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(54) Titre : CENTREUR DE TUBAGE A RESSORTS ARQUES MONTABLE SUR PLACE ET PROCEDE DE FABRICATION ASSOCIE
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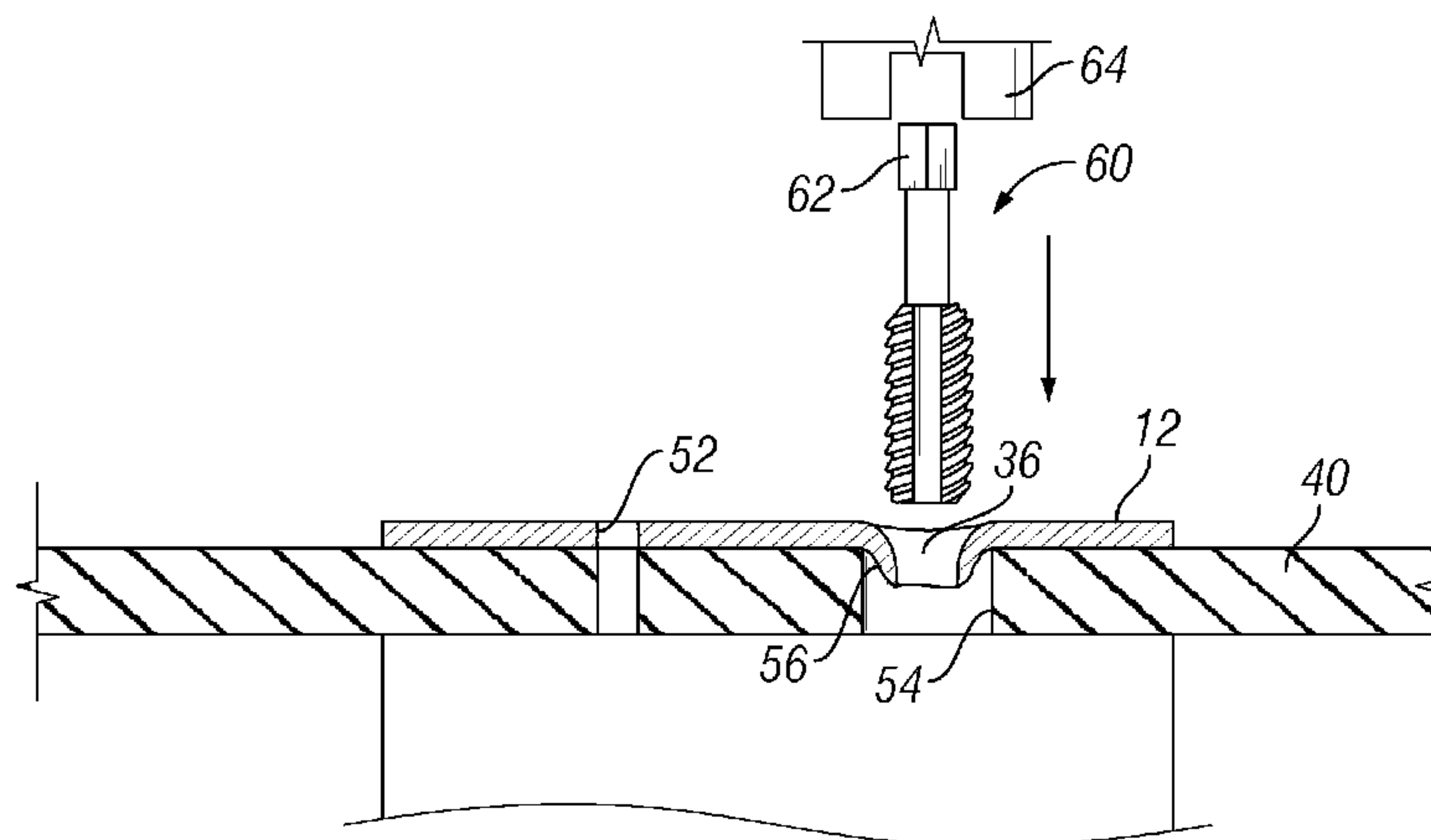


FIG. 7

(57) **Abrégé/Abstract:**

A casing centralizer is provided that may be shipped unassembled and is then assemblable at a well site. According to one embodiment, first and second collars each have a plurality of circumferentially spaced aligning slots and a corresponding plurality of threaded, extruded through-holes. A plurality of bow-springs each have a foot at each end. Each bow-spring axially extends between the first and second collars. The foot at one end of each bow-spring is disposed in one of the aligning slots of the first collar, and the foot at the other end is disposed in one of the aligning slots on the second collar. A plurality of threaded fasteners corresponding in number to the threaded extruded through-holes secure the ends of the bow-springs to the threaded extruded through-holes. The extruded through-holes have a flange height greater than a collar thickness adjacent to the extruded through-holes. The increased flange height allows more threads to be formed within the extruded holes, resulting in a stronger threaded connection with the threaded fasteners, and a correspondingly stronger, more durable centralizer. The foot is retained within the aligning slot to reinforce the coupling between the bow-spring and the collar. A method of manufacturing the casing centralizer is also provided.

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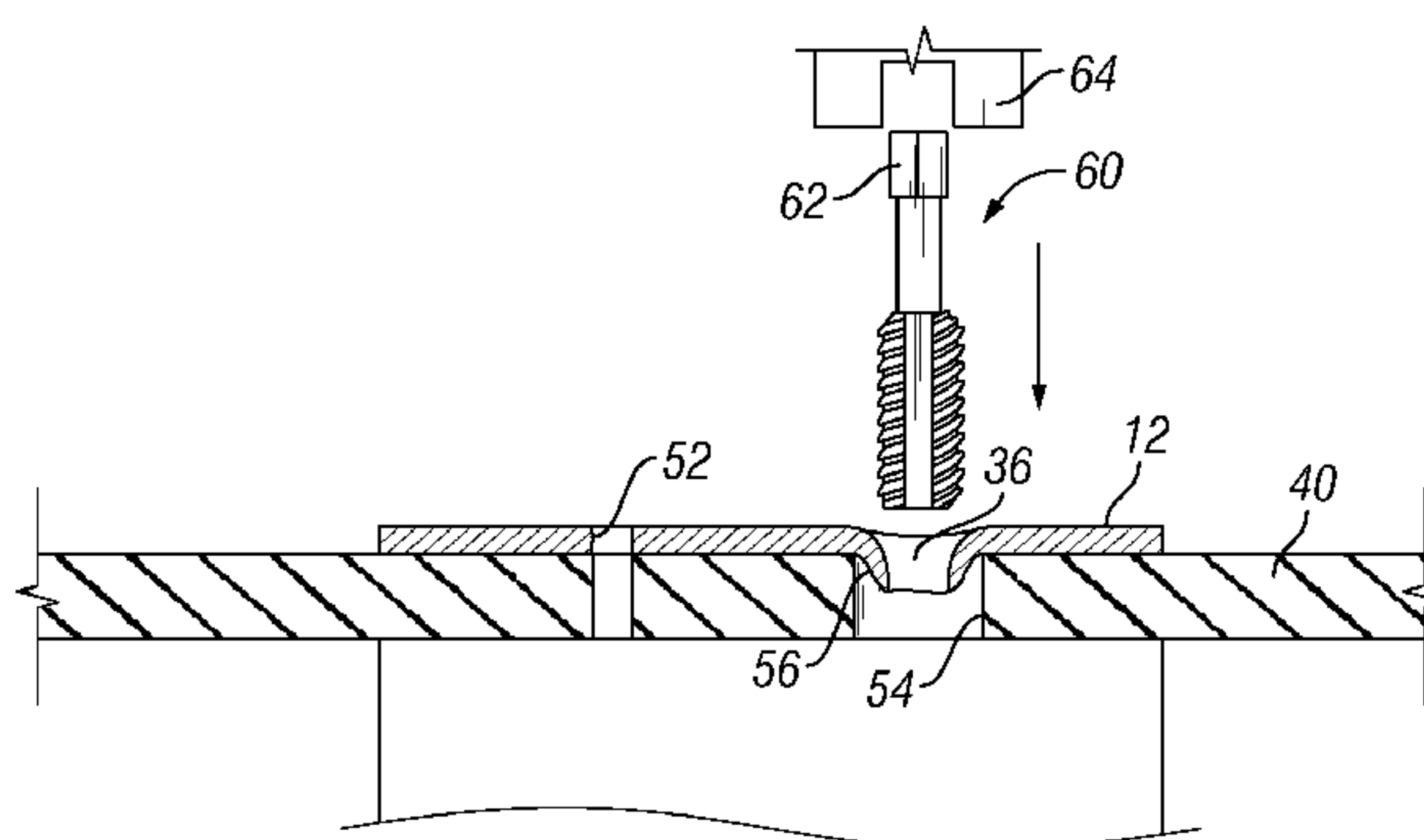


FIG. 7

(57) Abstract: A casing centralizer is provided that may be shipped unassembled and is then assemblable at a well site. According to one embodiment, first and second collars each have a plurality of circumferentially spaced aligning slots and a corresponding plurality of threaded, extruded through-holes. A plurality of bow-springs each have a foot at each end. Each bow-spring axially extends between the first and second collars. The foot at one end of each bow-spring is disposed in one of the aligning slots of the first collar, and the foot at the other end is disposed in one of the aligning slots on the second collar. A plurality of threaded fasteners corresponding in number to the threaded extruded through-holes secure the ends of the bow-springs to the threaded extruded through-holes. The extruded through-holes have a flange height greater than a collar thickness adjacent to the extruded through-holes. The increased flange height allows more threads to be formed within the extruded holes, resulting in a stronger threaded connection with the threaded fasteners, and a correspondingly stronger, more durable centralizer. The foot is retained within the aligning slot to reinforce the coupling between the bow-spring and the collar. A method of manufacturing the casing centralizer is also provided.



WO 2008/134333 A1

FIELD-ASSEMBLABLE BOW-SPRING CASING CENTRALIZER AND METHOD OF MAKING A CENTRALIZER

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates primarily to centralizers and methods for centering a casing string downhole within the borehole of a well. More particularly, the present invention relates to a centralizer that may be shipped more efficiently and is easily assemblable in the field.

Description of the Related Art

[0002] Centralizers are commonly secured at intervals along a casing string to radially offset the casing string from the wall of a borehole in which the casing string is subsequently positioned. The centralizers generally include evenly-spaced ribs that project radially outwardly from the casing string to provide the desired offset. Centralizers ideally center the casing string within the borehole to provide a generally continuous annulus between the casing string and the interior wall of the borehole. This positioning of the casing string within a borehole promotes uniform and continuous distribution of cement slurry around the casing string during the subsequent step of cementing the casing string in a portion of the borehole. Uniform cement slurry distribution results in a cement liner that reinforces the casing string, isolates the casing from corrosive formation fluids, and prevents unwanted fluid flow between penetrated geologic formations.

[0003] A bow-spring centralizer is a common type of centralizer that employs flexible bow-springs as the ribs. Bow-spring centralizers typically include a pair of axially-spaced and generally aligned collars that are coupled by multiple bow-springs. The bow-springs bow outwardly from the axis of the centralizer to engage the borehole to center a pipe received axially through the generally aligned bores of the collars. Configured in this manner, the bow-springs provide stand-off from the borehole, and flex inwardly as they encounter borehole obstructions, such as tight spots or protrusions into the borehole, as the casing string is installed into the borehole. Elasticity allows the bow-springs to spring back to substantially their original shape after passing an obstruction to maintain the desired stand-off between the casing string and the borehole.

[0004] Centralizers are usually assembled at a manufacturing facility and then shipped to the well site for installation on a casing string. The centralizers, or subassemblies thereof, may be assembled by welding or by other means such as displacing a bendable and/or deformable tab or coupon into an aperture to restrain movement of the end of a bow-spring relative to a collar. Other centralizers may be assembled into their final configuration by riveting the ends of a bow-spring to a pair of spaced-apart and opposed collars. The partially or fully assembled centralizers may then be shipped in trucks or by other transportation to the well site.

[0005] Pre-assembly of the centralizers reduces the amount of labor and tooling required at the well site, but partially or fully assembling the centralizers at a manufacturing facility greatly increases shipping costs due to a dramatically decreased shipping density since, due to the structure and the intended function of centralizers, assembled centralizers take up a very large amount of cargo space for relatively little weight. For example, a single casing string may require many truckloads of centralizers to be transported over very long distances and to remote locations, and the inefficiency of shipping pre-assembled centralizers adds substantially to the cost of completing a well.

[0006] Another factor that increases the costs of centralizers is the cost of assembly. Welding the end of each bow-spring to two opposed and spaced-apart collars is time-consuming and tedious. A typical bow-spring centralizer requires 12 or more welds by highly-skilled welder using specialized welding equipment, rods, and a special power supply. Furthermore, welding a bow-spring to a centralizer collar creates an undesirable heat-affected zone (HAZ) in the bow-spring and in the collar around each weld, and this HAZ can possibly weaken the material and render the centralizer more subject to mechanical failure.

[0007] Conventional fasteners, such as rivets and bendable tabs received within slots or apertures, may also be used to join a bow-spring to collars in a non-welded centralizer, but conventional fasteners such as these may present protrusions that may hang up during installation of the pipe string into the borehole thereby making installation of the centralizers and pipe string more difficult and time-consuming. Also, riveting and bending tabs into slots requires special equipment, such as mechanical presses and special tools, that is difficult to power, use, and maintain in the field.

[0008] U.S. Pat. No. 6,871,706 discloses a centralizer that requires a step of bending a retaining portion of the collar material into a plurality of aligned openings, each to receive one end of each

bow-spring. This step requires that the coupling operation needs to be performed in a manufacturing facility using a press. As shown in FIG. 1, the collars of the prior art centralizer are cut with a large recess adjacent to each set of aligned openings to accommodate passage of the bow spring that is secured to the interior wall of the collar. The recess substantially decreases the mechanical integrity of the collar due to the removal of a large portion of the collar wall to accommodate the bow-springs. The collars of the casing centralizer disclosed in the '706 Patent also require several additional manufacturing steps, including the formation of both internal and external (alternating) upsets in each collar to form the aligned openings for receiving and securing bow-springs, a time-consuming process that further decreases the mechanical integrity of the collar.

[0009] Improved centralizers and methods continue to be sought, particularly in view of the limitations of the prior art and the need for better or stronger centralizers. Considerations for the development of new centralizers and of new methods of assembling the centralizers include manufacturing costs, shipping costs, the costs associated with installing the centralizers onto pipe strings and the ease of running the pipe string into the well.

SUMMARY OF THE PRESENT INVENTION

[0010] A field-assemblable casing centralizer and method are disclosed. One embodiment provides a method of manufacturing a casing centralizer. A plurality of bow-springs are formed, each having two opposed ends, each end having an aperture adjacent to a foot for being received in an aligning slot in a collar to position the bow spring for coupling to the collar at the aperture. A first collar and a second collar are also formed, each collar having a plurality of circumferentially spaced aligning slots, each slot for receiving a foot at the end of a bow-spring. A plurality of collar through-holes are formed in the collar, in positions to align with apertures in the ends of a plurality of bow-springs. Each collar through-hole is formed adjacent to an aligning slot by positioning the collar on a supporting back-up member having an opening for receiving an aligned punch, and by then forcibly driving the punch through the wall of the collar and into the opening in the supporting back-up member to extrude a portion of the collar wall material into the opening. The preferred width of the punch is less than about 80% of the width of the opening in the supporting back-up member, or an amount sufficient to draw a portion of the collar wall material onto the annular space between the received punch and the interior wall

of the opening to form an extruded through-hole. Each collar through-hole is then threaded using a tap.

[0011] Another embodiment provides a bow-spring centralizer that may be field-assembled. First and second collars comprise a plurality of circumferentially-distributed, extruded through-holes that are threaded for receiving a fastener. The extruded and threaded through-holes have a protruding flange height resulting from the extrusion by the punch that is greater than the thickness of the collar wall adjacent to the extruded through-holes. A plurality of bow-springs each have a foot at protruding from each end adjacent to an aperture for receiving a fastener. The foot at one end of each of the plurality of bow-springs is disposed in an aligning slot of the first collar and secured in place by a threaded fastener installed through the aperture of the end of the bow-spring and threaded into an extruded through-hole. The foot at the other end of each bow-spring of each of the plurality of bow-springs is disposed in an aligning slot of the second collar and secured in place in the same manner. In this manner, only two fasteners, and no other structures, are required to secure each bow-spring to the pair of opposed and spaced-apart collars, and only one relatively portable tool may be required to assemble the centralizer in the field. Also, the foot and the aligning slot serve a dual purpose. The first, as discussed above, is that of aligning the aperture in the end of the bow-spring with an extruded through-hole in the collar for receiving a fastener. The second purpose is to reinforce the shear resistance of the mechanical coupling between the bow-spring and the collar. The foot is strategically placed in alignment with the anticipated direction of the shearing force applied to the coupling when the centralizer is secured to a tubular string and installed in a borehole. The aligning slots may conveniently be punched in the collar and adjacent to the extruded through-holes at the same time that the through-holes are punched and extruded.

[0012] Other embodiments, aspects, and advantages of the invention will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a perspective view of a prior art centralizer described in U.S. Patent 6,871,706.

[0014] FIG. 2 is a perspective view of one embodiment of a bow-spring centralizer according to the present invention.

[0015] FIG. 3 is a perspective view of one of the bow-springs of the centralizer of FIG. 2.

[0016] FIG. 4 is a side elevation view of a portion of the collar of the centralizer of FIG. 2.

[0017] FIG. 5 is a cross-sectional view of the collar supported on a supporting back-up member prior to forming the aligning slot and the extruded through-hole in the collar.

[0018] FIG. 6A is a cross-sectional view of the collar supported on the supporting back-up member, illustrating the step of forming an aligning slot and an extruded through-hole in the collar.

[0019] FIG. 6B is a detail view of the extruded through-hole taken along the portion encircled in FIG. 6A.

[0020] FIG. 7 is a cross-sectional view of the collar supported on the supporting back-up member, illustrating the step of threading the extruded through-hole formed in FIG. 6A.

[0021] FIG. 8 is a cross-sectional view of the collar supported on the supporting back-up member, showing the threads formed within the extruded through-hole in FIG. 7.

[0022] FIG. 9 is an interior perspective view of a portion of the collar after forming the aligning slot and threading the extruded through-hole, and after then receiving the foot from the end of a bow-spring and a threaded fastener, respectively.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

[0023] The present invention provides an improved centralizer that can be quickly and inexpensively assembled in the field. The few components that make up the centralizer may be shipped unassembled and efficiently packed to a well site to maximize shipping density and minimize shipping costs. Once at the well site, centralizers of the present invention may be quickly and inexpensively assembled using basic tools and with minimal skilled labor. A centralizer according to the invention requires no welding and is not subject to complications from HAZ's.

[0024] In one embodiment of the centralizer of the present invention, a first collar and a second collar each have a plurality of circumferentially spaced aligning slots and a corresponding plurality of threaded, extruded through-holes. A plurality of bow-springs each have a foot at each end and an aperture generally adjacent to the foot. Each bow-spring is axially extendable between the first and second collars when the collars are generally aligned and spaced one from the other to receive a bow-spring. The foot at one end of each bow-spring is disposed in one of the aligning slots of the first collar and fastened to the first collar with a threaded fastener. The

foot at the other end of that bow-spring is disposed in one of the retaining slots on the second collar and fastened to the second collar with a threaded fastener. A threaded fastener is inserted through each aperture at each end of the bow-spring and then threaded into an extruded through-hole in a collar to secure the ends of each bow-spring to the two opposed collars at opposed and corresponding through-holes to form a centralizer.

[0025] To maximize the ease and speed of assembly and/or disassembly of the centralizer, the bow-springs may be secured to a radially outward, exterior surface of each collar. This positioning of the bow-springs is, in contrast to that of conventional bow-springs on prior-art centralizers that typically retain the ends bow-springs inside a collar, allows each bow spring in the centralizer to be easily and independently installed, removed or replaced without necessarily removing any of the other bow-springs from the centralizer.

[0026] A method of manufacturing the casing centralizer is also provided, which includes the steps of extruding and threading holes in each collar, each for threadedly receiving a threaded fastener. The extruded through-holes have a radially-inwardly extruded flange height greater than the collar thickness immediately adjacent to the extruded through-holes. Preferably, the extruded flange height is at least 1.5 times a material thickness of the wall of the collar, and more preferably, the extruded height is between 2.0 and 3.0 times the material thickness of the wall of the collar. The increased extruded height allows more threads to be formed within the extruded holes, resulting in a much stronger threaded connection with the threaded fasteners and a correspondingly stronger and more durable centralizer.

[0027] FIG. 2 is a perspective view of one embodiment of a bow-spring centralizer 10 according to the invention. The centralizer 10 includes two generally cylindrical collars, a first collar 12, and a second collar 14, substantially aligned one with the other about a common centralizer axis 15. The collars 12, 14 may include two or more generally arcuate segments 38 coupled using hinged connections 17 to facilitate installation of the centralizer on long tubular strings. The collars 12, 14 are axially spaced one from the other. Six bow-springs 18 for extending between and flexibly positioning the two collars 12, 14 in a generally aligned and spaced-apart relationship are secured at their opposed ends to the two collars 12, 14 in the

manner described herein. Other embodiments of a centralizer according to the present invention may have any number of bow-springs, but will typically include between 6 and 8 bow-springs.

[0028] The bow-springs **18** are angularly spaced one from the others along the collars **12**, **14** and about the centralizer axis **15**, and are typically evenly spaced, i.e. with substantially the same angular spacing between each pair of adjacent bow-springs **18**.

[0029] As shown in FIG. 2, the bow-springs **18** bow radially outwardly from the axis **15** at their middle or contact portions **19** intermediate the collars **12**, **14**. The bow springs **18** may be formed of flexible and resilient materials that provide sufficient stand-off to center a heavy casing string within the borehole, but that also provide an appreciable resiliency to allow the bow-springs **18** to flex radially inwardly to accommodate borehole obstructions and irregularities as needed as the casing string is installed in a borehole.

[0030] A first end **20** of each bow-spring **18** comprises a foot **28** for being disposed in an aligning slot **21** of a collar, which as shown in the embodiment illustrated in FIG. 2, is one of a plurality of aligning slots **21** in the first collar **12**. Similarly, a second end **22** of each bow-spring **18** is disposed in an aligning slot **21** in the second collar **14**. Each of the collars **12**, **14** have a plurality of aligning slots **21** corresponding to the number of bow-springs **18** on the centralizer **10**. These aligning slots **21** may alternatively be referred to as retaining slots **21** for retaining the ends of the bow-springs **18** in a position to be coupled to the collar, and also for maintaining the bow-springs **18** in a generally aligned orientation with respect to the centralizer axis **15**. In the embodiment illustrated in FIG. 2, the aligning slots **21** extend all the way through the thickness of the wall of the collar **12**. In other embodiments, an aligning slot may only extend partially through a collar (e.g., into a recess or indentation in the wall of the collar).

[0031] Each bow-spring **18** is further secured at its first end **20** to the first collar **12** using a threaded fastener **24** inserted through an aperture (not shown in FIG. 2) in the first end **20** of a bow-spring **18**, and secured at its second end **22** to the second collar **14** using a threaded fastener **24** inserted through an aperture in the second end **22** of the bow-spring **18**. The bow-springs **18** may, therefore, be quickly and easily coupled to the first and second collars **12**, **14**, and the threaded members **24** may be easily threaded into the collars **12**, **14** using ordinary tools such as a hex wrench, socket wrench, or other type of wrench, depending on the type of fastener head

selected for the fastener. Further description of the structure and the method of forming the collars **12**, **14**, and of attaching the bow-springs **18** to the collars **12**, **14**, is provided below.

[0032] To maximize the ease and speed of assembly and/or disassembly of the centralizer **10**, the bow-springs **18** have been configured so that they may be secured as shown to the radially outward, exterior wall **25** of each collar **12**, **14**. This positioning of the ends **20**, **22** of the bow-springs **18** on the radially outward, exterior wall **25** is in contrast to that of conventional bow-springs of prior-art centralizers that typically secure each end of each bow-spring inside a collar, i.e. between the interior wall of the collar and the exterior wall of the casing string to be installed within the bore of the centralizer along its axis **15**. Thus, unlike with prior art centralizers, any of the bow-springs **18** in the centralizer **10** of the present invention may be independently installed or removed without removing the centralizer **10** from the casing and without removing any of the other bow-springs **18** from the centralizer. This feature increases the speed and reduces the costs of assembling the centralizer **20**. Also, being field-assemblable allows for two or more types of bow-springs to be usable with the same type of centralizer collars. A user can maintain a smaller inventory, but still select the specific type of bow-spring centralizer according to the length, shape, material and strength needed to serve a particular application and have bow-springs of that type delivered to the well site for assembly with a single, or “universal,” type of collars for that given diameter of tubular string.

[0033] FIG. 3 is a perspective view of one of the bow-springs **18** included with the centralizer **10** shown in FIG. 2. The bow-spring **18** includes feet **28**, **30** on the respective ends **20**, **22**, respectively. The feet **28**, **30** in this embodiment are inwardly bent ends of the bow-springs **18**. Alternative types of feet may include upset portions of the bow-springs or short, stub-like threaded posts threadedly secured to the ends of the bow-spring. Adjacent to each foot **28**, **30** are respective apertures **32**, **34**, which may alternatively be referred to as bow-spring through-holes **32**, **34** to distinguish them from the extruded through-holes **36** in the first and second collars **12**, **14**. The feet **28**, **30** are adapted for being received in the aligning slots **21** on the respective collars **12**, **14** (FIG. 2). A threaded fastener **24** (FIG. 2) may be inserted through each bow-spring through-hole **32** or **34** and subsequently threaded into the threads of an extruded through-hole **36** in the collar **12** or **14** (discussed below in relation to FIG. 4).

[0034] FIG. 4 is a side elevation view of a portion of a typical collar 12 or 14 of FIG. 2. The aligning slot 21 and the threaded, extruded through-hole 36 are positioned one adjacent to the other on the collar 12. The extruded through-hole 36 includes internal threads 37 into which the threaded fastener 24 (FIG. 2) may be threaded to secure an end 20 or 22 of the bow-spring 18 to the collar 12. The collar 12 may include a radially inwardly rimmed portion 23 that approaches or contacts an outer wall of a casing segment (not shown) received within the bore of the collar 12 along the axis 15 (FIG. 2), and a radially outward portion 26 that provides a generally annular gap between the interior wall of the radially outward portion 26 of the collar 12 and the exterior wall of the casing received into the bores of the generally aligned collars 12, 14. This structure provides enhanced rigidity and strength to the collar. Also, the annular gap provides sufficient clearance between each of the collars 12, 14 and the casing segment received therethrough so that the casing does not interfere with either insertion of the foot 28 (FIG. 3) into the aligning slot 21 or the threading of the fastener 24 into the threaded, extruded through-hole 36. Thus, the feet 28 on the ends 20, 22 of the bow-springs 18, and the ends of the fasteners 24, may extend inwardly beyond a thickness of the collar 12 or 14 without substantially interfering with the outer wall of the casing. This feature prevents the fasteners 24 and the feet 28 from catching or hanging up on an obstruction within the borehole, and enables the casing string to be installed more quickly and easily in the borehole.

[0035] FIGS. 5-8 are cross-sectional views of an exemplary first collar 12 supported on a supporting member 40, schematically illustrating one method of forming the aligning slot 21 (see FIG. 4) and the threaded, extruded through-hole 36 (see FIG. 4) into the collar 12 according to one embodiment of the present invention. For simplicity, the first collar 12 is illustrated in FIGS. 5-8 as a basic circular ring, excluding certain reinforcing features such as the radially inward rimmed portion 23 and the radially outward portions 26 that are shown in the perspective view of FIG. 4.

[0036] FIG. 5 is a cross-sectional view of the wall of the first collar 12 hanging or otherwise supported on a supporting back-up member 40 prior to forming the aligning slot 21 and the extruded through-hole 36 (see FIG. 4) in the wall of the first collar 12. The supporting back-up member 40 may be, for example, a worktable or a mandrel designed specifically for use in making the first collar 12, and is not part of the centralizer 10. The supporting back-up member

40 includes adjacent openings **52**, **54**. A pair of reciprocating (relative to the openings) punches **42** and **44** are positioned adjacent the openings **52** and **54** in the supporting back-up member **40** and aligned with the openings **52** and **54**, respectively, for forming an aligning slot **21** and an extruded through-hole **36**. The punches **42**, **44** of this embodiment are schematically illustrated as having radially-moveable (relative to the axis of the collar blank **12**) heads **46**, **48** to which the punches **51**, **53** are secured, respectively. The punches **51**, **53** may be, for example, made of a hardened material, and the punches may be removable from the heads.

[0037] The punches may have selected dimensions favorable for perforating the specific thickness and grade of sheet metal or other relatively thin-walled workpieces such as the collar **12**. The heads **42**, **44** may be powered to deliver sufficient punching forces to the punches **51**, **53**. For example, the heads **42**, **44** may operated together or independently, and they may be hydraulically and/or pneumatically powered, or they may be driven with a pair of rotatable threaded guide axles (not shown). Alternatively, the heads **42**, **44** may be either automatically or manually driven by a weighted assembly, or driven manually by an operator using a leveraged actuator (not shown). Other ways of driving the heads **42**, **44** or otherwise imposing sufficient penetrating forces to the punches **51**, **53** to perforate the collar **12** may be devised according to the present invention. .

[0038] FIG. 6A is a cross-sectional view of the first collar **12** supported on the supporting back-up member **40** illustrating the step(s) of forming an aligning slot **21** and an extruded through-hole **36** in the first collar **12**. Although shown together in this figure, the aligning slot **21** and (not yet extruded) through-hole **36** may be independently formed in separate steps. The slot for making the aligning slot, or the “slot” punch, **51** and the corresponding opening **52** in the supporting back-up member **40** cooperate to form the aligning slot **21** in the first collar **12** for receiving the foot of a bow-spring. In particular, the slot punch **51** has a dimension **d1** and the cooperating opening **52** on the supporting member **40** has a dimension **d2** that is at least greater than **d1**. The dimension **d1** of the slot punch **51** and the dimension **d2** of the opening **52** are substantially similar, so that the slot punch **51** fits very closely within the corresponding opening **52**. In particular, the dimension **d1** of the punch **51** may be at least 90% of the dimension **d2** of the opening **52**. Thus, as the head **42** is driven downwardly toward the first collar **12**, the slot punch **51** shears a coupon **55** (see FIG. 5A) from the collar **12**, thereby creating the aligning slot

21 (FIG. 4). In the process of shearing the collar **12**, the elongate coupon **55** of collar material is punched from the collar **12**.

[0039] Still referring to FIG. 6A, the punch **53** and the corresponding opening **54** cooperate to form an extruded through-hole **36** in the first collar **12**. The punch **53** has dimension **d3** and the cooperating opening **54** in the supporting member **40** has a dimension **d4** that is substantially greater than **d3**. While the punch **53** is driven downwardly toward the first collar **12** by the head **48**, the punch **53** penetrates the collar **12** as it moves into the general center of the opening **54**. Due to the annular gap defined between the exterior of the punch **53** (of dimension **d3**) and the cooperating interior of the opening **54** (of dimension **d4**), the collar **12** wall material is radially-inwardly plastically deformed (rather than simply sheared) in proximity to the punch **53**, drawing or extruding a portion of the collar wall material (the "extruded portion") **56** between the punch **53** and the opening **54** prior to ultimate (shear) material failure. Thus, the through-hole **36** in the first collar **12** is formed as an extruded through-hole **36**.

[0040] It should be noted that the dimensions **d1**, **d2**, **d3**, and **d4** are shown in the plane of the page, and do not necessarily indicate the dimensions **51**, **53** of the punches relative to the dimensions of opening **52**, **54**. For example, the slot retainer **21** formed in FIG. 6A typically includes both a slot width (shown in FIG. 5) and a slot length (not shown, but may be substantially greater than the slot width). Thus, the slot punch **51** and the cooperating opening **52** are typically elongate, having respective widths **d1** and **d2** in the plane of the page a length into the page that is greater than their widths **d1**, **d2**. The punch **53** and opening **54** are generally circular, however, so that the opening **54** may receive the punch **53** to form an extruded and generally cylindrical through-hole that may subsequently be threaded. Thus, the punch **53** and the cooperating opening **54** are typically circular, having respective diameters **d3**, **d4**, respectively.

[0041] Only one aligning slot **21** and one extruded through-hole **36** are shown in FIGS. 5 and 6A; the collar **12** may be subsequently rotated about its axis **15** on the supporting back-up member **40** and additional aligning slots **21** and extruded through-holes **36** may be formed at any desired angular spacing about the circumference of the first collar **12**. Alternately, a collar **12**

may be quickly made using multiple punches positioned at different angles to the axis and acting simultaneously.

[0042] FIG. 6B is a detail view of an exemplary extruded through-hole 36 taken along the portion encircled in FIG. 6A. The collar 12 has a material thickness, "t," and the extruded through-hole 36 has a "flange height," h, defined as illustrated. The diameter d3 of the punch 53 is preferably less than about 80% of the diameter d4 of the opening 54, and more preferably between about 65% and 75% of the diameter d4 of the opening 54. The ration between the diameters of the punch and the opening may vary depending on the diameter of the collar and the thickness and material of the collar. The resulting flange height h of the extruded through-hole is typically at least 1.5 times the thickness, t, of the collar 12, and may be between about 2.0 and 3.0 times the thickness, t, of the collar 12. The increased flange height, h, of the extruded portion 56, as compared with the thickness, t, of the surrounding collar material, desirably provides more surface area for threads to be formed within the extruded through-hole 36, resulting in a much stronger threaded connection for securing the bow-spring to the collar using a fastener.

[0043] The movement of the heads 42, 44 and the punches 51, 53 may be relatively rapid and "explosive," such as performed by a stamping operation, or it may be slow and controlled, such as may be performed by a controlled movement of the heads 42, 44. A number of factors may be considered in selecting the speed of movement of the heads 42, 44 and the punches 51, 53, such as the strength of the collar material, the thickness, t, of the collar material, and the mechanical properties of the punches collar material and of the 51, 53. For forming the slot 21 with the punch 51, the movement may be rapid, such as to maximize manufacturing productivity when forming multiple slots 21 in many collars 12. A quick movement of the punch 51 may maximize the shearing effect, as well. By contrast, the speed of movement of the punch 53 in forming the extruded hole 36 may affect the flange height, h, of the extruded hole 36. For example, slower, more controlled punch movement may result in more plastic deformation (elongation) of the extruded hole 36 prior to shear. The temperature of the collar 12 is also likely to affect the extent of the elongation. If the collar 12 is sufficiently heated, the collar material may allow a generally longer extrusion. If the collar 12 is instead worked at or near ambient temperature, the movement of the punch 53 may be relatively slow to minimize the possibility of premature shear in the extruded through-hole 36.

[0044] FIG. 7 is a cross-sectional view of the collar 12 supported on the supporting member 40, illustrating the step of threading the extruded through-hole 36 that was formed in FIG. 6. The extruded through-hole 36 may be tapped by a thread tapping tool ("thread tap") 60. The thread tap 60 includes a shank 62 that may be gripped and rotated by a chuck 64, such as may be provided on a drill press or hand-held drill, or possibly on a hand-held tool for manually tapping a thread. The thread tap 60 is aligned with the extruded through-hole 36 and urged axially downward into the extruded through-hole 36 while rotating to form threads in the extruded through-hole 36. FIG. 8 is a cross-sectional view of the collar 12 supported on the supporting member 40, showing the threads 66 formed within the extruded through-hole 36 in FIG. 7.

[0045] FIG. 9 is an interior perspective view of a portion of the collar 12 after forming the aligning slot 21 and forming and tapping the extruded through-hole 36. The first end 20 of the bow-spring 18 (which is mostly hidden in this view – see FIG. 3) is secured to the collar 12. The foot 28 of the bow-spring 18 is protruding through the aligning slot 21. The foot 28 fits closely with the aligning slot 21 to substantially constrain movement of the bow-spring 18 with respect to the collar 12 to maintain the generally axially extending orientation of the bow-spring 18 with respect to the centralizer axis 15 (see FIG. 2). The fastener 24 is threadedly engaged with the threaded, extruded through-hole 36 to securely fasten the bow-spring 18 to the collar 12. The other end of the bow-spring 18 may be similarly attached to the second collar 14, as shown in FIG. 2. This attachment of the bow-springs 18 to the collars 12, 14 is relatively simple and fast, yet provides a robust, high-strength, and durable assemblage of the centralizer 10.

[0046] The invention, therefore, includes both the provision of a field-assemblable casing centralizer and a method of manufacturing the field-assemblable centralizer. The centralizer may be shipped unassembled to increase shipping density and decrease associated shipping costs. Once at the well site, the components of the centralizer, such as the collars and the bow-springs, may be assembled easily using minimal tools, skills, and labor. The bow-springs are desirably secured to outer portions of the collars and may therefore be quickly and easily removed or replaced without having to remove the casing centralizer from the casing. The extruded through-holes in the collar are extruded to increase the number of threads that may be disposed within the through-holes, which increases the strength of the threaded connection made up using the threaded fasteners and improves the overall strength and durability of the

centralizer. While the invention has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised which do not depart from the scope of the invention as disclosed herein. Accordingly, the scope of the invention should be limited only by the attached claims.

[0047] There is a generally large number of combinations of dimensions and materials that may be used to implement the present invention, and there are no specific ratios or parameters that are required to implement the present invention. Those skilled in the art will recognize that the extruded hole can be obtained in the manner disclosed herein for those materials having sufficient ductility, but may not be obtained using materials having excessive hardness, and that the material will often dictate the ratio of the width of the punch to the width of the opening in the backing member that will produce a satisfactory extruded hole that can be successfully tapped and used to implement the present invention.

[0048] The terms “comprising,” “including,” and “having,” as used in the claims and specification herein, shall be considered as indicating an open group that may include other elements not specified. The terms “a,” “an,” and the singular forms of words shall be taken to include the plural form of the same words, such that the terms mean that one or more of something is provided. The term “one” or “single” may be used to indicate that one and only one of something is intended. Similarly, other specific integer values, such as “two,” may be used when a specific number of things is intended. The terms “preferably,” “preferred,” “prefer,” “optionally,” “may,” and similar terms are used to indicate that an item, condition or step being referred to is an optional (not required) feature of the invention.

[0049] The term “pair” may be used to indicate two items that are not identical in structure, size, shape and material, but are substantially identical with respect to the properties or structure related to the characteristic or quality being referred to in the context of the disclosure using that term. An insubstantial change that does not materially affect the use of the present invention does not make one item not form a “pair” with the substantially similar item.

CLAIMS

What is claimed is:

1. A method of manufacturing a casing centralizer, comprising:
 - forming a plurality of bow-springs, each having a first end and a second end; and each having a foot at each end;
 - forming a first collar and a second collar, each having a plurality of circumferentially spaced bow-spring aligning slots, each bow-spring aligning slot configured for receiving a foot on the end of a bow-spring;
 - forming at least one extruded through-hole in each collar and adjacent to each aligning slot by positioning each collar on a supporting back-up member having an opening aligned with a punch, and by driving the punch through the collar wall and into the opening, wherein the diameter of the punch is less than about 80% of a diameter of the opening on the supporting member; and
 - tapping each extruded through-hole to threadedly receive a fastener.
2. The method of claim 1, wherein forming the aligning slots comprises driving a second punch through the collar into a second opening in the supporting back-up member, wherein a width of the second punch is smaller a width of the second opening on the supporting back-up member.
3. The method of claim 1, further comprising:
 - fastening a first end of each bow-spring to the first collar using a fastener threadedly engaged with one of the threaded extruded through-holes in the first collar; and
 - fastening a second end of each bow-spring to the second collar using a second fastener threadedly engaged with one of the threaded collar through-holes in the second collar.
4. The method of claim 3, further comprising securing each bow-spring to a radially outwardly disposed surface of each collar.

5. The method of claim 1, wherein the step of forming each extruded through-hole in a collar comprises forming an extruded through-hole having a height of at least about 1.5 times the material thickness of the collar.
6. The method of claim 1, wherein the step of forming each extruded through-hole comprises forming an extruded through-hole having a flange height of between about 2.0 to 3.0 times the material thickness of the collar.
7. The method of claim 1, wherein each of the aligning slots in the circumferential wall of the collar have a generally circumferentially-extending slot length and a generally axially-extending slot width of substantially less than the slot length.
8. The method of claim 1, further comprising forming the feet of each bow-spring by inwardly bending the ends of the bow-springs to create an angled portion at each end of the bow-spring.
9. A casing centralizer, comprising:
 - first and second collars each having a plurality of circumferentially spaced aligning slots and a corresponding plurality of threaded, extruded through-holes, wherein the extruded through-holes have a flange height greater than the collar thickness adjacent to the extruded through-holes;
 - a plurality of bow-springs, each having an aperture and a foot at each end, each bow-spring extending between the first and second collars, with the foot at one end of each bow-spring disposed in one of the aligning slots of the first collar to align the adjacent aperture on the end of the bow-spring with an extruded through-hole of the first collar, and the foot at the other, opposite end of the bow-spring disposed in one of the aligning slots on the second collar to align the adjacent aperture on the end of the bow-spring with an extruded through-hole of the second collar; and
 - a plurality of threaded fasteners corresponding in number and pitch of threads to the threaded extruded through-holes for securing one end of each of the bow-springs to each of the

first and second collars by inserting a fastener through each aperture aligned with an extruded through-hole and by threading the fastener into the threaded and extruded through-holes.

10. The casing centralizer of claim 9, wherein the bow-springs are disposed on outwardly facing surfaces of each collar.

11. The casing centralizer of claim 9, wherein the flange height of each extruded through-hole is at least 1.5 times the collar thickness.

12. The casing centralizer of claim 9, wherein the flange height of each extruded through-hole is between about 2.0 to 3.0 times the collar thickness.

13. The casing centralizer of claim 9, wherein the feet comprise inwardly bent portions on the ends of the bow-springs.

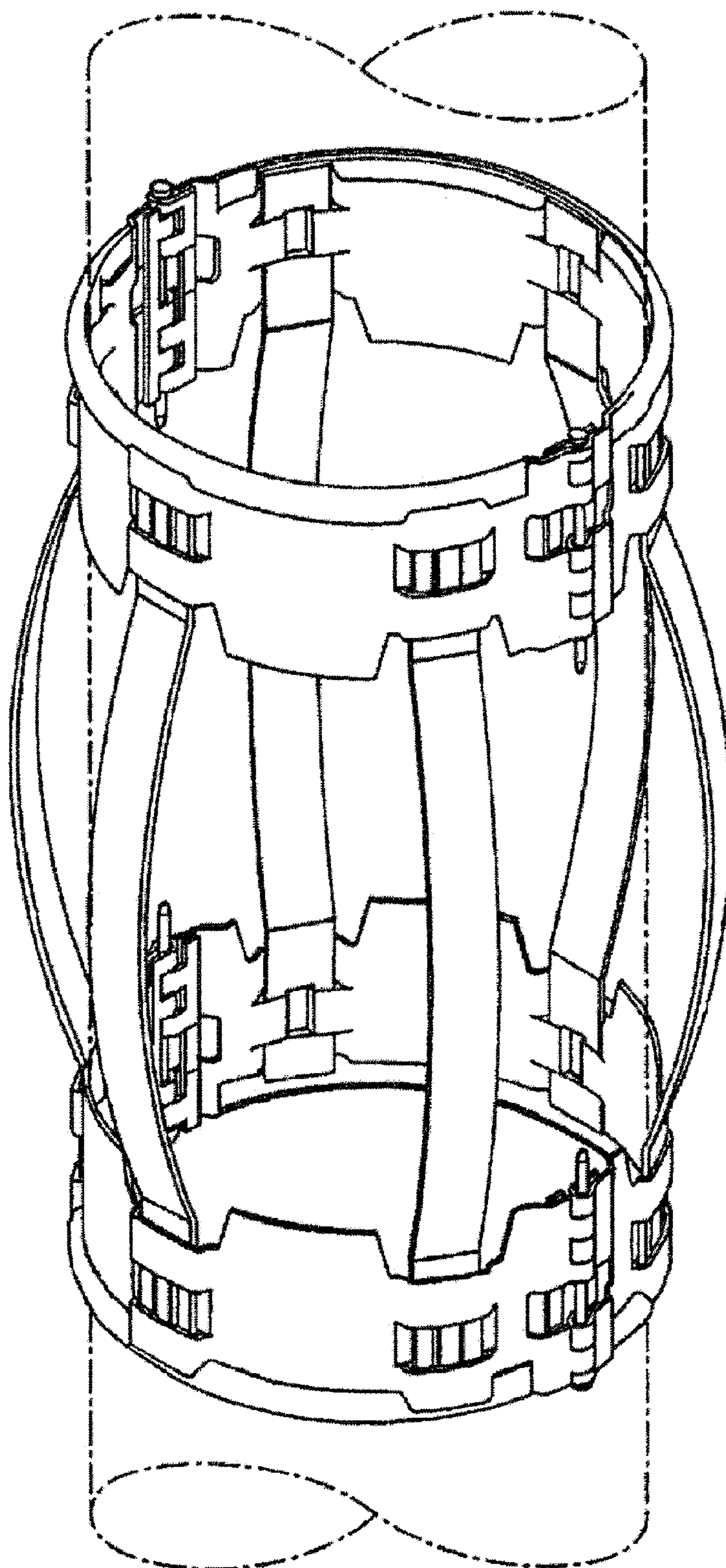
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FIG. 1
(Prior Art)

2/6

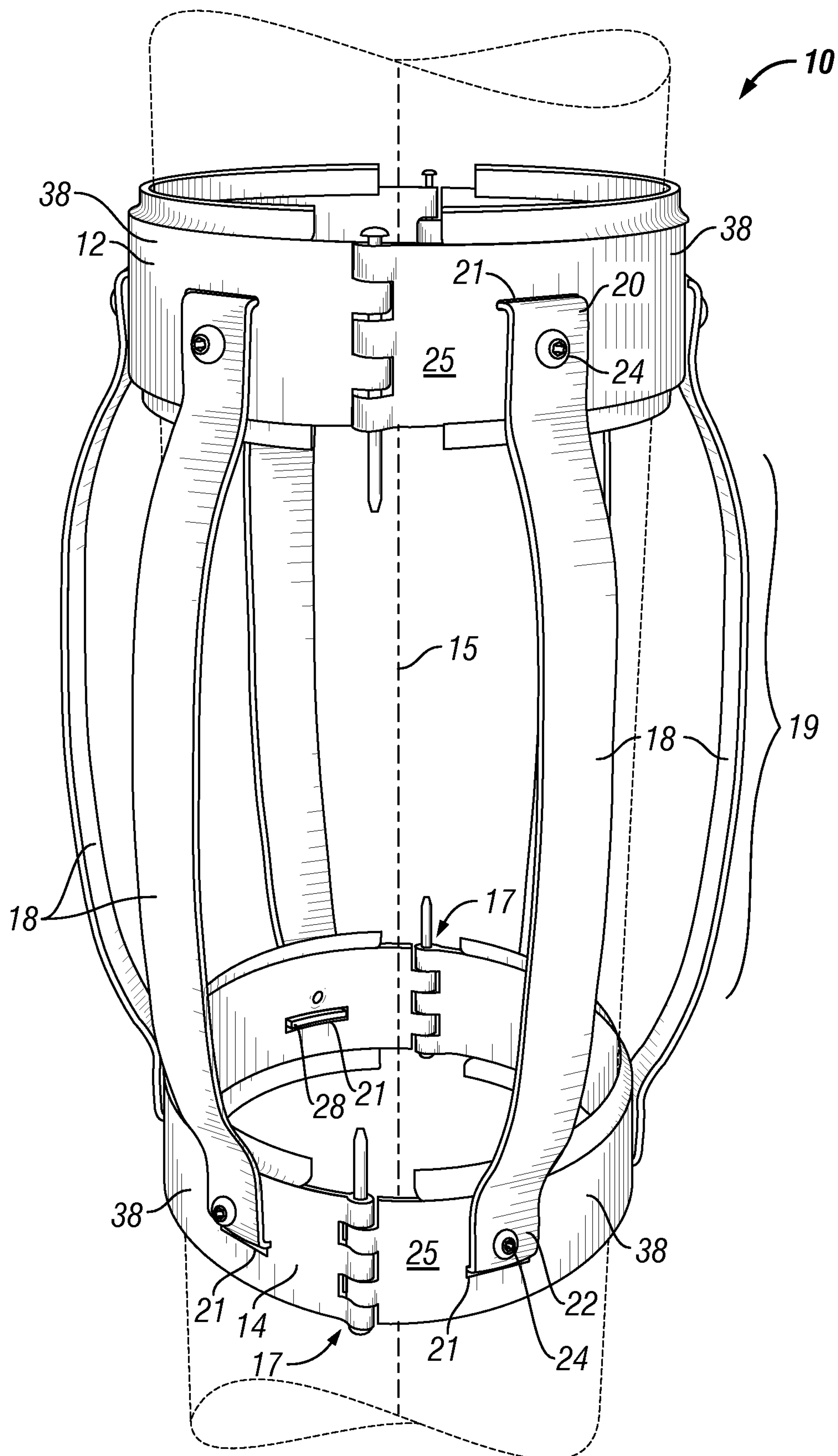
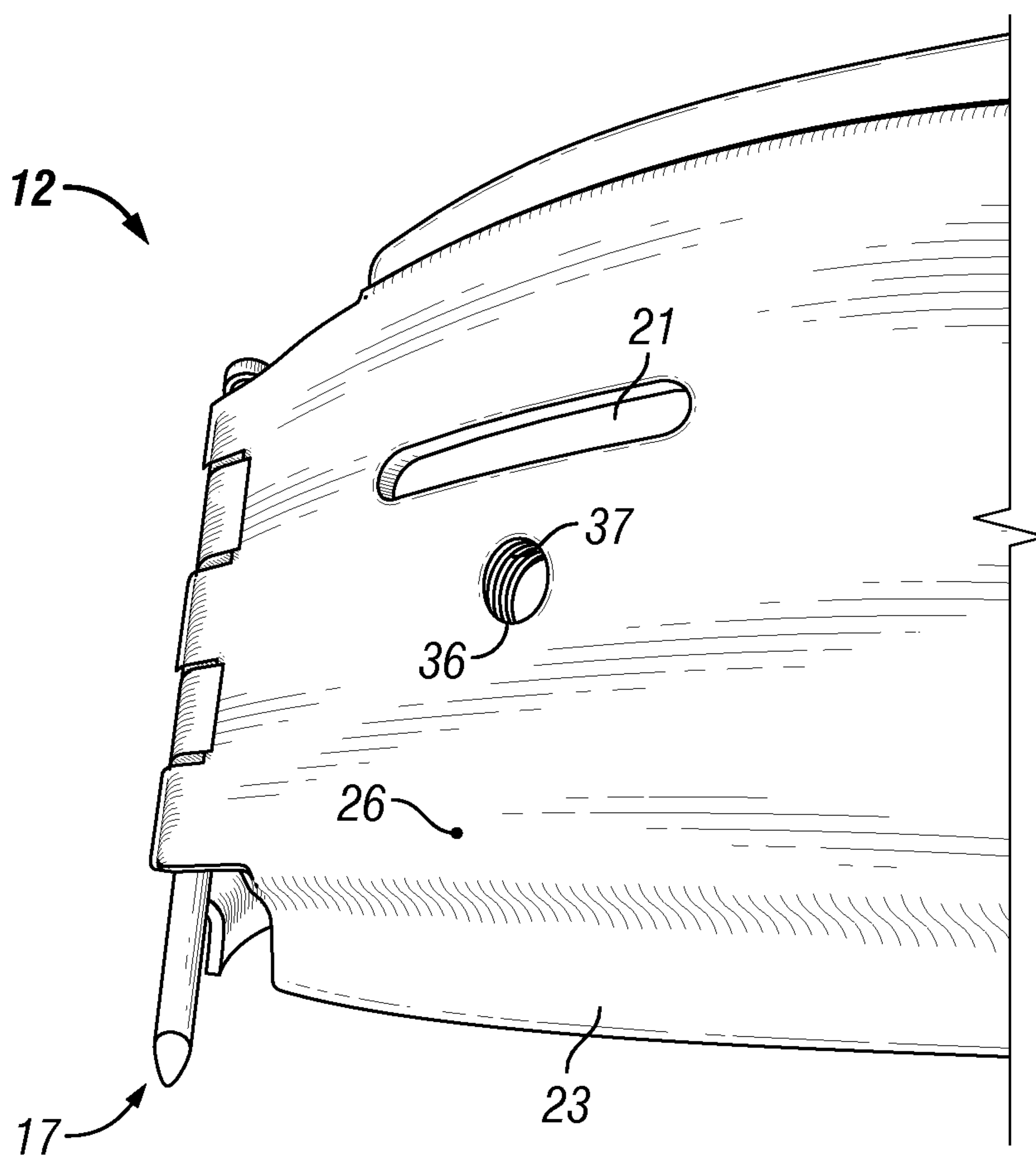
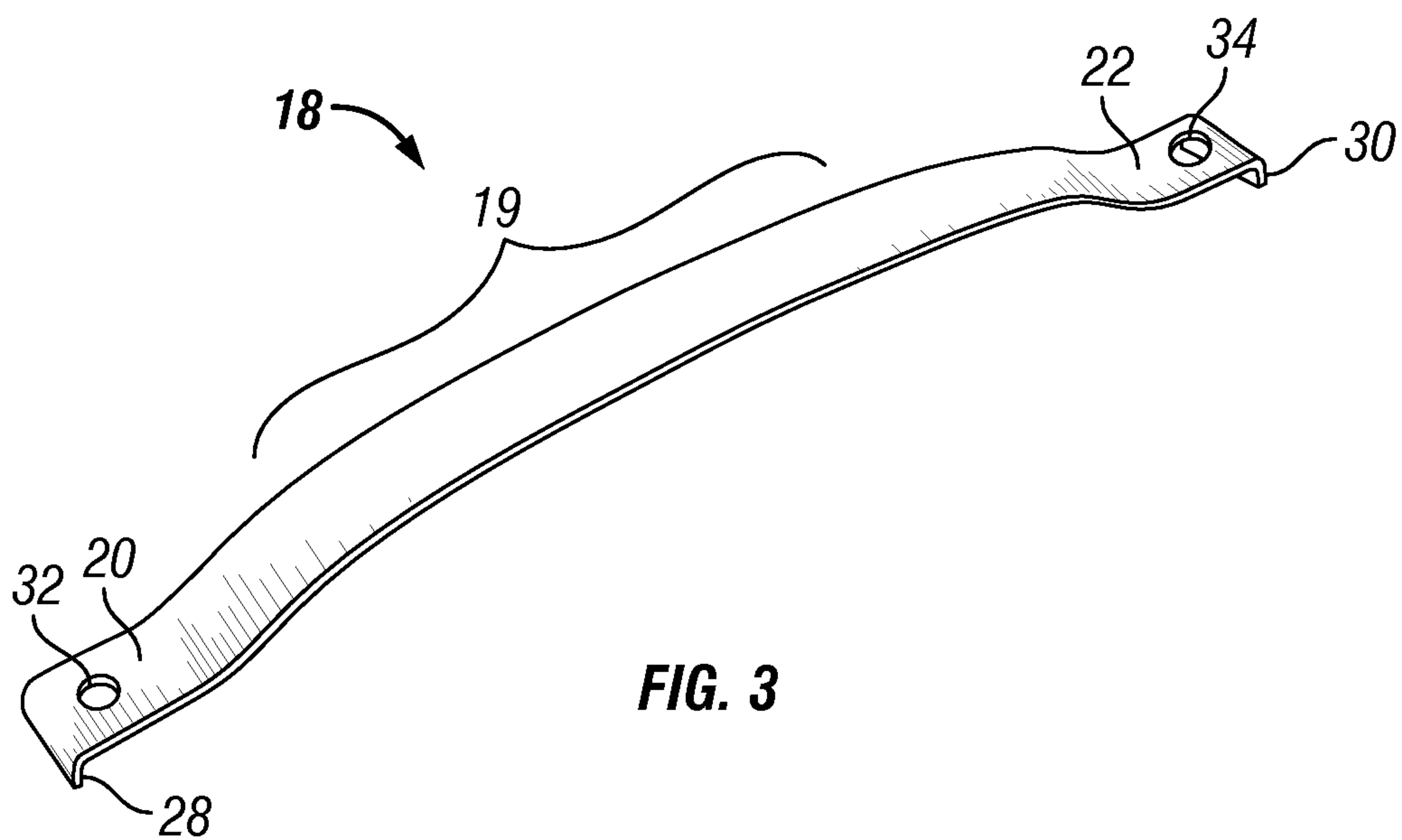
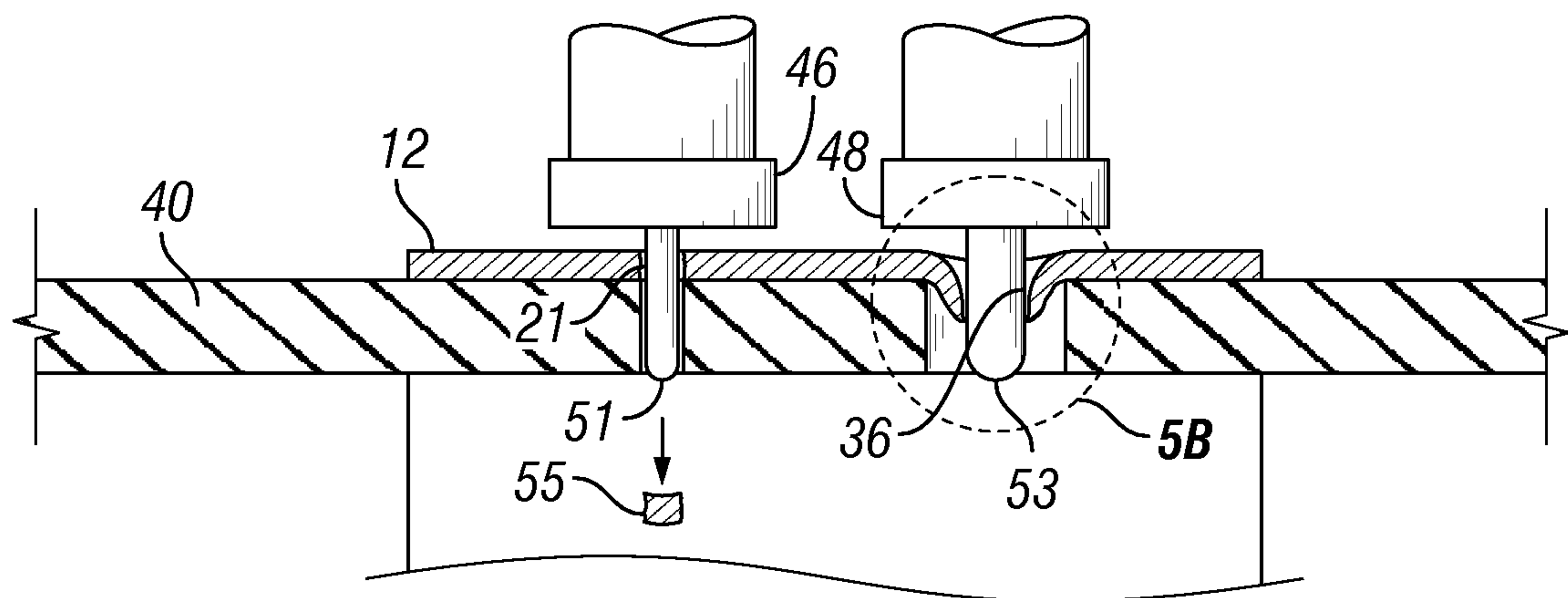
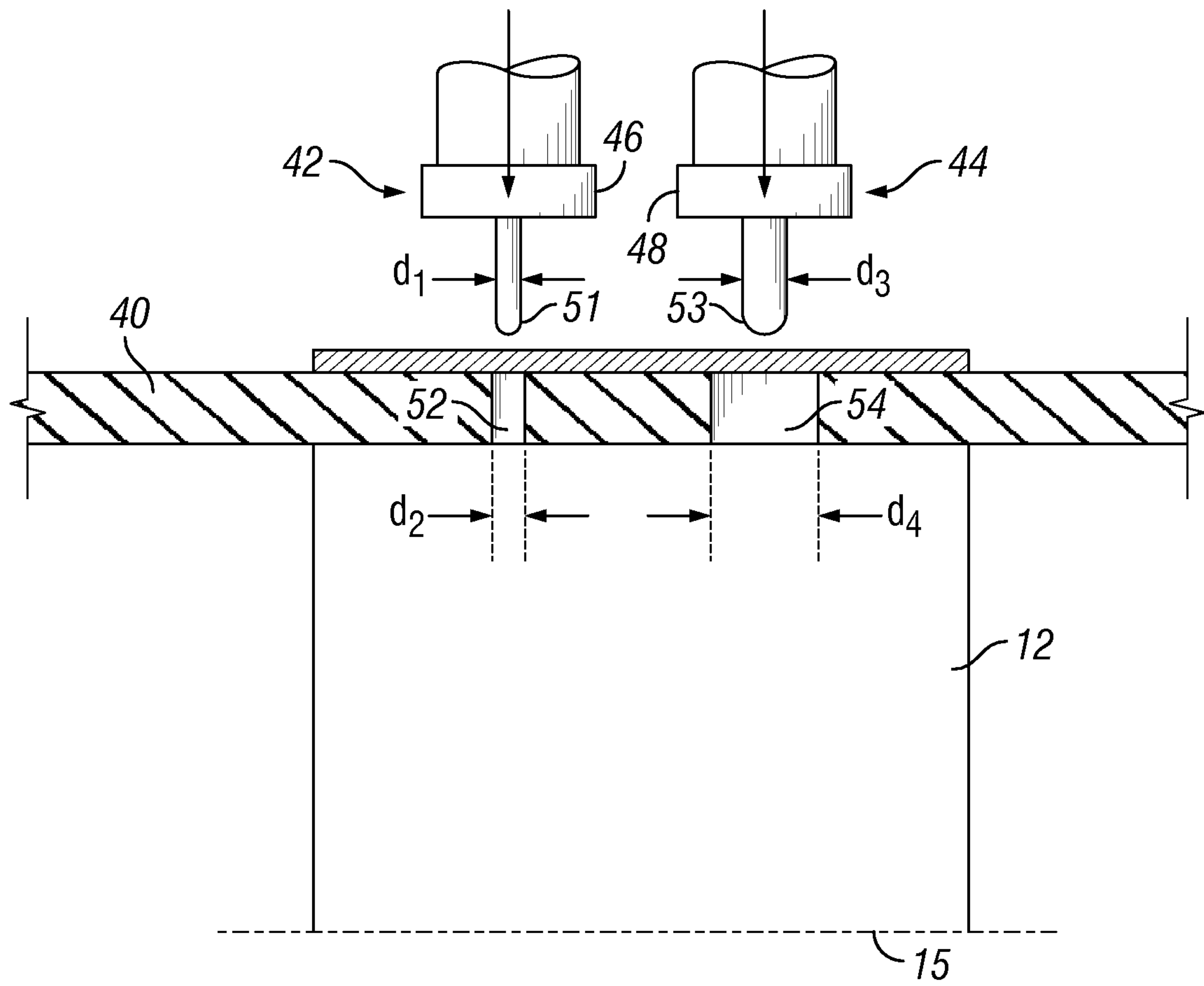


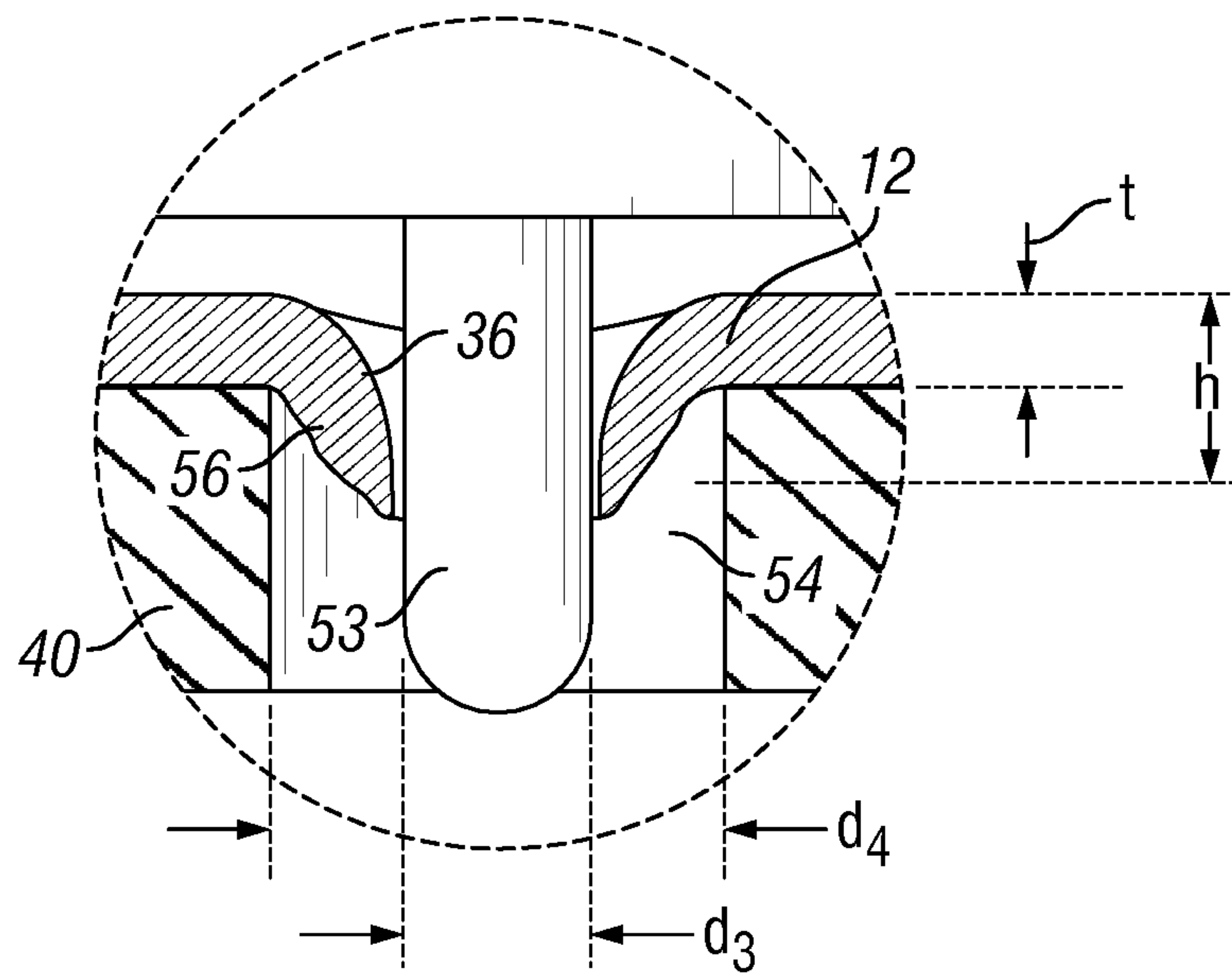
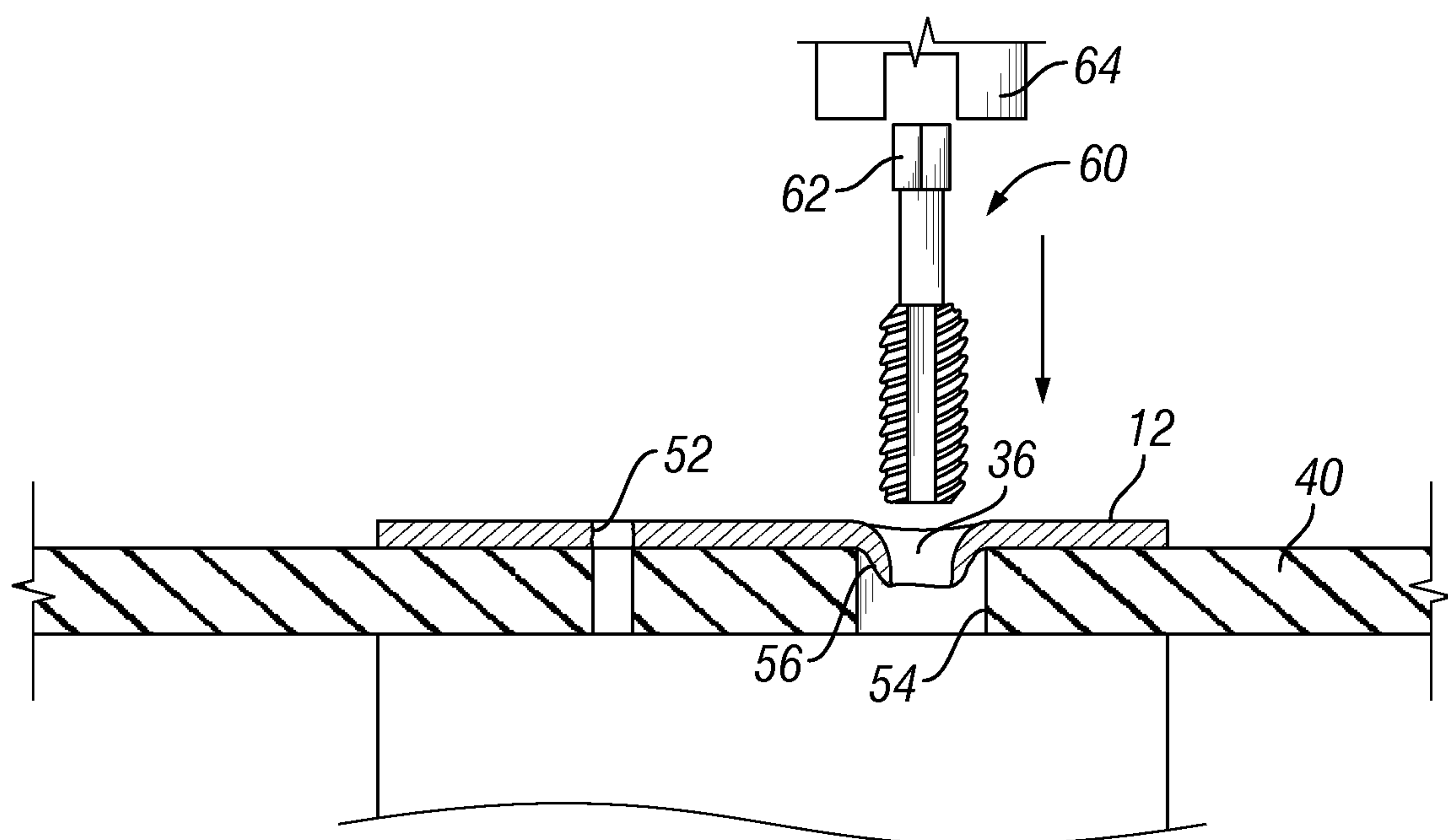
FIG. 2

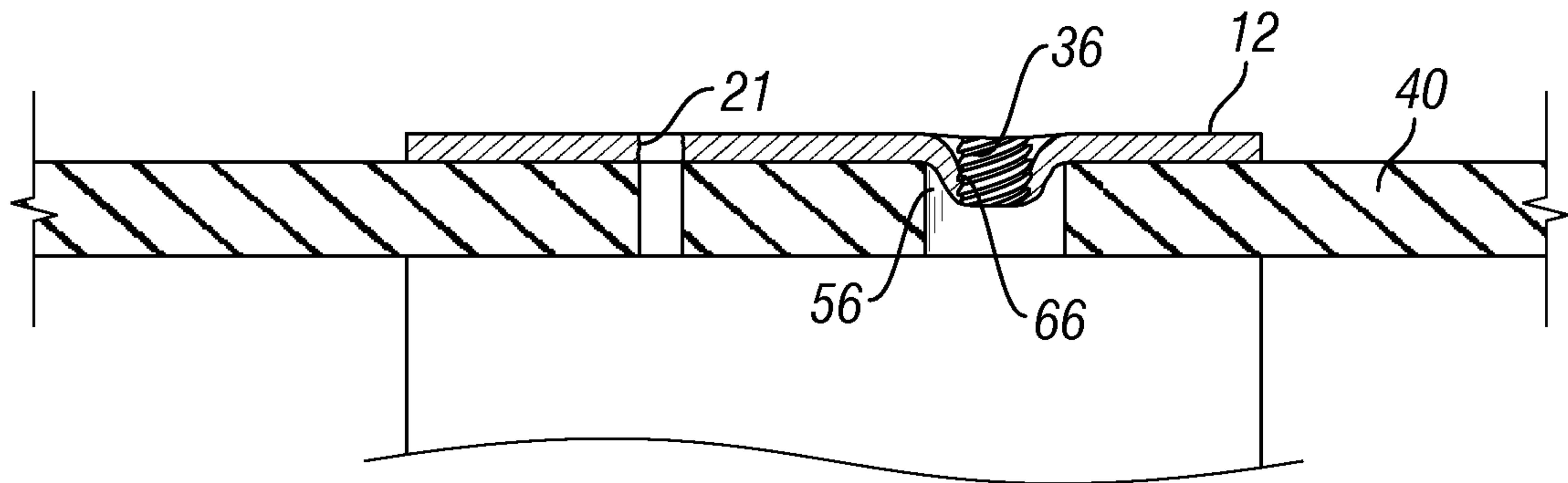
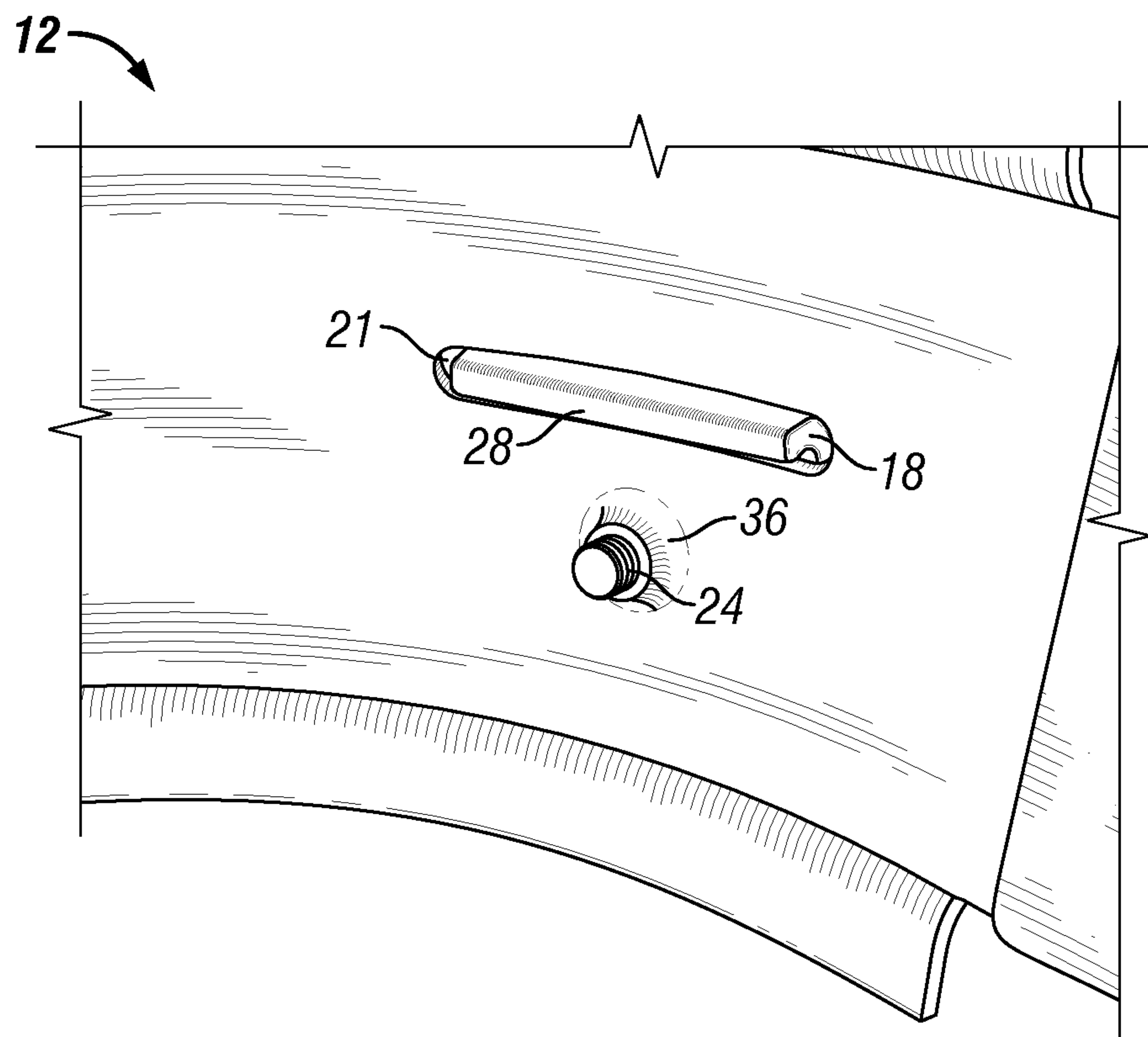
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4/6



5/6**FIG. 6B****FIG. 7**

6/6**FIG. 8****FIG. 9**

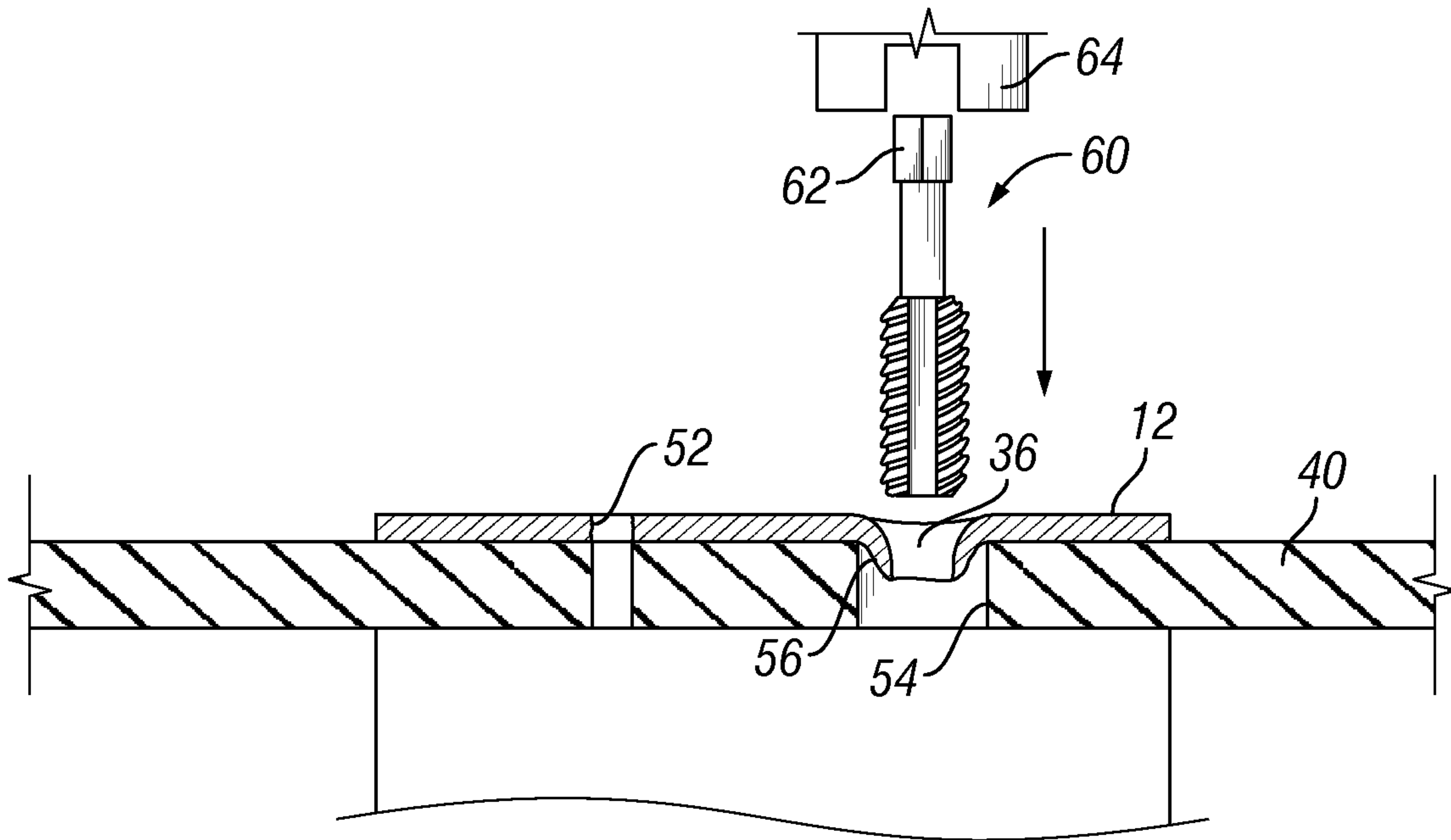


FIG. 7