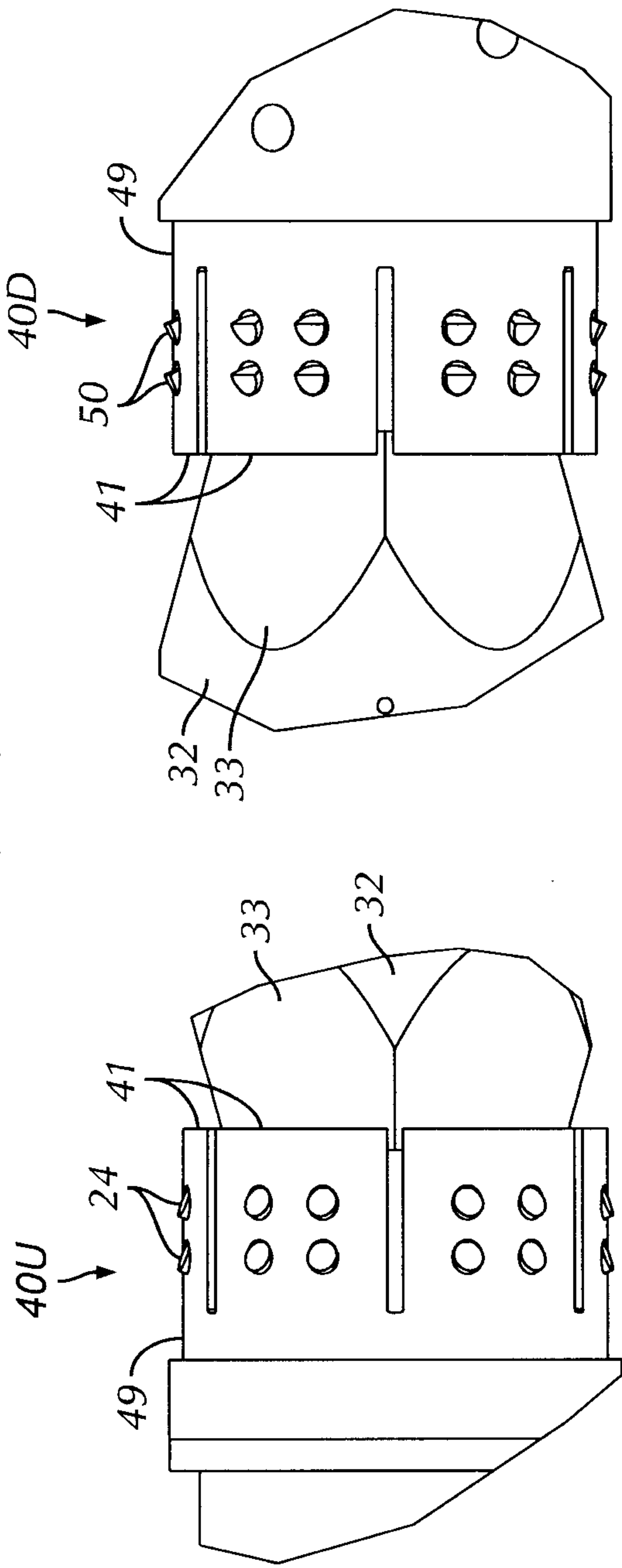


FIG. 23A-3

FIG. 23A-2

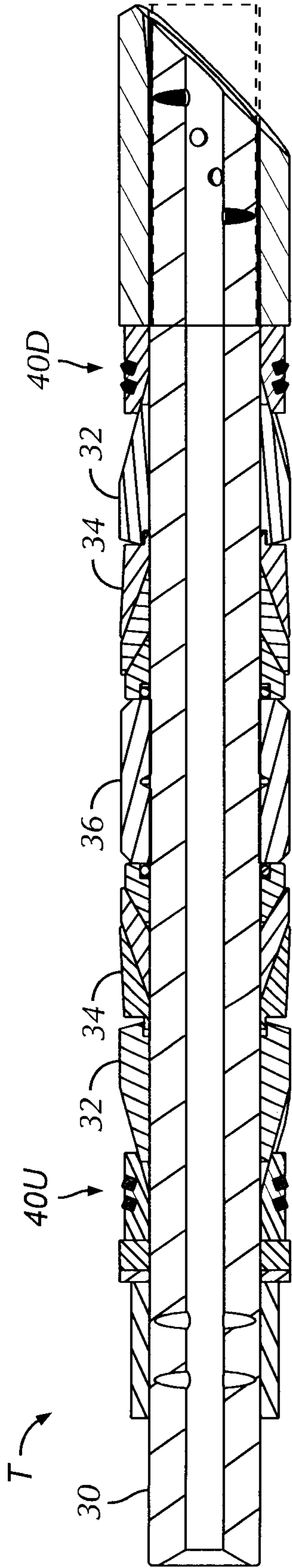


FIG. 23B-1

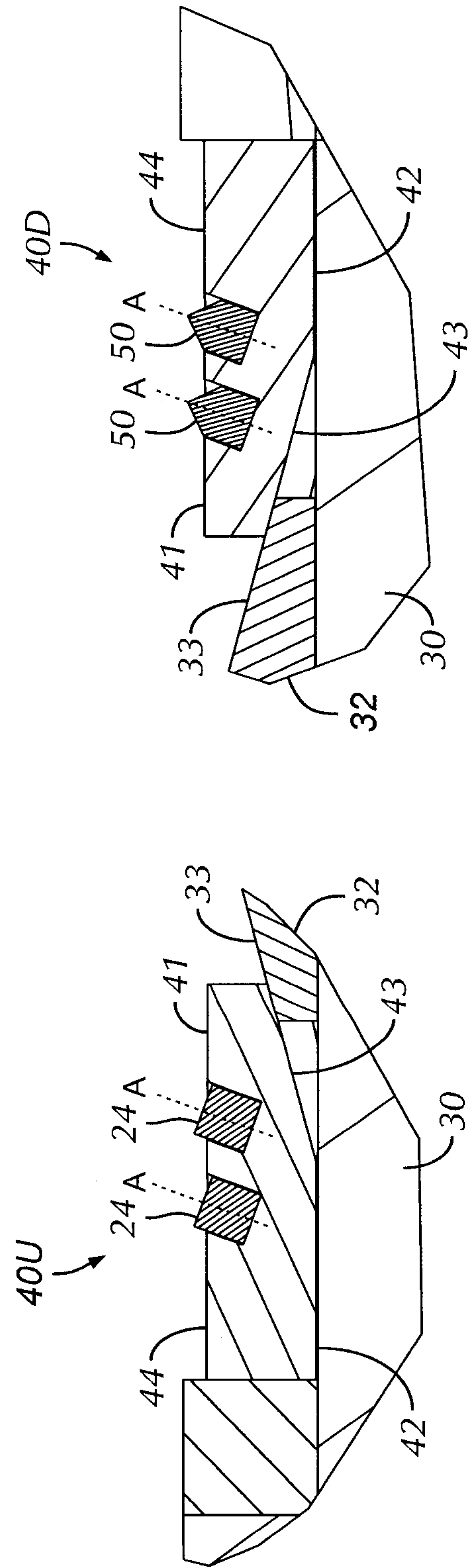


FIG. 23B-2

FIG. 23B-3

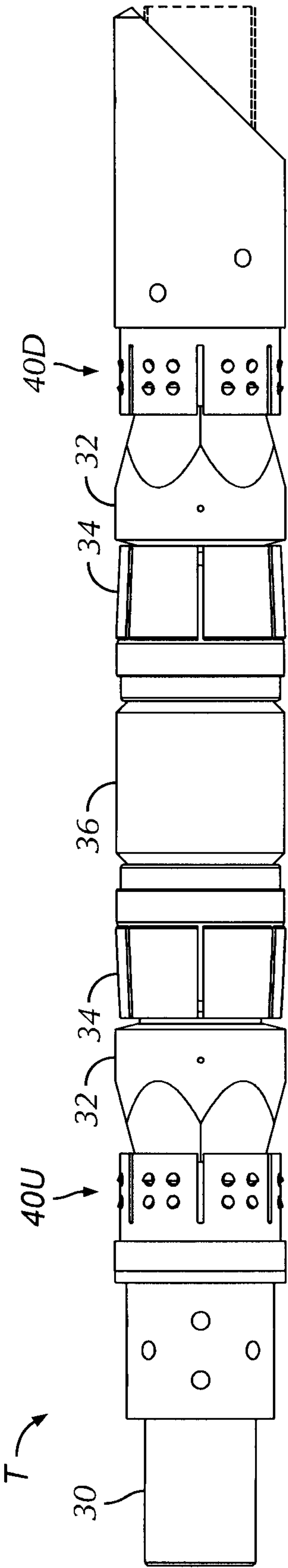


FIG. 24A

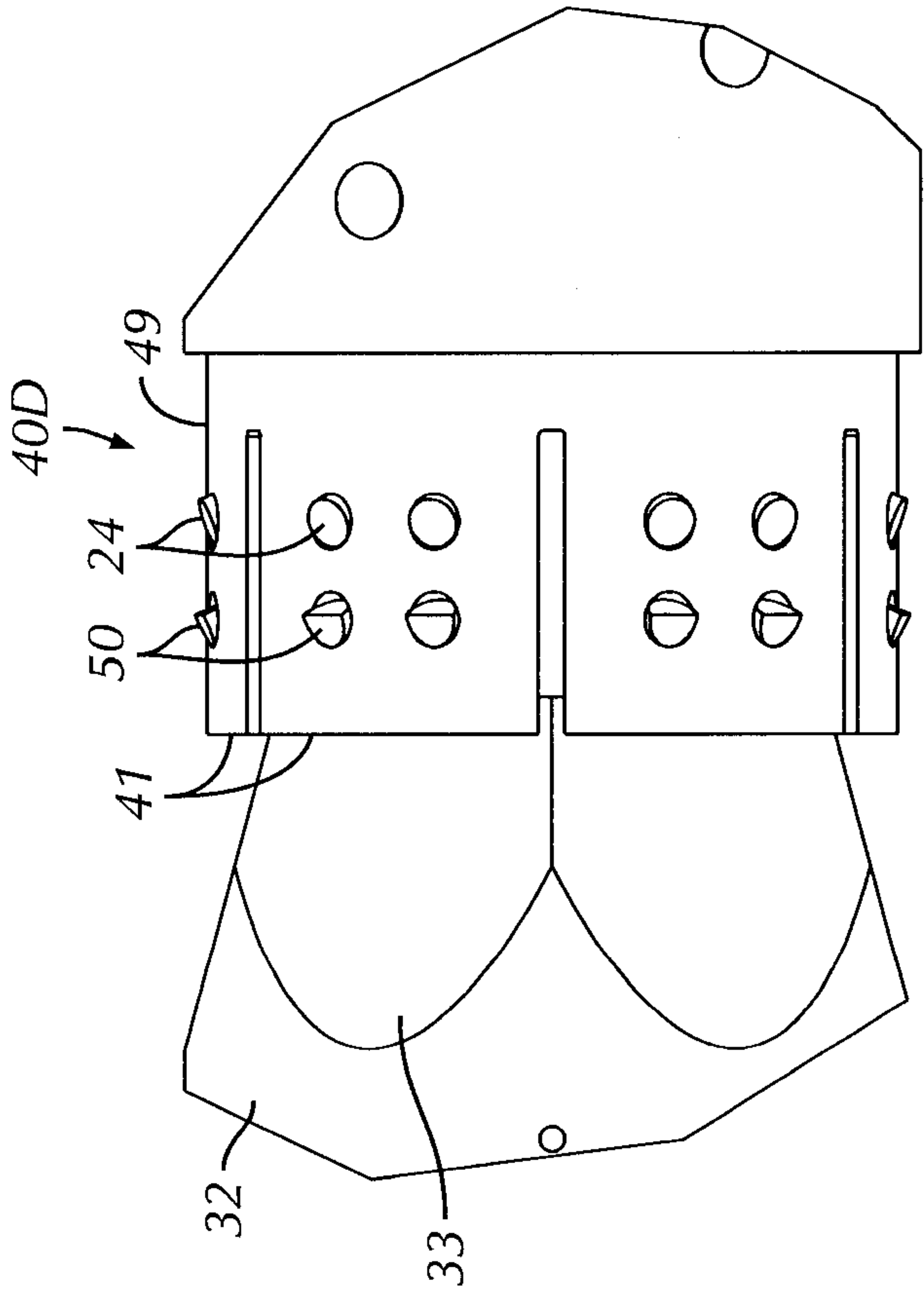
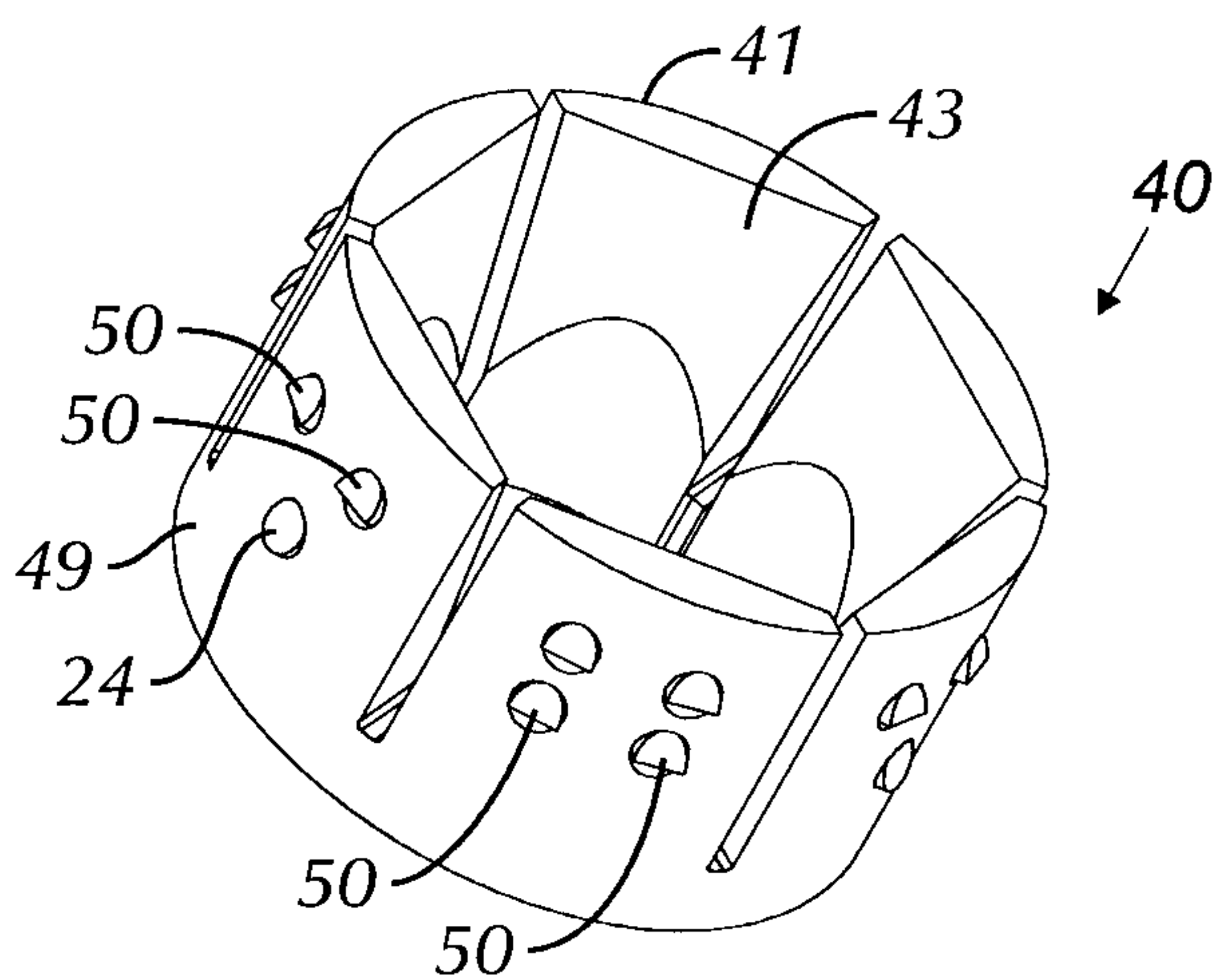
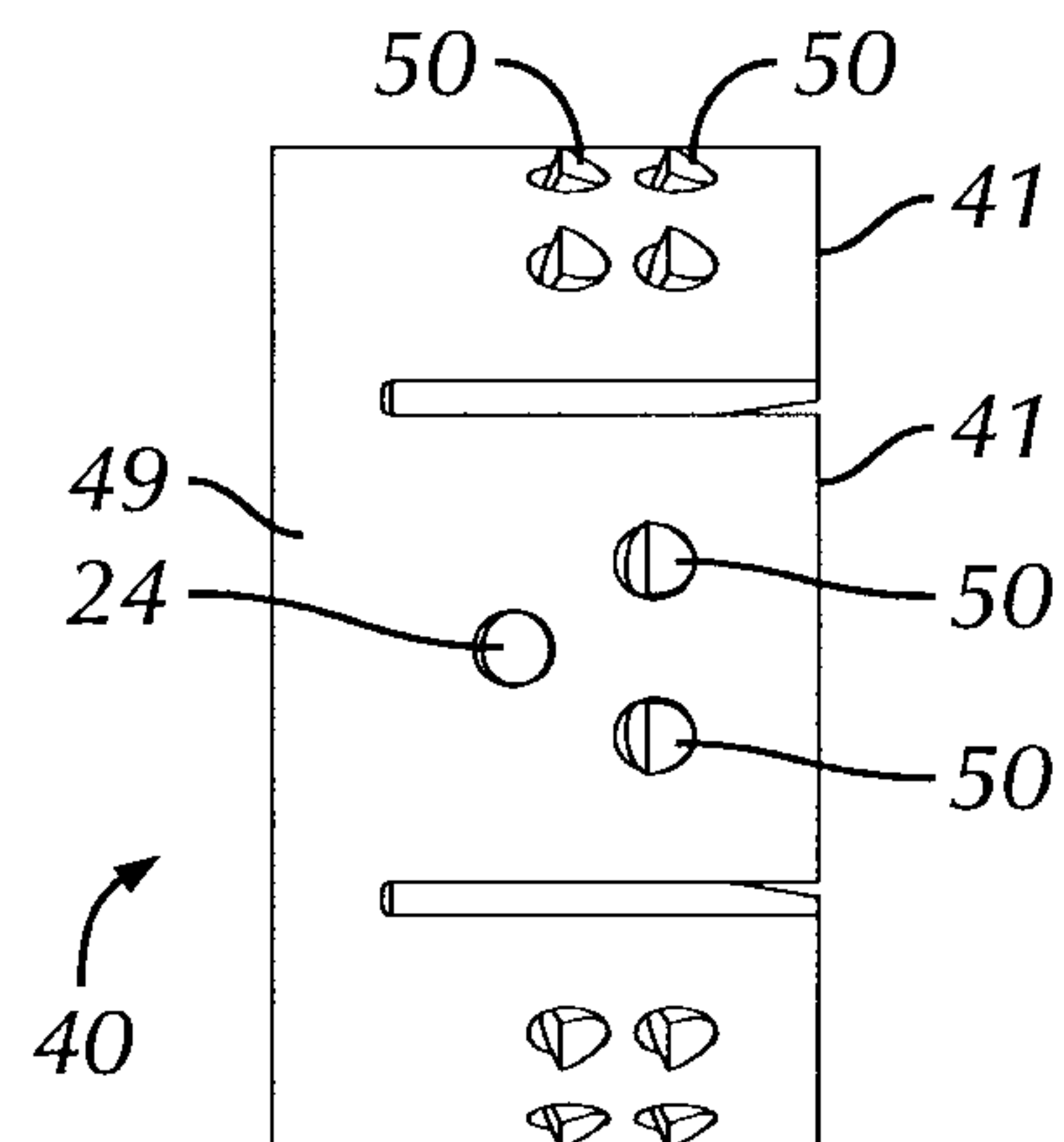
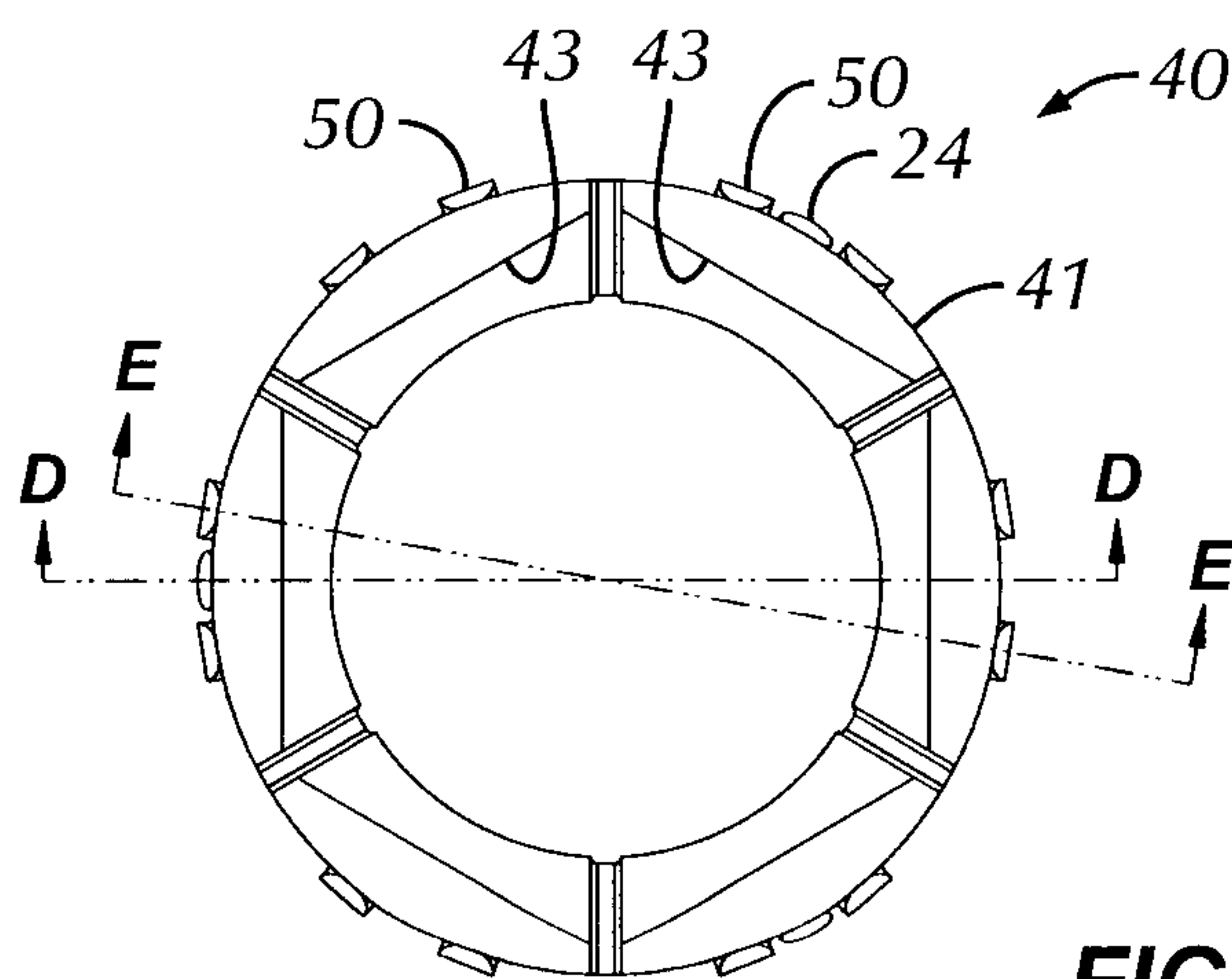
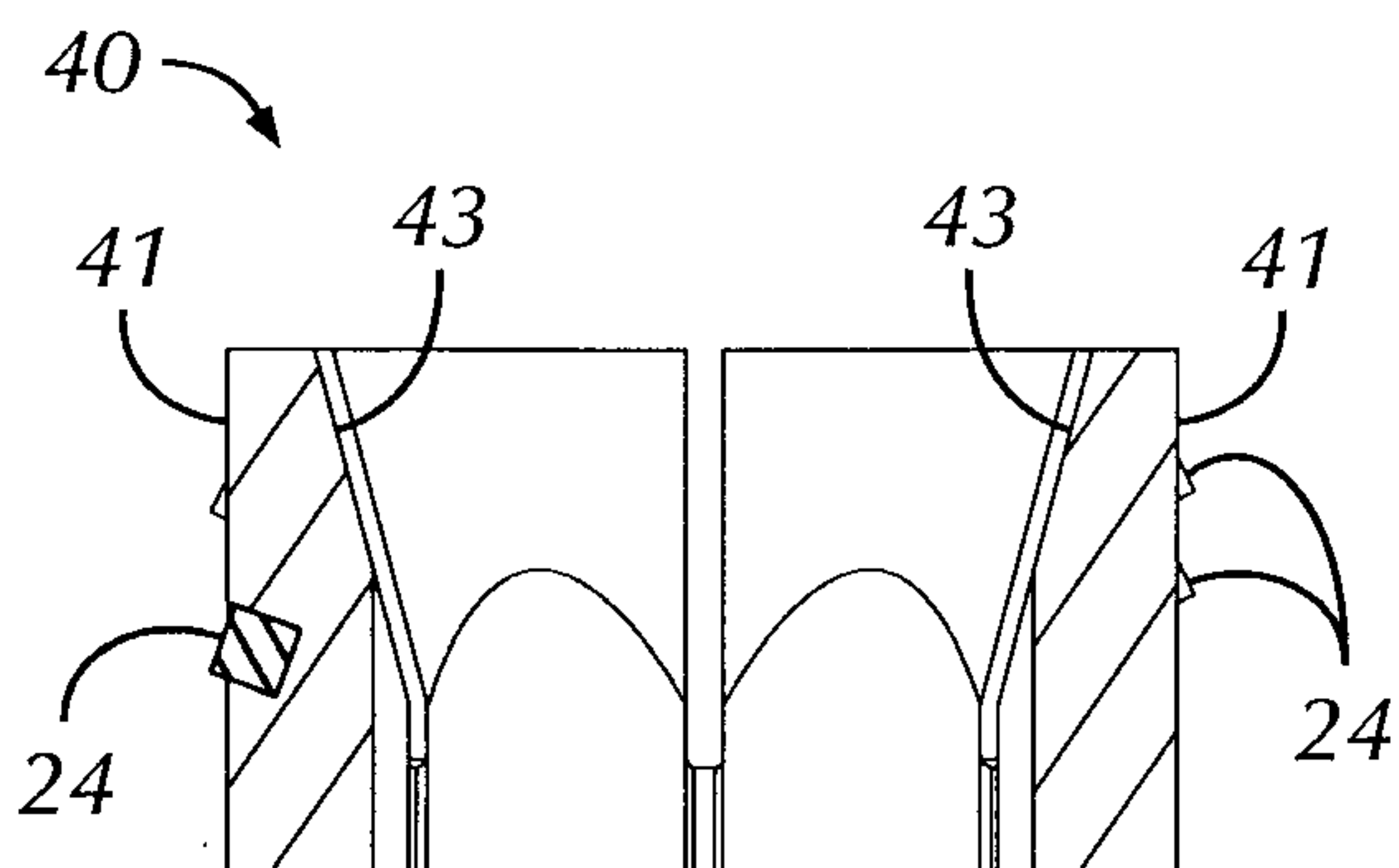
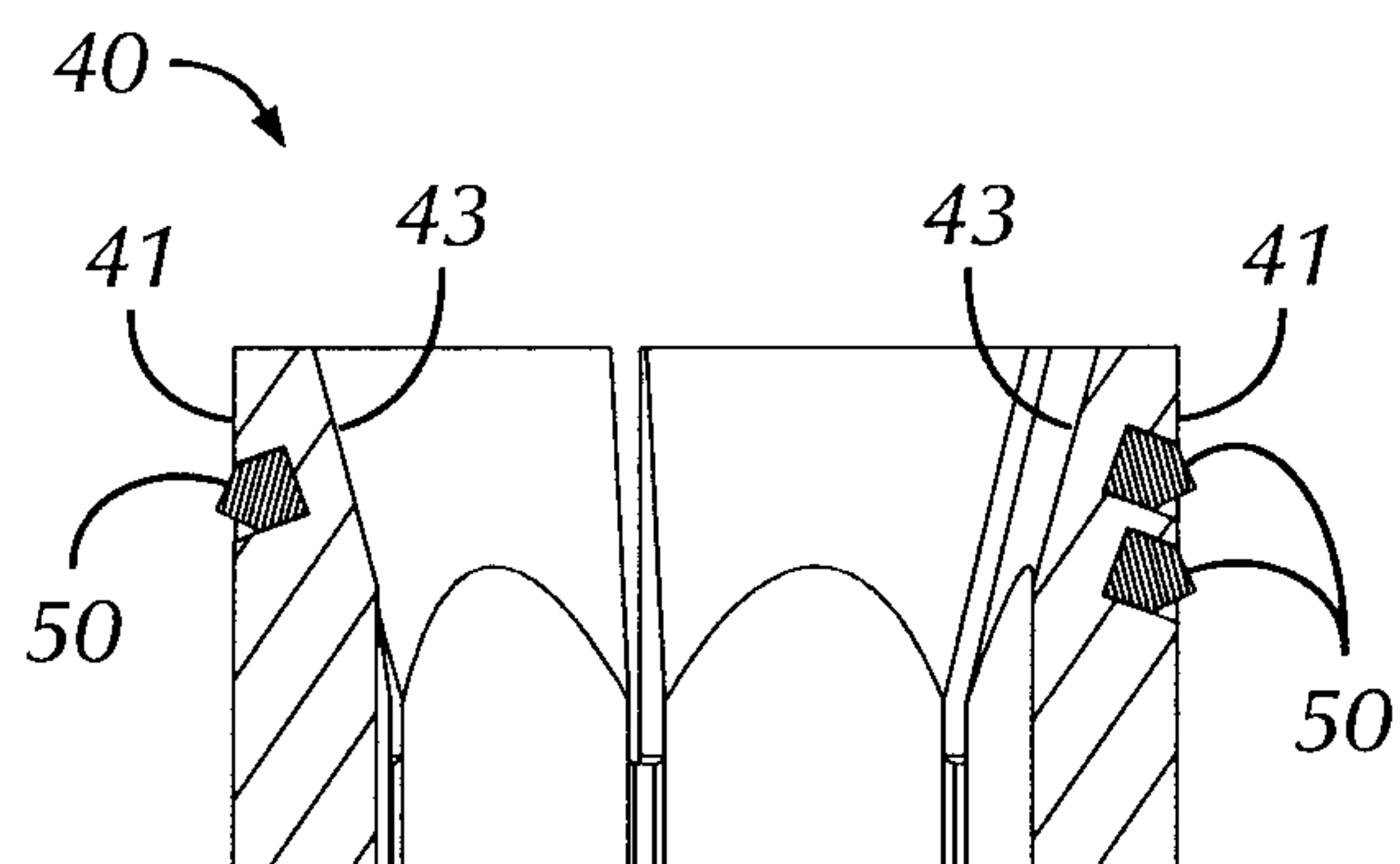


FIG. 24B

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**FIG. 25A****FIG. 25B****FIG. 25C****FIG. 25D****FIG. 25E**

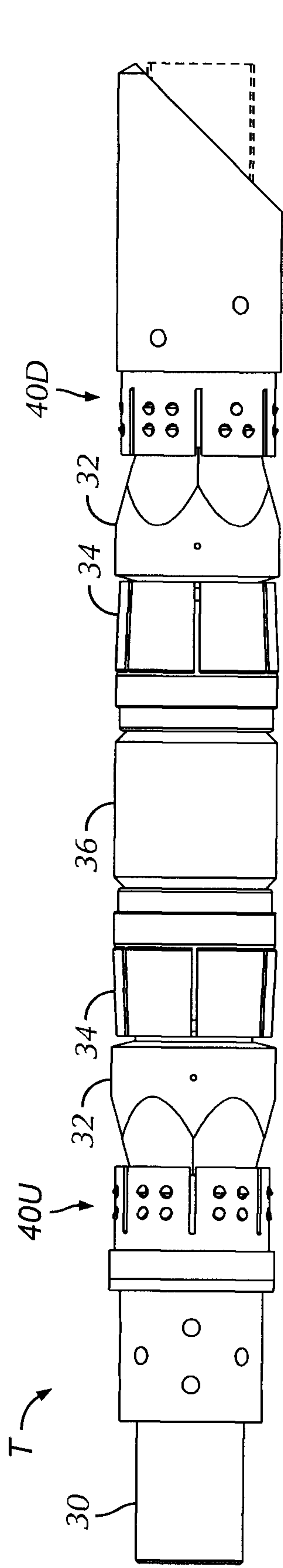


FIG. 26A

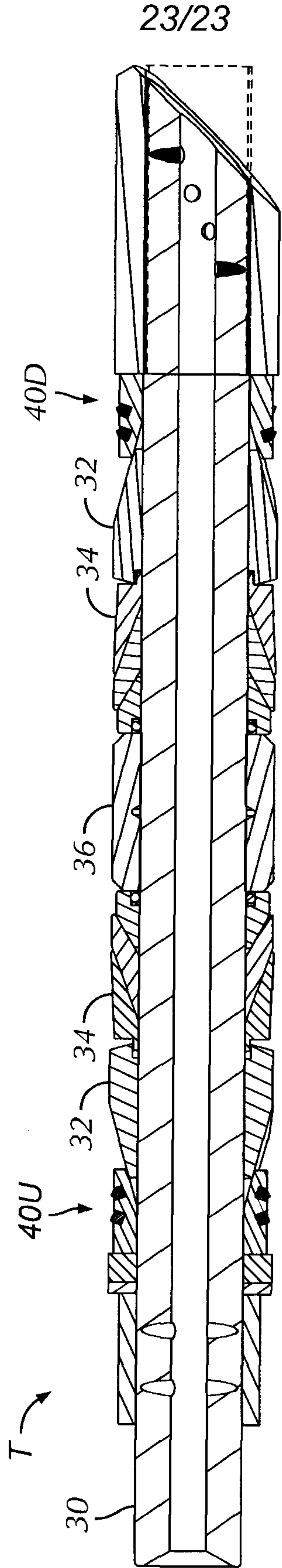


FIG. 26B

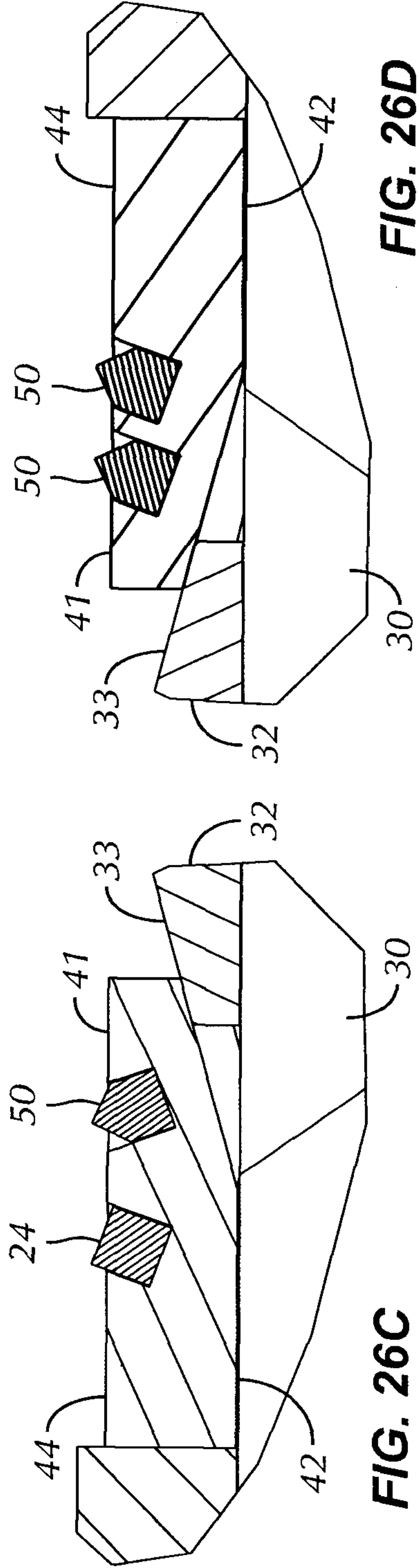


FIG. 26D

