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(54) **FIELD-ASSEMBLABLE BOW-SPRING CASING CENTRALIZER AND METHOD OF MAKING A CENTRALIZER**

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Description

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] US4545436 and GB2242457 both disclose casing centralizers having a plurality of bow-springs which are connected at either end to first and second collars. In US4545436 the bow-springs are connected to the collars using rivets or by welding, whereas in GB2242457 they are connected using nuts and bolts.

[0010] 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.

SUMMERY OF THE PRESENT INVENTION

[0011] 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.

[0012] 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.

[0013] Other embodiments, aspects, and advantages of the invention will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. **1** is a perspective view of a prior art centralizer described in U.S. Patent 6,871,706.

[0015] FIG. **2** is a perspective view of one embodiment of a bow-spring centralizer according to the present invention.

[0016] FIG. **3** is a perspective view of one of the bow-springs of the centralizer of FIG. **2**.

[0017] FIG. **4** is a side elevation view of a portion of the collar of the centralizer of FIG. **2**.

[0018] 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.

[0019] 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.

[0020] FIG. **6B** is a detail view of the extruded through-hole taken along the portion encircled in FIG. **6A**.

[0021] 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**.

[0022] 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**.

[0023] 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

[0024] 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.

[0025] 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.

[0026] 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.

[0027] 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.

[0028] 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.

[0029] 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**.

[0030] 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.

[0031] 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).

[0032] 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 to 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.

[0033] 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.

[0034] 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**).

[0035] 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.

[0036] 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**.

[0037] 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.

[0038] 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 the 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..

[0039] 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**.

[0040] 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**.

[0041] 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** arc 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.

[0042] 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.

[0043] 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.

[0044] 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**.

[0045] 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**.

[0046] 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**.

[0047] 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.

[0048] 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.

[0049] 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.

[0050] 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

1. A method of manufacturing a casing centralizer (10), comprising:

   forming a plurality of bow-springs (18), each having a first end (20) and a second end (22), and each having a foot (28, 30) at each end; and forming a first collar (12) and a second collar (14), each having a plurality of circumferentially spaced bow-spring aligning slots (21), each bow-spring aligning slot (21) configured for receiving a foot (28, 30) on the end (20, 22) of a bow-spring (18);

   characterized by:

   forming at least one extruded through-hole (36) in each collar (12, 14) and adjacent to each aligning slot (21) by positioning each collar (12, 14) on a supporting back-up member (40) having an opening (54) aligned with a punch (53), and by driving the punch (53) through the collar wall and into the opening (54), wherein the diameter (d3) of the punch (53) is less than about 80% of a diameter (d4) of the opening (54) on the supporting member (40); and
   tapping each extruded through-hole (36) to threadedly receive a fastener (24).

2. The method of claim 1, wherein forming the aligning slots (21) comprises driving a second punch (51) through the collar (12, 14) into a second opening (52) in the supporting back-up member (40), wherein a width (d1) of the second punch (51) is smaller than a width (d2) of the second opening (52) on the supporting back-up member (40).

3. The method of claim 1, further comprising:

   fastening a first end (20) of each bow-spring (18) to the first collar (12) using a fastener (24) threadedly engaged with one of the threaded extruded through-holes (36) in the first collar (12); and
   fastening a second end (22) of each bow-spring (18) to the second collar (14) using a second fastener (24) threadedly engaged with one of the threaded collar through-holes (36) in the second collar (14).

4. The method of claim 3, further comprising securing each bow-spring (18) to a radially outwardly disposed surface of each collar (12, 14).

5. The method of claim 1, wherein the step of forming each extruded through-hole (36) in a collar (12, 14) comprises forming an extruded through-hole (36) having a height (h) of at least about 1.5 times the material thickness (t) of the collar (12, 14).

6. The method of claim 1, wherein the step of forming each extruded through-hole (36) comprises forming an extruded through-hole (36) having a flange height (h) of between about 2.0 to 3.0 times the material thickness (t) of the collar (12, 14).

7. The method of claim 1, wherein each of the aligning slots (21) in the circumferential wall of the collar (12, 14) 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 (28, 30) of each bow-spring (18) by inwardly bending the ends (20, 22) of the bow-springs (18) to create an angled portion at each end (28, 30) of the bow-spring (18).

9. A casing centralizer (10), **characterized by**:

   first and second collars (12, 14) each having a plurality of circumferentially spaced aligning slots (21) and a corresponding plurality of threaded, extruded through-holes (36), wherein the extruded through-holes (36) have a flange height (h) greater than the collar thickness (t) adjacent to the extruded through-holes (36);
   a plurality of bow-springs (18), each having an aperture (32, 34) and a foot (28, 30) at each end (20, 22), each bow-spring (18) extending between the first and second collars (12, 14), with the foot (30) at one end (22) of each bow-spring (18) disposed in one of the aligning slots (21) of the first collar (12) to align the adjacent aperture (34) on the end of the bow-spring (18) with an extruded through-hole (36) of the first collar (12), and the foot (28) at the other, opposite end (20) of the bow-spring (18) disposed in one of the aligning slots (21) on the second collar (14) to align the adjacent aperture (32) on the end of the bow-spring with an extruded through-hole (36) of the second collar (14); and
   a plurality of threaded fasteners (24) corresponding in number and pitch of threads to the threaded extruded through-holes (36) for securing one end (20, 22) of each of the bow-springs (18) to each of the first and second collars (12, 14) by inserting a fastener (24) through each aperture (32, 34) aligned with an extruded through-hole (36) and by threading the fastener (24) into the threaded and extruded through-holes (36).

10. The casing centralizer of claim 9, wherein the bow-springs (18) are disposed on outwardly facing sur-

faces of each collar (12, 14).

11. The casing centralizer of claim 9, wherein the flange height (h) of each extruded through-hole (36) is at least 1.5 times the collar thickness (t).

12. The casing centralizer of claim 9, wherein the flange height (h) of each extruded through-hole (36) is between about 2.0 to 3.0 times the collar thickness (t).

13. The casing centralizer of claim 9, wherein the feet (28, 30) comprise inwardly bent portions on the ends (20, 22) of the bow-springs (18).

Patentansprüche

1. Verfahren zur Herstellung einer Zentriereinrichtung für Futterrohre (10), umfassend:

das Herstellen einer Anzahl an Bogenfedern (18), jeweils mit einem ersten Ende (20) und einem zweiten Ende (22) und jeweils mit einem Fuß (28, 30) an jedem Ende; und

das Herstellen einer ersten Futterrohrmuffe (12) und einer zweiten Futterrohrmuffe (14), jeweils mit einer Anzahl an um ihren Umfang herum beabstandeten Bogenfeder-Ausrichtungsschlitzen (21), wobei die Bogenfeder-Ausrichtungsschlitze (21) jeweils so gestaltet sind, dass sie einen Fuß (28, 30) an einem Ende (20, 22) einer Bogenfeder (18) aufnehmen können;

dadurch gekennzeichnet, dass

man mindestens ein extrudiertes Durchgangsloch (36) in jeder Futterrohrmuffe (12, 14) und benachbart zu jedem Ausrichtungsschlitz (21) herstellt, indem man jede Futterrohrmuffe (12, 14) auf einem Stützelement (40) positioniert, das eine Öffnung (54) hat, die mit einer Punze (53) ausgerichtet ist, und die Punze (53) durch die Wand der Futterrohrmuffe und in die Öffnung (54) treibt, wobei der Durchmesser (d3) der Punze (53) weniger als 80% des Durchmessers (d4) der Öffnung (54) auf dem Stützelement (40) beträgt; und

in jedes extrudierte Durchgangsloch (36) ein Gewinde schneidet, so dass es ein Befestigungselement (24) mit Gewinde aufnehmen kann.

2. Verfahren nach Anspruch 1, wobei das Herstellen der Ausrichtungsschlitze (21) das Treiben einer zweiten Punze (51) durch die Futterrohrmuffe (12, 14) in eine zweite Öffnung (52) in dem Stützelement (40) umfasst, wobei eine Breite (d1) der zweiten Punze (51) kleiner ist als eine Breite (d2) der zweiten Öffnung (52) auf dem Stützelement (40).

3. Verfahren nach Anspruch 1, bei dem man zudem:

ein erstes Ende (20) jeder Bogenfeder (18) an der ersten Futterrohrmuffe (12) unter Verwendung eines Befestigungselements (24) befestigt, das über ein Gewinde mit einem der mit Gewinde versehenen, extrudierten Durchgangslöcher (36) in der ersten Futterrohrmuffe (12) verbunden ist; und

ein zweites Ende (22) jeder Bogenfeder (18) an der zweiten Futterrohrmuffe (14) unter Verwendung eines zweiten Befestigungselements (24) befestigt, das über ein Gewinde mit einem der mit Gewinde versehenen, extrudierten Durchgangslöcher (36) in der zweiten Futterrohrmuffe (14) verbunden ist.

4. Verfahren nach Anspruch 3, bei dem man zudem jede Bogenfeder (18) an einer radial auswärts positionierten Oberfläche jeder Futterrohrmuffe (12, 14) befestigt.

5. Verfahren nach Anspruch 1, wobei man zudem jeweils bei dem Schritt Herstellen des extrudierten Durchgangslochs (36) in einer Futterrohrmuffe (12, 14) ein extrudiertes Durchgangsloch (36) herstellt mit einer Höhe (h), die mindestens etwa das 1,5-Fache der Materialdikke (t) der Futterrohrmuffe (12, 14) beträgt.

6. Verfahren nach Anspruch 1, wobei man zudem jeweils bei dem Schritt Herstellen des extrudierten Durchgangslochs (36) ein extrudiertes Durchgangsloch (36) herstellt mit einer Flanschhöhe (h), die etwa das 2,0- bis 3,0-Fache der Materialdicke (t) der Futterrohrmuffe (12, 14) beträgt.

7. Verfahren nach Anspruch 1, wobei die Ausrichtungsschlitze (21) in der Umfangswand der Futterrohrmuffe (12, 14) jeweils eine im Großen und Ganzen in Richtung des Umfangs verlaufende Schlitzlänge und eine im Großen und Ganzen axial verlaufende Schlitzbreite haben, die erheblich kleiner ist als die Schlitzlänge.

8. Verfahren nach Anspruch 1, bei dem man zudem jeweils die Füße (28, 30) der Bogenfeder (18) durch einwärts Biegen der Enden (20, 22) der Bogenfedern (18) herstellt, so dass ein abgewinkelter Abschnitt an jedem Ende (28, 30) der Bogenfeder(18) hergestellt wird.

9. Zentriereinrichtung für Futterrohre (10), **gekennzeichnet durch**:

eine erste und eine zweite Futterrohrmuffe (12, 14), die jeweils eine Anzahl an um ihren Umfang herum beabstandeten Ausrichtungsschlitzen

(21) und eine entsprechende Anzahl an mit Gewinde versehenen, extrudierten Durchgangslöchern (36) besitzen, wobei die extrudierten Durchgangslöcher (36) eine Flanschhöhe (h) haben, die größer ist als die Dicke (t) der Futterrohrmuffen in Nachbarschaft zu den extrudierten Durchgangslöchern (36);

eine Anzahl an Bogenfedern (18), jeweils mit einer Öffnung (32, 34) und einem Fuß (28, 30) an jedem Ende (20, 22), wobei die Bogenfedern (18) jeweils zwischen einer ersten und einer zweiten Futterrohrmuffe (12, 14) verlaufen und der Fuß (30) an einem Ende (22) jeder Bogenfeder (18) in einen der Ausrichtungsschlitze (21) der ersten Futterrohrmuffe (12) eingebracht worden ist, so dass die benachbarte Öffnung (34) an dem Ende der Bogenfeder (18) mit einem extrudierten Durchgangsloch (36) der ersten Futterrohrmuffe (12) ausgerichtet ist, und der Fuß (28) an dem anderen, gegenüberliegenden Ende (20) der Bogenfeder (18) in einen der Ausrichtungsschlitze (21) an der zweiten Futterrohrmuffe (14) eingebracht worden ist, so dass die benachbarte Öffnung (32) an dem Ende der Bogenfeder mit einem extrudierten Durchgangsloch (36) der zweiten Futterrohrmuffe (14) ausgerichtet ist; und

eine Anzahl an mit Gewinde versehenen Befestigungselementen (24), die in ihrer Anzahl und der Anzahl der Gewindegänge den mit Gewinde versehenen, extrudierten Durchgangslöchern (36) entsprechen, so dass ein Ende (20, 22) der jeweiligen Bogenfedern (18) jeweils an der ersten und der zweiten Futterrohrmuffe (12, 14) befestigt werden kann, indem ein Befestigungselement (24) durch jede Öffnung (32, 34) eingeführt wird, die mit einem extrudierten Durchgangsloch (36) ausgerichtet ist, und das Befestigungselement (24) in die mit Gewinde versehenen, extrudierten Durchgangslöcher (36) eingeschraubt wird.

10. Zentriereinrichtung für Futterrohre nach Anspruch 9, wobei die Bogenfedern (18) jeweils auf radial auswärts zeigenden Oberflächen der jeweiligen Futterrohrmuffen (12, 14) positioniert sind.

11. Zentriereinrichtung für Futterrohre nach Anspruch 9, wobei die Flanschhöhe (h) jedes extrudierten Durchgangslochs (36) mindestens das 1,5-Fache der Dicke (t) der Futterrohrmuffe beträgt.

12. Zentriereinrichtung für Futterrohre nach Anspruch 9, wobei die Flanschhöhe (h) jedes extrudierten Durchgangslochs (36) etwa das 2,0- bis 3,0-Fache der Dicke (t) der Futterrohrmuffe beträgt.

13. Zentriereinrichtung für Futterrohre nach Anspruch 9, wobei die Füße (28, 30) einwärts gebogene Abschnitte an den Enden (20, 22) der Bogenfedern (18) umfassen.

Revendications

1. Procédé de fabrication d'un centreur de colonne de tubage (10), comprenant :

la formation d'une pluralité de ressorts arqués (18), ayant chacun une première extrémité (20) et une seconde extrémité (22) ; et ayant chacun un pied (28, 30) à chaque extrémité ; et

la formation d'un premier collier (12) et d'un second collier (14), ayant chacun une pluralité de fentes d'alignement de ressort arqué espacées circonférentiellement (21), chaque fente d'alignement de ressort arqué (21) étant configurée pour recevoir un pied (28, 30) sur l'extrémité (20, 22) d'un ressort arqué (18) ;

caractérisé par :

la formation d'au moins un trou traversant extrudé (36) dans chaque collier (12, 14) et adjacent à un côté de chaque fente d'alignement (21) par le positionnement de chaque collier (12, 14) sur un organe de renfort et de support (40) ayant une ouverture (54) alignée avec un poinçon (53), et par entraînement du poinçon (53) à travers la paroi de collier et dans l'ouverture (54), le diamètre (d3) du poinçon (53) étant inférieur à environ 80 % d'un diamètre (d4) de l'ouverture (54) sur l'organe de support (40) ; et

le taraudage de chaque trou traversant extrudé (36) pour recevoir par filetage une fixation (24).

2. Procédé selon la revendication 1, dans lequel la formation des fentes d'alignement (21) comprend l'entraînement d'un second poinçon (51) à travers le collier (12, 14) dans une seconde ouverture (52) dans l'organe de renfort et de support (40), une largeur (d1) du second poinçon (51) étant inférieure à une largeur (d2) de la seconde ouverture (52) sur l'organe de renfort et de support (40).

3. Procédé selon la revendication 1, comprenant en outre :

la fixation d'une première extrémité (20) de chaque ressort arqué (18) au premier collier (12) à l'aide d'une fixation (24) mise en prise par filetage avec l'un des trous traversants extrudés filetés (36) dans le premier collier (12) ; et

la fixation d'une seconde extrémité (22) de chaque ressort arqué (18) au second collier (14) à l'aide d'une seconde fixation (24) mise en prise par filetage avec l'un des trous traversants de collier filetés (36) dans le second collier (14).

4. Procédé selon la revendication 3, comprenant en outre l'attache de chaque ressort arqué (18) à une surface disposée radialement vers l'extérieur de chaque collier (12, 14).

5. Procédé selon la revendication 1, dans lequel l'étape de formation de chaque trou traversant extrudé (36) dans un collier (12, 14) comprend la formation d'un trou traversant extrudé (36) ayant une hauteur (h) d'au moins environ 1,5 fois l'épaisseur de matériau (t) du collier (12, 14).

6. Procédé selon la revendication 1, dans lequel l'étape de formation de chaque trou traversant extrudé (36) comprend la formation d'un trou traversant extrudé (36) ayant une hauteur de rebord (h) comprise entre environ 2,0 et 3,0 fois l'épaisseur de matériau (t) du collier (12, 14).

7. Procédé selon la revendication 1, dans lequel chacune des fentes d'alignement (21) dans la paroi circonférentielle du collier (12, 14) a une longueur de fente en extension généralement circonférentielle et une largeur de fente en extension généralement axiale sensiblement inférieure à la longueur de fente.

8. Procédé selon la revendication 1, comprenant en outre la formation des pieds (28, 30) de chaque ressort arqué (18) par flexion vers l'intérieur des extrémités (20, 22) des ressorts arqués (18) pour créer une portion coudée à chaque extrémité (28, 30) du ressort arqué (18).

9. Centreur de colonne de tubage (10), **caractérisé par** :

des premier et second colliers (12, 14) ayant chacun une pluralité de fentes d'alignement espacées circonférentiellement (21), et une pluralité correspondante de trous traversants extrudés filetés (36), dans lequel les trous traversants extrudés (36) ont une hauteur de rebord (h) supérieure à l'épaisseur de collier (t) adjacente aux trous traversants extrudés (36) ;
une pluralité de ressorts arqués (18), ayant chacune une ouverture (32, 34) et un pied (28, 30) à chaque extrémité (20, 22), chaque ressort arqué (18) s'étendant entre les premier et second colliers (12, 14), avec le pied (30) à une extrémité (22) de chaque ressort arqué (18) disposée dans l'une des fentes d'alignement (21) du premier collier (12) pour aligner l'ouverture adjacente (34) sur l'extrémité du ressort arqué (18) avec un trou traversant extrudé (36) du premier collier (12), et le pied (28) à l'autre extrémité opposée (20) du ressort arqué (18) disposé dans l'une des fentes d'alignement (21) sur le second collier (14) pour aligner l'ouverture adjacente (32) sur l'extrémité du ressort arqué avec un trou traversant extrudé (36) du second collier (14) ; et
une pluralité de fixations filetées (24) correspondant en nombre et en pas de filetage aux trous traversants extrudés filetés (36) pour attacher une extrémité (20, 22) de chacun des ressorts arqués (18) à chacun des premier et second colliers (12, 14) par insertion d'une fixation (24) à travers chaque ouverture (32, 34) alignée avec un trou traversant extrudé (36) et par filetage de la fixation (24) dans les trous traversants filetés et extrudés (36).

10. Centreur de colonne de tubage selon la revendication 9, dans lequel les ressorts arqués (18) sont disposés sur des surfaces tournées vers l'extérieur de chaque collier (12, 14).

11. Centreur de colonne de tubage selon la revendication 9, dans lequel la hauteur de rebord (h) de chaque trou traversant extrudé (36) est d'au moins 1,5 fois l'épaisseur de collier (t).

12. Centreur de colonne de tubage selon la revendication 9, dans lequel la hauteur de rebord (h) de chaque trou traversant extrudé (36) est comprise entre environ 2,0 et 3,0 fois l'épaisseur de collier (t).

13. Centreur de colonne de tubage selon la revendication 9, dans lequel les pieds (28, 30) comprennent des portions fléchies vers l'intérieur sur les extrémités (20, 22) des ressorts arqués (18).

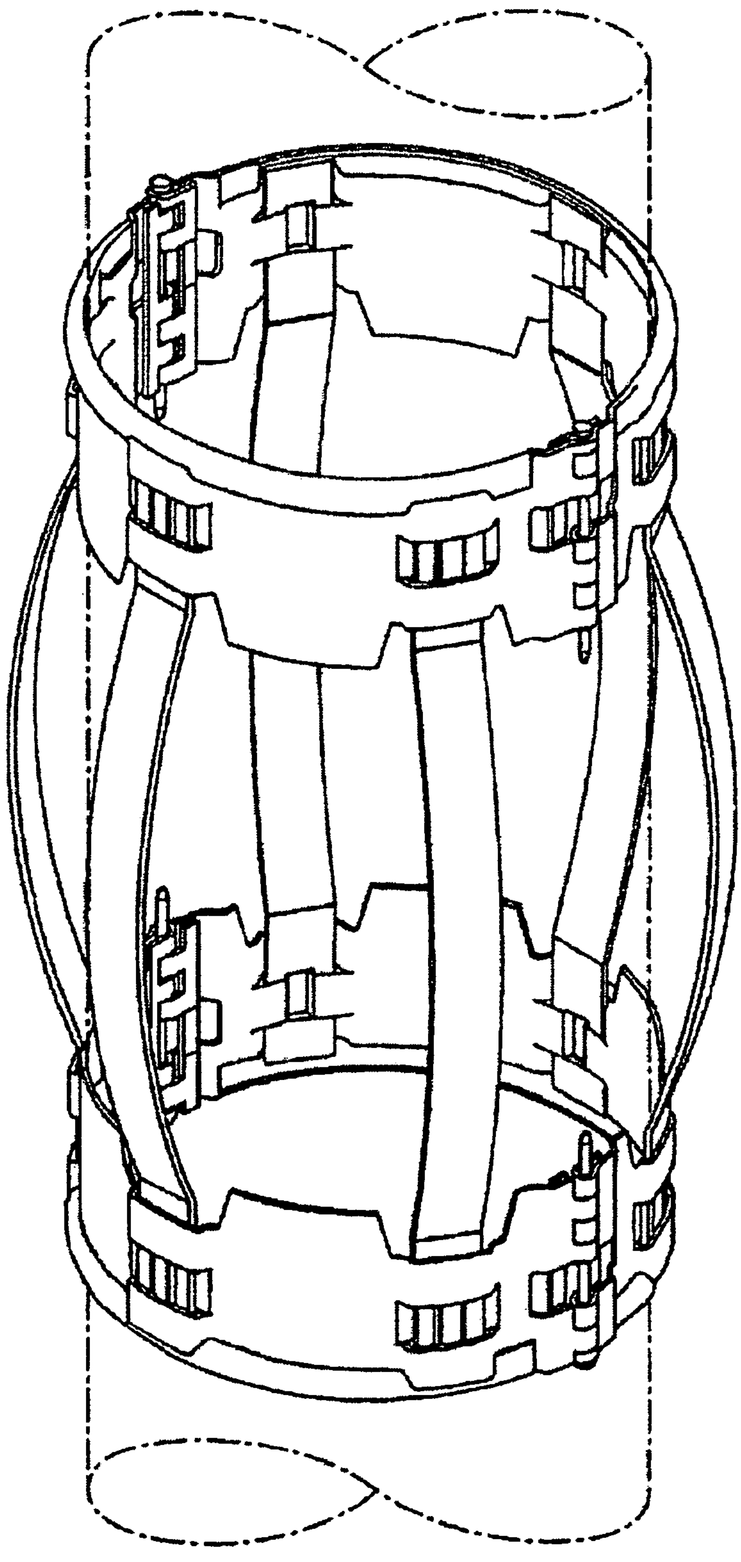

FIG. 1
(Prior Art)

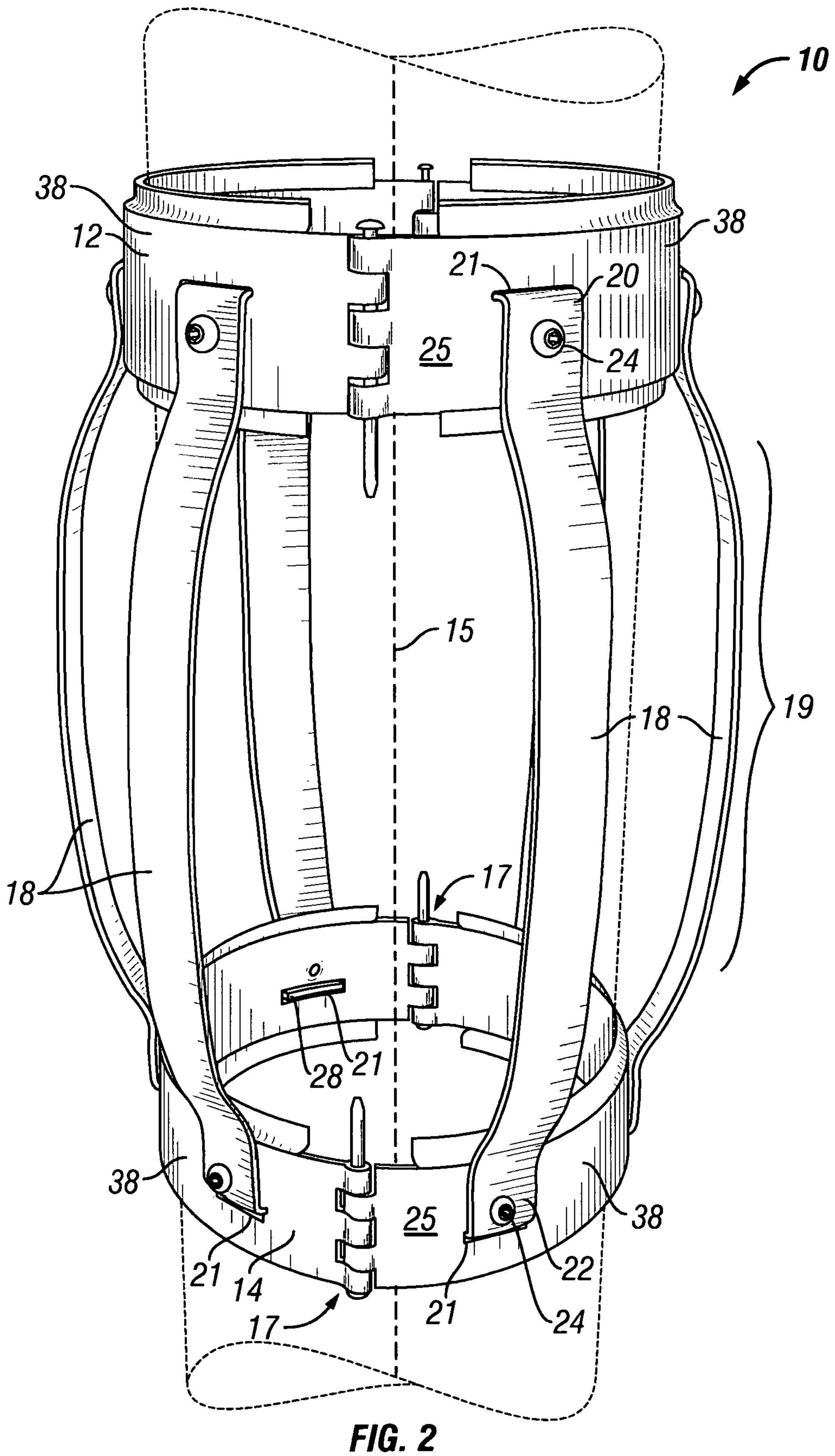

FIG. 2

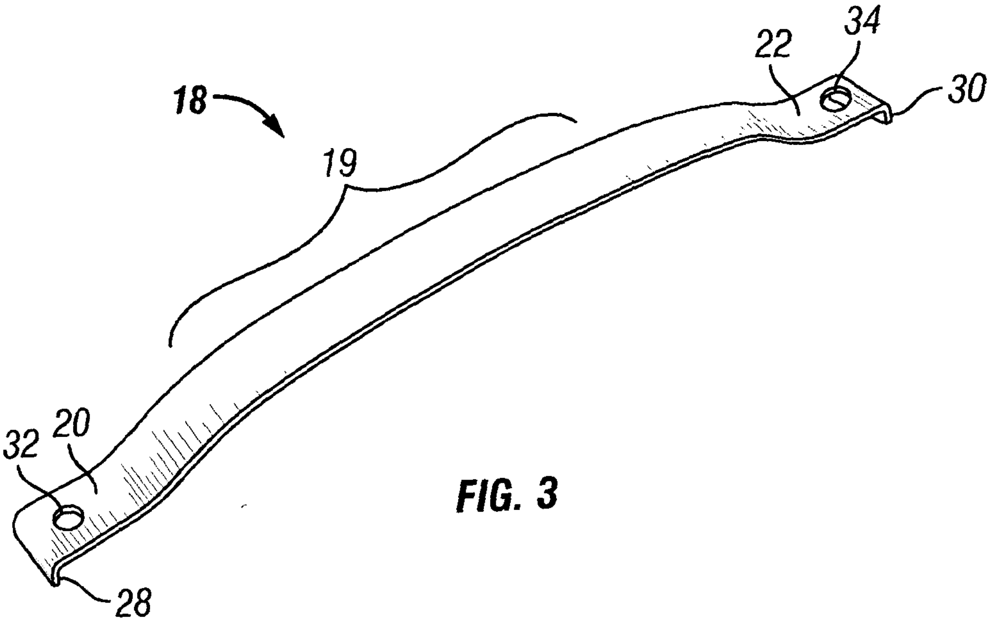

FIG. 3

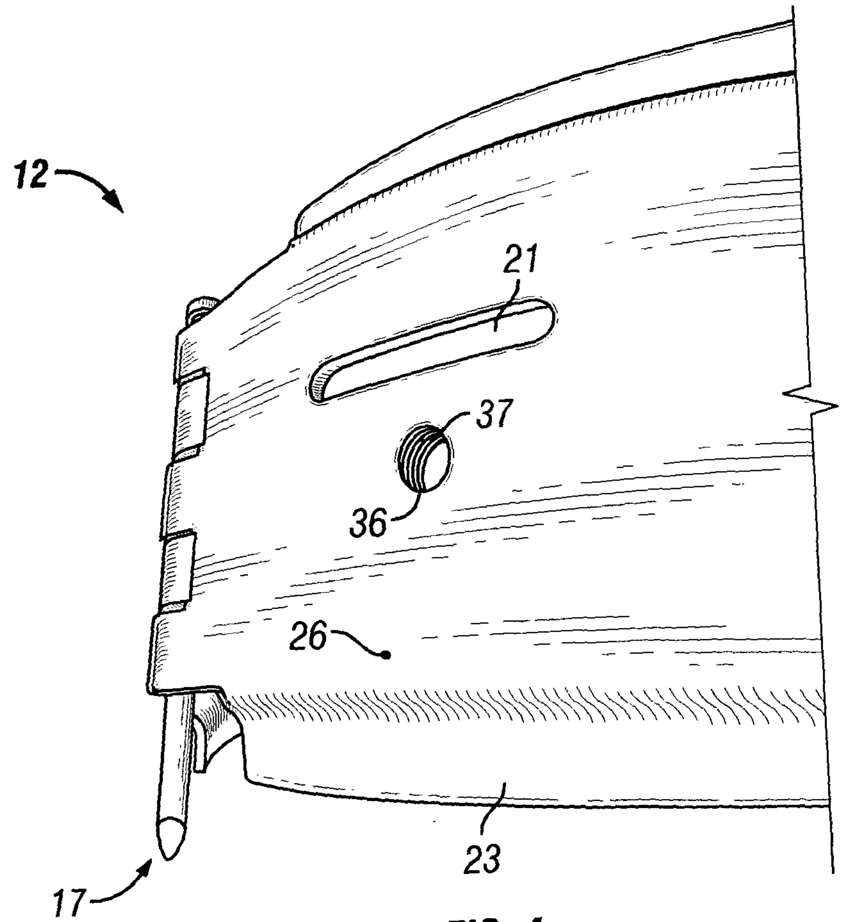

FIG. 4

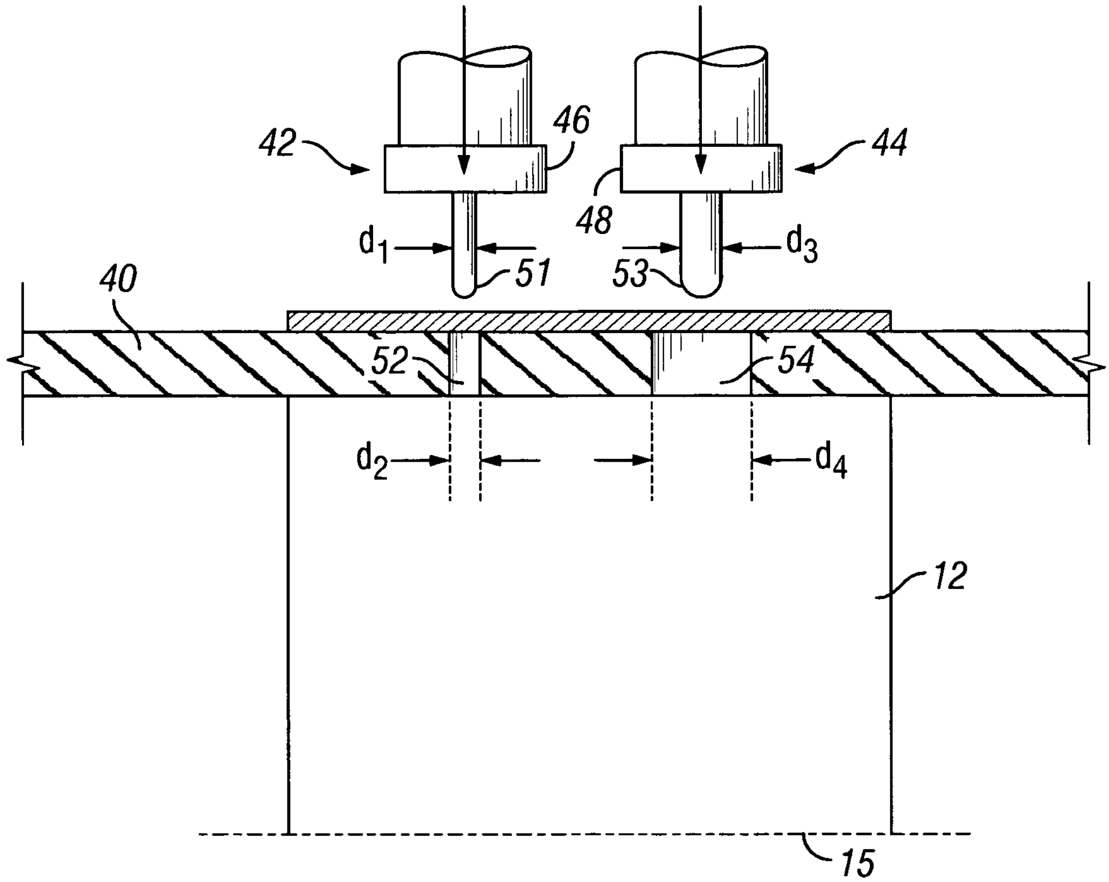
42
46
44
48
d_1
d_3
51
53
40
52
54
d_2
d_4
12
15

FIG. 5

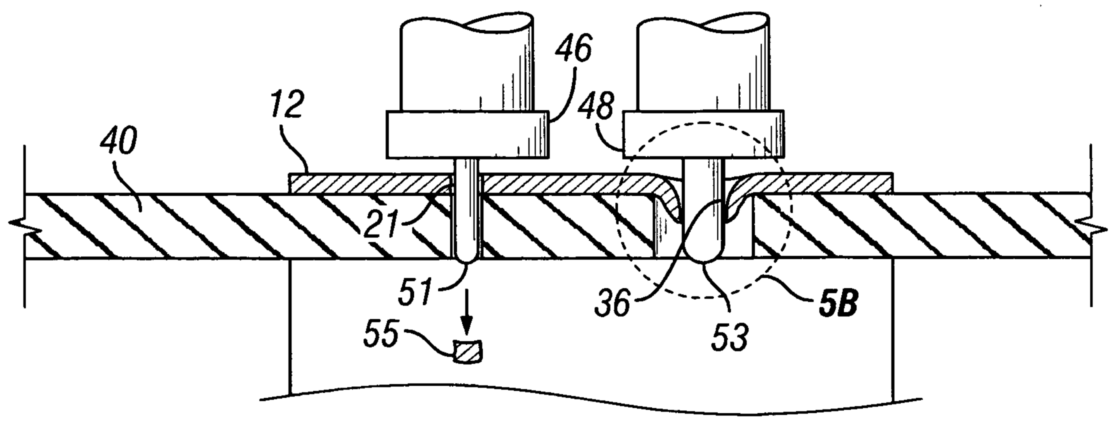
46
12
48
40
21
51
36
53
5B
55

FIG. 6A

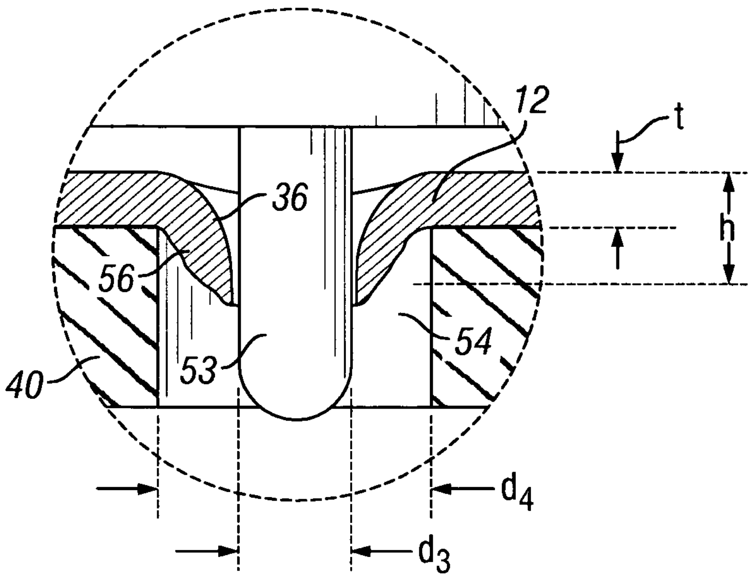

FIG. 6B

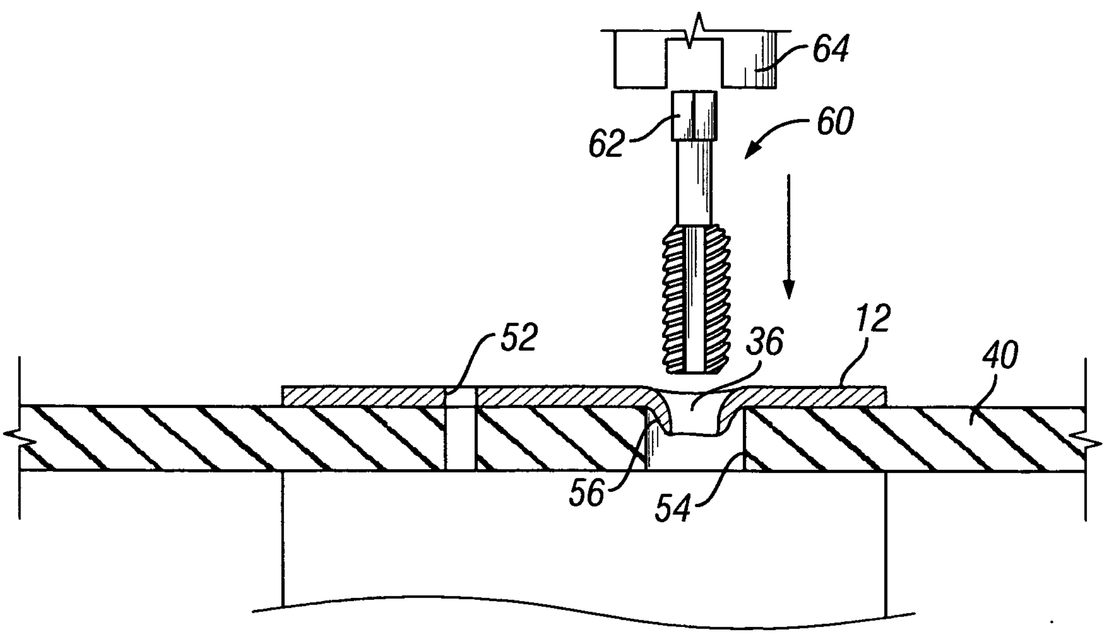

FIG. 7

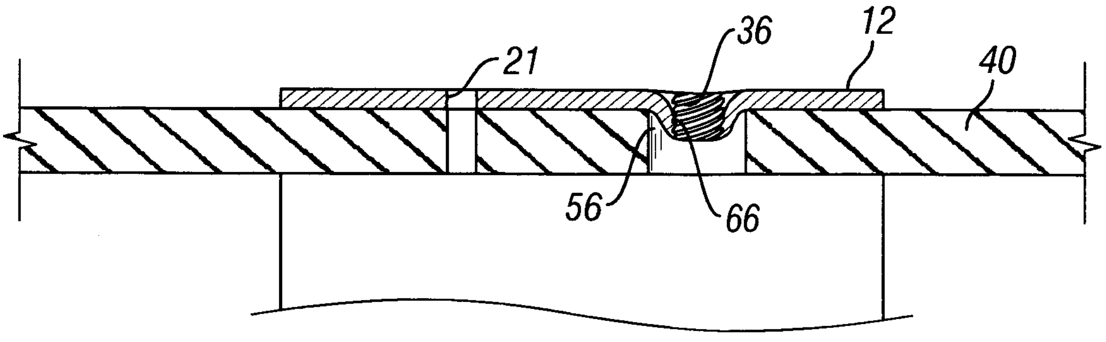

FIG. 8

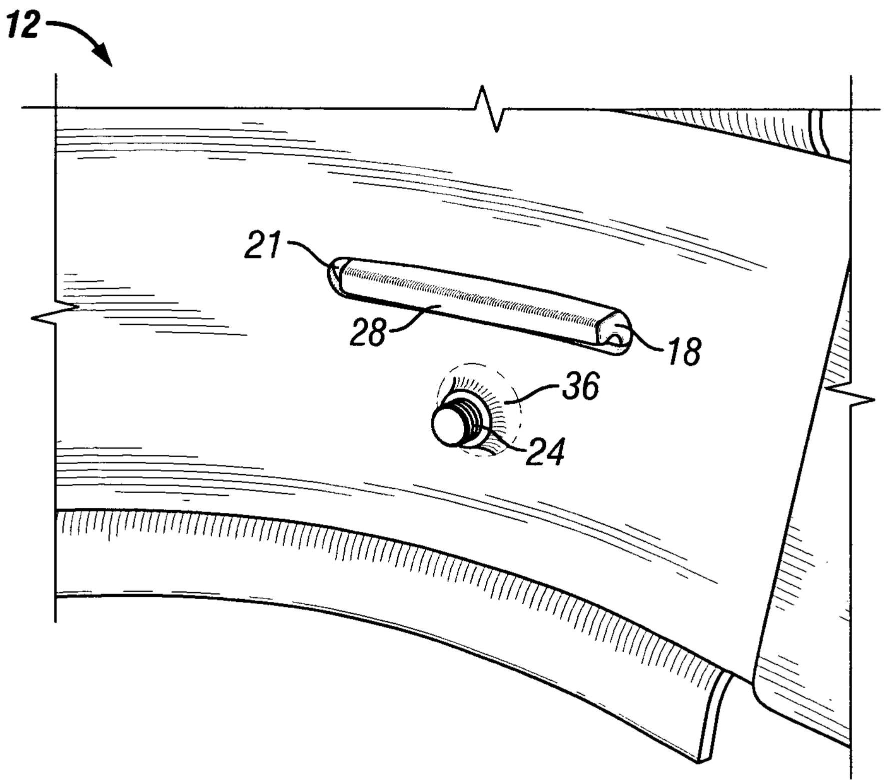

FIG. 9

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- US 4545436 A **[0009]**
- GB 2242457 A **[0009]**