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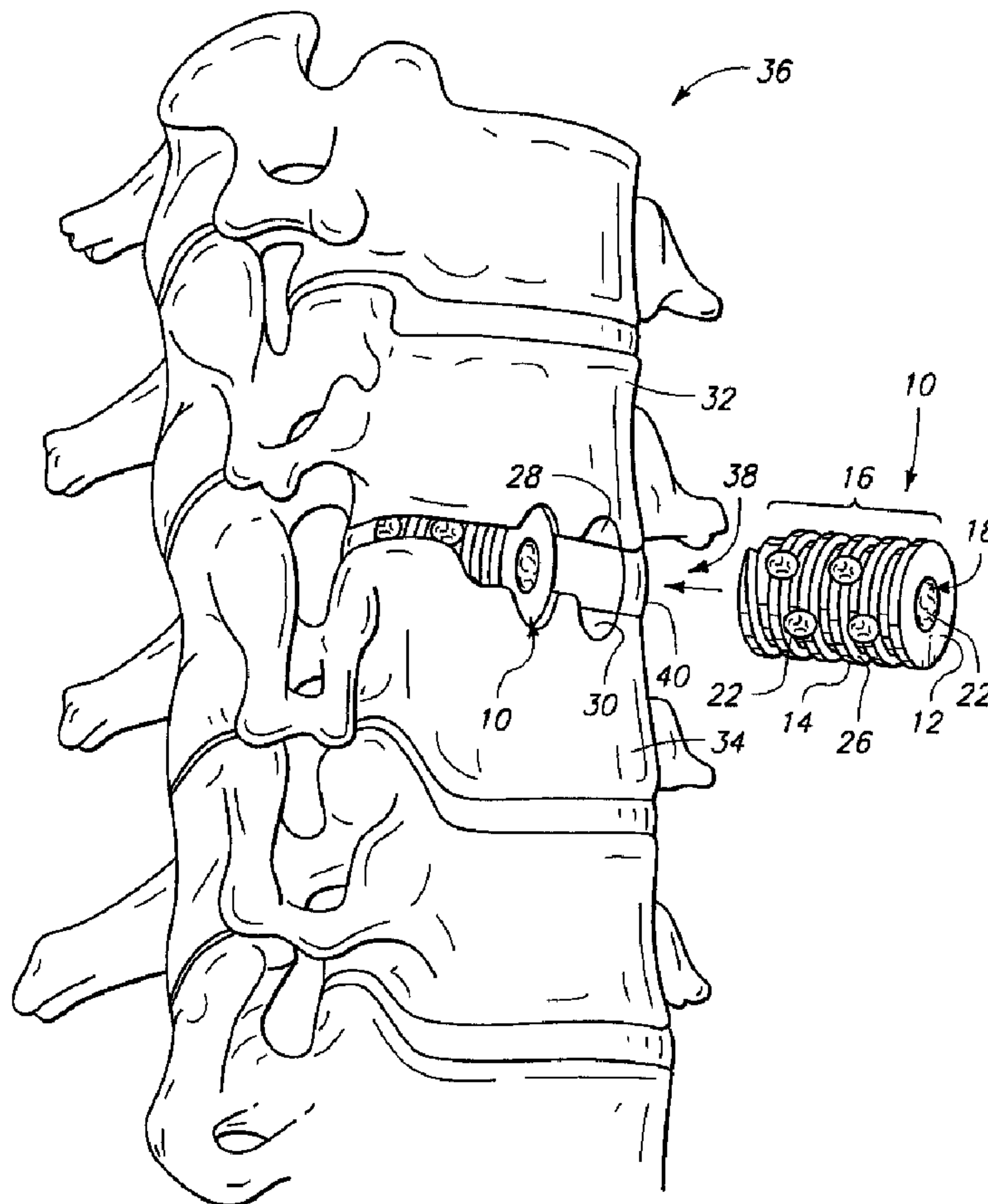
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(54) Titre : **IMPLANT OSSEUX POSSEDANT DES CARACTERISTIQUES DE STABILISATION POUR FUSION  
OSSEUSE**

(54) Title: **INTERBODY BONE IMPLANT HAVING CONJOINING STABILIZATION FEATURES FOR BONY FUSION**



(57) Abrégé/Abstract:

A bone joining implant has a rigid, implantable base body having an outer surface with at least one bone bed engaging portion configured for engaging between a pair of bone bodies to be joined. At least one spline is provided by the bone bed engaging



**(57) Abrégé(suite)/Abstract(continued):**

portion, the spline being constructed and arranged to extend outwardly of the body and having an undercut portion. Upon implantation, the undercut portion of the implant is configured to engage with a bone bed provided in the bone bodies to be joined so as to provide instantaneous fixation there between. In one embodiment, the implant is a vertebral interbody fusing device. The base body is cylindrical and the spline is an undercut thread helically configured about the body. In another embodiment, the base body forms a bridging portion for encircling a vertebra to be removed, and splines in the form of strips of material extend outwardly of top-most and bottom-most portions of the body. Each spline has a undercut portion such that each spline mates in interlocking engagement with top-most and bottom-most neighboring vertebra having bone beds for receiving the splines there along. The mid-most vertebra is then removed (corpectomy), after which an enforcing brace is received therein.

ABSTRACT OF THE DISCLOSURE

A bone joining implant has a rigid, implantable base body having an outer surface with at least one bone bed engaging portion configured for engaging between a pair of bone bodies to be joined. At least one spline is provided by the bone bed engaging portion, the spline being constructed and arranged to extend outwardly of the body and having an undercut portion. Upon implantation, the undercut portion of the implant is configured to engage with a bone bed provided in the bone bodies to be joined so as to provide instantaneous fixation there between. In one embodiment, the implant is a vertebral interbody fusing device. The base body is cylindrical and the spline is an undercut thread helically configured about the body. In another embodiment, the base body forms a bridging portion for encircling a vertebra to be removed, and splines in the form of strips of material extend outwardly of top-most and bottom-most portions of the body. Each spline has a undercut portion such that each spline mates in interlocking engagement with top-most and bottom-most neighboring vertebra having bone beds for receiving the splines there along. The mid-most vertebra is then removed (corpectomy), after which an enforcing brace is received therein.

## TECHNICAL FIELD

This disclosure relates to surgical joining of bone bodies, and more particularly to instant fixation and staged bone fusion of bone bodies, such as spinal vertebrae.

## BACKGROUND OF THE INVENTION

Although the immediate effort leading to this disclosure is directed toward the lumbar spine (anterior or posterior in approach), the described vertebral implants for immediate fixation and staged stabilization leading to arthrodesis (bone fusion) of bone bodies may be used in a bone fracture or osteotomy to fuse together resulting bone bodies, and across one or more joints or articulations. Furthermore, the implants may be used in the lumbar, thoracic and cervical spine.

To facilitate fusion and healing of fractured bones, it has long been known to utilize fixation plates and screws to hold together disunited bone bodies. Typically, the separate bone bodies are formed when a single bone fractures, requiring bone reunion. Plates are secured across a fracture region with screws, joining together the bone bodies. The plates hold the bone bodies together in proximate relation, facilitating bone growth and fusion there between. In this manner, the bone bodies are supported in close proximity, or in direct contact which facilitates fusion there between. For cases where it is impossible to fixture together bone bodies internally of a patient's skin, external fixation is used. For external fixation, threaded pins are rigidly secured

1 into each bone body. The pins, which extend outwardly of a patient's  
2 skin, are fixtured together with an external fixation device, placing the  
3 bone bodies in adjacent proximate position to promote healing there  
4 between. However, this is not practical for certain joints such as joints  
5 formed between spinal vertebrae.

6 An early technique for achieving arthrodesis between adjacent bone  
7 bodies across a joint or articulation is the well known Cloward  
8 Technique for use in the human cervical spine. A solitary dowel of  
9 bone is tapped into place in a prepared circular bed that is smaller  
10 than the dowel of bone. The dowel acts as a wedge, distracting the  
11 surrounding soft tissues of the joint, and separating the bone bodies or  
12 vertebrae joined there along. The intervertebral disc substantially  
13 comprises the soft tissues of the joint. The dowel of bone is inserted,  
14 or wedged into place, providing its own stability by putting an annulus  
15 of the disc on stretch. Additionally, simple friction of the inserted  
16 dowel between adjacent vertebral bodies stabilizes axial dislocation.  
17 However, a second surgical procedure must be performed to extract or  
18 harvest the dowel of bone, substantially adding trauma to the procedure,  
19 increasing costs, as well as increasing the threat of infection to the  
20 patient. Alternatively, bank bone from human donors can be used, but  
21 bank bone is less osteogenic and may introduce infection, or even  
22 transmission of Acquired Immune Deficiency Syndrome (AIDS) or  
23 hepatitis. Furthermore, bone morphogenic protein, hydroxyapatite, or  
24 other bone stimulating material may be utilized. Additionally, there has

1 been a need to ensure the implant remains axially secured which has  
2 lead to further developments.

3 As a step forward from the Cloward Technique, the Bagby metal  
4 dowel (U.S. Patent No. 4,501,269) utilizes the same principle. A  
5 perforated cylindrical hollow implant is inserted between prepared  
6 surfaces across a vertebral joint. The inserted implant immediately  
7 stabilizes the joint by spreading the bony surfaces apart in wedged  
8 opposition to surrounding tissue. This initial stabilization is more  
9 substantial because a metal dowel, unlike a bone dowel, will not be  
10 absorbed or fatigue in use. Over time, fusion occurs through and  
11 around the implant which is filled with bone fragments. Use of the  
12 metal dowel eliminates the need for a second operation to harvest a  
13 dowel of bone. Bone fragments to be inserted in the implant are  
14 retrieved during preparation of the circular beds in each vertebra.  
15 Furthermore, such a metal implant avoids the disadvantage of having to  
16 use bone bank to obtain donor bone. The Bagby implant described in  
17 U.S. Patent No. 4,501,269 has a smooth outer surface, interrupted only  
18 by numerous openings or fenestrations through which bone ingrowth and  
19 through growth can occur. Bone morsels or bone grafts are typically  
20 harvested when preparing the circular bed in each vertebra, after which  
21 they are placed into the fenestrated metal cylindrical implant. The  
22 Bagby implant is then driven or tapped into place in a manner similar  
23 to the placement of Cloward's Bone Dowel, which was solely directed  
24 for use in the cervical spine.

1       Improvements have also been made to "Cloward's Technique"  
2       wherein two dowel bone grafts are posteriorly inserted (Wiltberger's  
3       Technique) between adjacent lumbar vertebral bodies. Furthermore,  
4       threaded surfaces have been added to such bone grafts in order to  
5       keep the grafts in place (Otero-Vich German Application Number  
6       3,505,567, published June 5, 1986). More recently, a number of U.S.  
7       Patents have proposed combining the threaded features from threaded  
8       bone grafts with a metal implant, resulting in rigid threaded implant  
9       structures for placement between adjacent spinal vertebrae.

10       One threaded metal fusion implant disclosed in Michelson (U.S.  
11       Patent No. 5,015,247) provides a cylindrical fusion implant having an  
12       outer diameter sized larger than the space between adjacent vertebrae  
13       to be fused. Threads provided on the exterior of the member engage  
14       the vertebrae to axially secure the implant there between. The implant  
15       has a plurality of openings configured along the cylindrical surface to  
16       promote bone ingrowth. However, the threads per se of the implant  
17       do not function as a fastener to fix together the adjacent vertebral  
18       bodies. Instead, the implant functions as a wedge, imparting a  
19       distraction force across the disc which stabilizes the articulation formed  
20       there between by stretching the annulus of the disc. In fact, the  
21       threaded implant relies solely on the annulus to provide stabilization  
22       between the vertebrae, in direct responsive to wedge-induced distraction  
23       created there between. Distraction of the annulus stabilizes the two  
24       vertebrae, enabling ingrowth to later occur within the implant.

1 Therefore, through-growth and fusion (arthrodesis) occur between the  
2 adjacent vertebrae subsequent thereto depending on the immobilizing  
3 potential of an intact healthy annulus which may or may not be  
4 present. Therefore, there is a need to provide an implant that  
5 produces immediate fixation per se between bone bodies following  
6 insertion and independent of the annulus. Particularly for cases where  
7 the annulus structure is substantially or completely weakened or damaged  
8 at surgery of implantation, the wedge-effect of prior art threaded  
9 implants will not produce any distraction forces across the annulus.  
10 Also, when the implant is used to arthrodese and change angulation, a  
11 healthy annulus cannot be totally corralled to be placed on stretch. As  
12 a result, there is no form of stabilization or fastening between bone  
13 bodies sufficient to enable the occurrence of arthrodesis there between  
14 when the annulus is weakened or inadequate.

15 Another threaded implant disclosed in Ray (U.S. Patent No.  
16 5,005,104) provides a threaded fusion cage that is configured to be  
17 implanted in close adjoining pairs between adjacent vertebral bodies.  
18 Threads of adjacent cages are configured in overlapping relation when  
19 they are implanted. However, the fusion cages function only as wedges,  
20 imparting distraction forces across the annulus. The distraction forces  
21 immediately stabilize the intervertebral articulation by stretching the  
22 annulus of the disc immediately after implantation. Over time, the  
23 adjacent vertebrae fuse together. However, where a stretched annulus  
24 does not provide sufficient stabilization, initial early bone growth is

1 seriously hindered, if not completely prevented. Furthermore, a  
2 stretched annulus can still allow slight motion.

3 For bone fusion to occur with any of the above devices, the  
4 invasion of new delicate blood vessels from the adjacent healthy bone  
5 is necessary for the creation of new living interconnecting bone. Where  
6 complete stabilization does not occur instantaneously upon implantation,  
7 motion can disrupt the in growth of delicate blood vessels. Disruption  
8 of the vessels then restricts or even prevents bone healing there  
9 between. The same problem occurs with any of the above mentioned  
10 implant techniques, including the threaded techniques of Otero-Vich and  
11 Michelson. Even when the annulus is completely on stretch, the threads  
12 per se of these constructions do not function in the manner of  
13 conventional screws, extending through one object and into another.  
14 Namely, they do not function to fasten together adjacent bodies by  
15 coaction of the thread with each body. Alternatively, they do not  
16 fasten together bodies by action of the thread with one body, and  
17 action of a fastener head with the other body. Instead, the threads  
18 merely act as a series of ridges that engage with each adjacent bone  
19 body, while the implant body functions as a wedge. The implant  
20 distracts apart the vertebral bodies which stretches the annulus, and  
21 stabilizes the articulation as a consequence thereof, while the thread  
22 functions solely to prevent axial dislodgement.

23 A further area of prior art relates to implants having surface  
24 features that enable bony ingrowth to occur. For example, beads of

1 titanium have been provided on the stems of hip implants to form such  
2 features. Ingrowth by a bone bed with the structural features occurs  
3 some time after implantation. Therefore, fixation is not immediately  
4 present as a result of the surface features, and some other fixation  
5 must be relied upon until ingrowth occurs. With the exception of the  
6 Cloward Bone Dowel and Otero-Vich, the above-mentioned vertebral  
7 body implant devices incorporate fenestrations or openings that tend to  
8 facilitate bony ingrowth into the metal spinal implants.

9       Additionally, Lin et al. (U.S. Patent No. 4,778,469) teaches a  
10 surface construction of a space occupier having a pattern for tissue  
11 ingrowth in the surface of an implant. Tapered posts having undercuts  
12 are provided along a surface of a hip implant. Subsequent to  
13 implantation, physiological bone ingrowth occurs within the undercuts,  
14 helping to fix the implant within the bone. However, this construction  
15 does not enable immediate fixation via the undercuts. Instead, it relies  
16 upon physiological bone ingrowth which takes time to occur. Therefore,  
17 other mechanisms must be relied upon to maintain implant fixation  
18 within the bone prior to ingrowth. Such is also the case with the  
19 previously mentioned vertebral implants.

20       Therefore, there is a present need to provide implant devices that  
21 fasten bone bodies together directly upon implantation. There is also  
22 a need to provide such a device that facilitates staged stabilization,  
23 ultimately leading to bone fusion there between. The final stage of  
24 bone fusion through and around the implant substantially eliminates any

1 need for the implant to maintain the fusion, thus allowing the bone  
2 union to provide primary support there between, i.e. the implant can  
3 be removed without reversing the arthrodesis in such cases as chronic  
4 infection. Furthermore, there is a need to provide such a device for  
5 fixing bone bodies together across an articulation or joint (arthrodesis).  
6 Particularly, this need exists where soft tissues of an articulation have  
7 deteriorated to such a condition that distraction across the articulation  
8 will not produce stability. For example, prior art devices (including the  
9 above-mentioned vertebral body implant devices) cannot stabilize an  
10 articulation by inducing a wedging apart, or stretching of an annulus  
11 where the annulus is weakened or absent. Therefore, interim stability  
12 cannot be imparted between adjacent vertebrae at the time of surgery.  
13 Such interim stability is needed for successful fusion. As a result,  
14 ingrowth and through growth needed to fuse the bone bodies together  
15 for long-term stability is less likely to occur on a routine basis.

#### 17 BRIEF DESCRIPTION OF THE DRAWINGS

18 Preferred embodiments of the invention are described below with  
19 reference to the following accompanying drawings.

20 Fig. 1 is a perspective view of a vertebral structure showing a  
21 pair of vertebral interbody implants embodying this invention, one  
22 inserted and the other positioned for insertion. A solitary implant (not  
23 shown) may be used in certain cases;

1        Fig. 2 is a side elevational view illustrating the vertebral interbody  
2        implant of Fig. 1;

3        Fig. 3 is a leading end view taken generally on line 3-3 of Fig.  
4        2;

5        Fig. 4 is a trailing end view taken generally on line 4-4 of Fig.  
6        2;

7        Fig. 5 is an unrolled plan view of the outer peripheral surface  
8        of the vertebral interbody implant of Figs. 1-3;

9        Fig. 6 is a cross sectional view taken generally on line 6-6 of Fig.  
10       3 of the vertebral interbody implant immediately after implantation;

11       Fig. 7 is a fragmentary and enlarged cross-sectional view taken  
12       generally on line 7-7 of Fig. 5 and shows initial surface through growth  
13       diagrammatically;

14       Fig. 8 is a cross sectional view taken generally on line 8-8 of Fig.  
15       4 of the vertebral interbody implant subsequent to implantation and  
16       illustrating bone in-growth (diagrammatically) including the bone grafts  
17       with interlocking;

18       Fig. 9 is a cross sectional view corresponding to that of Fig. 8,  
19       but taken later in time and illustrating advanced bone through-growth  
20       (diagrammatically) beyond surface growth and ingrowth of Figs. 7 and  
21       8, and illustrates bone joining and connecting vertebrae;

22       Fig. 10 is a cross sectional view taken generally on line 10-10 of  
23       Fig. 2 illustrating bone through-growth at the same time as that  
24       depicted in Fig. 9, but in histologic detail;

1        Fig. 11 is a cross sectional view corresponding to that of Fig. 10,  
2        but taken later in time and illustrating bone remodelling;

3        Fig. 12 is a fragmentary and enlarged centerline sectional view  
4        depicting a vertebral interbody implant having an alternative undercut  
5        thread construction with bony through growth;

6        Fig. 13 is a fragmentary and enlarged centerline sectional view  
7        depicting a vertebral interbody implant having another alternative  
8        undercut thread construction;

9        Fig. 14 is a fragmentary and enlarged centerline sectional view  
10       depicting a vertebral interbody implant having a third alternative  
11       undercut thread construction;

12       Fig. 15 is a perspective view illustrating a bridging vertebral  
13       interbody implant embodying this invention for use in performing a  
14       corpectomy;

15       Fig. 16 is a front elevational view of a vertebral structure showing  
16       three vertebrae, with a midmost one having a visible cancerous or  
17       benign tumor;

18       Fig. 17 is a front elevational view of the vertebral structure of  
19       Fig. 16 depicting the cephalad and caudad vertebrae prepared to receive  
20       the alternatively constructed interbody implant of Fig. 15;

21       Fig. 18 is a front elevational view of the vertebral structure of  
22       Fig. 17 after receiving the alternatively constructed interbody implant;  
23       and  
24

Fig. 19 is a front elevational view of the device of Figs. 15 and 18 after removal of the mid-most vertebra, insertion of a medial cruciate baffle, and prior to closure of the surgical wound.

#### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

In accordance with one aspect of the invention, a bone joining implant is engaged between a pair of bone bodies to be joined. The implant has a rigid, implantable base body with an outer surface having at least one bone bed engaging portion. The outer surface engages with a bone bed prepared in each bone body to be joined. One or more splines are provided by the bone bed engaging portion. The spline is constructed and arranged to engage outwardly of the implant body. Furthermore, the spline has an undercut portion configured to engage with the bone bed provided in each bone body to be joined.

In accordance with another aspect, the invention further provides a bone joining implant comprising a rigid, implantable base body having an outer surface with at least one bone bed engaging portion configured for engaging between bone beds on a pair of bone bodies to be joined; and at least one spline comprising a thread provided by the bone bed engaging portion, the spline constructed and arranged to extend outwardly of the body and having at least one tapering undercut portion to produce a cross-sectional configuration with a radial outer portion having a dimension sized larger than a radial inner portion, the undercut portion configured to engage the spline in interlocking relation with a bone bed provided in each of the bone bodies to be joined.

In accordance with another aspect, the invention further provides a bone joining member comprising a tubular body having an outer dimension sized to be received between a pair of adjacent bone bodies to be joined and a thread extending about the body configured to engage in assembly with each adjacent bone body, the thread being undercut along a radial

inner portion to engage with a correspondingly prepared bed in each bone.

In accordance with another aspect of the invention, a vertebral interbody implant is engaged between a pair of adjacent vertebrae to be joined. The implant has a body sized to be received between a pair of adjacent vertebrae to be joined. The body forms an outer surface having at least one bone bed engaging portion configured to be engaged with a bone bed on each of a pair of vertebrae to be joined. At least one thread is formed by the bone bed engaging portion that extends radially outward of the body in a generally helical configuration. The thread is configured to engage in assembly with each adjacent vertebra. Furthermore, the thread has an undercut portion provided on a radial inner portion for engaging in interlocking relation with a bone bed in each vertebra. In assembly, the implant engages in interlocking relation with a pair of vertebrae joined there along.

In accordance with another aspect, the invention further provides a vertebral interbody implant comprising an implantable body sized to be received between a pair of adjacent vertebrae to be joined; an outer surface formed by the body having at least one bone bed engaging portion configured to be engaged with a bone bed on each of a pair of vertebrae to be joined; at least one thread formed by the bone bed engaging portion, extending radially outward of the body, and configured in a generally helical configuration, the thread being configured to engage in assembly with adjacent vertebra; and an undercut portion provided on a radial inner portion of the thread, the undercut portion engaging in interlocking relation with the bone bed in each vertebra; wherein, in assembly the implant engages in interlocking relation with a pair of vertebrae joined there along.

In accordance with yet another aspect of the invention, a vertebrae bridging implant is received about a vertebral body to be removed by a corpectomy. An implantable body on the implant has an inner dimension sized to be received about the

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vertebral body to be removed. An outer dimension on the body is sized to be received between a pair of vertebrae to be joined adjacent thereto. The body has an outer surface with a bone bed engaging portion configured to be engaged with bone beds on each vertebra to be joined. An undercut spline extends outwardly of the body, provided by the bone bed engaging portion. In assembly, the spline mates in interlocking engagement with the bone bed of each vertebra, joining the non-adjacent vertebrae in interlocking relation.

In accordance with another aspect, the invention further provides a vertebral bridging implant configured for use in performing a corpectomy, comprising: an implantable body having an inner dimension sized to be received about a vertebral body to be removed, and an outer dimension sized to be received between a pair of vertebrae to be joined adjacent thereto; an outer surface provided by the body has a bone bed engaging portion configured to be engaged with bone beds on each vertebra to be joined; an undercut spline provided by the bone bed engaging portion, the spline extending outwardly of the body, the spline in assembly mating in interlocking engagement with the bone bed of each vertebra; and a bridging portion having a central chamber therein, providing the inner dimension sized to be received about a vertebral body to be removed, the central chamber constructed and arranged to substantially encircle a vertebral body to be removed therefrom, a top-most and a bottom-most portion of the bridging portion defining at least one of a pair of the bone bed engaging portions there along; upon implantation of the spline within each prepared bone, the top-most and the bottom-most portions being mated in interlocking assembly with bone beds of neighbouring associated vertebra there along, wherein the implant is mated in interlocking engagement with top-most and bottom-most neighbouring vertebral while encircling a mid-most vertebral body to be removed.

A preferred embodiment bone joining implant in accordance with the invention is first described with reference to

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Figures 1 through 11. Such an implant is described further below with respect to a threaded vertebral interbody implant having an undercut thread portion. The undercut threaded implant is designated in Figures 1-11 generally with numeral 10. A pair of implants 10 are depicted in this implementation.

1 Alternatively, a single implant could be used. As shown in Figure 1,  
2 such comprises a rigid, cylindrical base body 12 having a helically  
3 configured spline or thread 14 configured on an outer surface 16 of  
4 body 12. A central chamber 18 is formed within body 12 for receiving  
5 bone graft material 20 therein. Large and small fenestrations 22 and  
6 24 extend through surface 16 into chamber 18 for facilitating bony  
7 ingrowth and through growth therethrough. Thread 14 has an undercut  
8 26 which meshes in assembled engagement within bone beds 28 and 30  
9 in vertebra 32 and 34. Each bed 28 and 30 forms complementary  
10 female threads for receiving the undercut thread in interlocking  
11 engagement there along. For purposes of this disclosure, a spline shall  
12 include any thread, web, strip, ridge, or portion of material formed from  
13 continuous material, or broken into fragments (interrupted).

14 As shown in Figure 1, vertebrae 32 and 34 comprise neighboring  
15 bone bodies of a vertebral column 36. A resilient articulation 38 or  
16 joint is formed between vertebra 32 and 34 by a disc 40 extending  
17 there between. Anatomically, the disc is made up of a central nucleus  
18 pulposus and an outer encircling annulus. The annulus and nucleus  
19 pulposus are composed of laminae of fibrous tissue and fibro-cartilage.  
20 The nucleus pulposus, located at the center of the disc, comprises a  
21 soft, pulpy, highly elastic substance. The annulus is formed from  
22 laminae of fibrous tissue extending in criss-crossing fashion to encircle  
23 the nucleus pulposus. Additionally, the intervertebral disc is adherent,  
24 by its cephalad and caudad surfaces, to a thin layer of hyaline cartilage

1 that covers the top and bottom surfaces of adjacent vertebrae. In a  
2 healthy patient, adjacent vertebra 32 and 34 are spaced apart by the  
3 disc 40. However, degenerative disc disease and localized trauma can  
4 cause degradation or complete loss of the soft tissue components  
5 between neighboring vertebrae. For example, the annulus can partially  
6 or completely tear which can seriously degrade the structural condition  
7 of the articulation. Additionally, fluid can escape from the nucleus  
8 pulposus. When any of the above happens, vertebrae 32 and 34,  
9 loaded by the normal weight bearing of a patient, are pressed into  
10 closer adjoining positions, which can result in pinching of nerves that  
11 extend from between vertebrae of the spinal column (not shown).

12 Therefore, there is a need to recover the disc spacing provided  
13 by a normal healthy disc 40 by way of inserting implants 10.  
14 Furthermore, there is a need to provide implants 10 with a fixation that  
15 instantly interlocks adjacent vertebra 32 and 34 together upon being  
16 implanted. Furthermore, there is a need for such an implant 10 that  
17 facilitates staged stabilization resulting in arthrodesis to occur between  
18 the vertebral bodies, following initial implantation.

19 As a result, implant 10 can be inserted, preferably in left and  
20 right laterally positioned pairs, between adjacent vertebrae of patients  
21 who have bad, ruptured or degenerative discs. A solitary implant may  
22 also be used in chosen cases. For example, the implant can be axially  
23 oriented anterior to posterior, or even laterally. In summary, implants  
24 10 are adapted for implantation between prepared bony surfaces or beds

1 28 and 30 of articulation 38. A typical implantation might involve  
2 placement of one or more implants 10 as required in order to stabilize  
3 and fix the joint during bone ingrowth and through-growth of the  
4 implant structure. Bone growth is also accomplished outside of and  
5 surrounding the implant.

6 Preparation of bone beds 28 and 30 is performed according to  
7 well known techniques in the art, with the exception that presently  
8 available tapping devices are modified according to one implementation  
9 of this invention. During a surgical procedure, a prepared and exposed  
10 vertebral column 36 receives a hollow guide tube (not shown) having  
11 teeth at its lower end. The tube (or sleeve) is mated with its lower  
12 end engaging across articulation 38, wherein the teeth engage vertebrae  
13 32 and 34. A drill (not shown) is then guided down the tube in order  
14 to drill a pilot hole between the vertebrae, imparting the general cutout  
15 configuration to beds 28 and 30. Subsequently, a preliminary tapping  
16 device is received through the tube into the pilot hole where female  
17 threads of rectangular cross section are cut into beds 28 and 30. The  
18 female threads are undersized in width, requiring further self-tapping by  
19 the implant during insertion. Alternatively, the tapping device can be  
20 configured to cut female threads having an undercut cross section sized  
21 and configured to conform with the undercut threads 14 on implant 10.  
22 For the case where threads are cut with a rectangular cross section,  
23 implant 10 has self-tapping features provided by thread 14. The self-  
24 tapping features enlarge the radial outermost portion of each

1 complementary corresponding female thread provided by beds 28 and 30,  
2 respectively.

3 An additional benefit is provided when implant 10 is self-tapped  
4 into an undersized female thread in each bone bed 28 and 30.  
5 Namely, in practice it proves difficult to maintain precise spaced apart  
6 positioning of vertebrae 32 and 34 following drilling of beds 28 and 30.  
7 Therefore, even slight variations in spacing produce a misfit between the  
8 outer surface of implant 10 and each bed 28 and 30. However, where  
9 implant 10 has self-tapping features, the self-tapping mitigates any slight  
10 misfit condition by at least partially reforming the beds 28 and 30  
11 during insertion. Furthermore, a laterally positioned pair of implants  
12 10 proves difficult to implant with a perfect fit up between the implants  
13 and the bone beds. Typically, a first site is prepared and one implant  
14 is inserted, after which a second site is prepared and a second implant  
15 is inserted. However, the bone beds at each site tend to shift as each  
16 implant is inserted since the pair of implants are not inserted  
17 simultaneously.

18 Figure 2 illustrates undercut threaded implant 10 in a side  
19 elevational view corresponding to a preferred rotationally positioned and  
20 implanted configuration within a patient. Large fenestrations 22 are  
21 formed along a pair of perpendicular axes that substantially bisect  
22 vertical and horizontal planes of a patient receiving the implant. Large  
23 fenestrations 22 are sized and located to allow for reorganization or  
24 hardening of bone by maturity after initial bone healing. Figure 3

1 clearly illustrates such a configuration. In this manner, top most or  
2 cephalad and bottom most or caudad portions of implant 10 present an  
3 outer surface that is void of any large openings or fenestrations. Such  
4 a surface substantially enhances load bearing there along, following  
5 implantation. However, such placement of large fenestrations 22 still  
6 provides a significant path for subsequent ingrowth and through growth  
7 between adjacent vertebral bodies receiving implant 10. Additionally,  
8 small fenestrations 24 provide paths for ingrowth and through growth.  
9 Furthermore, the above-described orientation and size of fenestrations  
10 22 is well suited for staged fusion and subsequent bone remodelling,  
11 leading to structurally enhanced fusion between vertebrae 32 and 34.

12 Implant 10 of Figure 2 is depicted with a plastic end cap 42 that  
13 mounts in engagement with an opening 44 formed in a trailing end 46  
14 (as shown in Figure 4). End cap 42 is optionally mounted to implant  
15 10 when performing a bilateral implantation by way of a posterior  
16 approach. Such a posterior surgical approach presents a special  
17 concern; namely, that the dura of the spinal cord might rub against the  
18 driving or trailing end 46 of implant 10. Therefore, end cap 42 is  
19 secured in opening 44 to protect the spinal cord, following implantation  
20 of implant 10 and the inserted bone graft material therein.

21 Additionally, small fenestrations 24 are formed in implant 10.  
22 The small fenestrations 24 extend substantially throughout the walls of  
23 the cylindrical implant. Small fenestrations 24 offer avenues of ingrowth  
24 of bone between vertebrae 32 and 34, which is stimulated by bone graft

1 material placed within central chamber 18 during implantation. In this  
2 manner, fenestrations 24 serve to facilitate earlier and more thorough  
3 ingrowth of bone within implant 10. Furthermore, fenestrations 24  
4 enhance overall through growth of bone through implant 10.

5 Large fenestrations 22 are preferably sized and configured to  
6 interrupt no more than one complete width of thread 14. Hence, the  
7 total amount of interlocking of undercut thread 14 with bone beds 28  
8 and 30 is optimized. According to this construction, fenestration 22  
9 extends substantially between a first and a third adjacent portion of  
10 helically wound thread 14, while interrupting a second, or middle  
11 portion. A taper 56, also provided along end 50 reduces the height of  
12 thread 14 substantially to a diameter of base body 12, immediately  
13 adjacent leading end 50. Placement of fenestrations 22 in close  
14 proximity with leading end 50 tends to interrupt thread 14, at least  
15 partially providing a self-tapping feature there along. Furthermore,  
16 fenestrations 22 allow for self depositing of bone chips during the self  
17 tapping process of implant 10. Bone chips are delivered into the large  
18 and small fenestrations 22 and 24, as well as into central chamber 18  
19 during self tapping of the implant. Such bone chips supplement bone  
20 graft material 20 that is packed into the implant, which together  
21 encourage the early process of arthrodesis. These delivered bone chips  
22 produced in self tapping remain alive since they never leave the  
23 patient's body. Therefore, they tend to be more osteogenic than if they  
24 were nonviable.

1 As shown in Figure 2, fenestrations 22 only partially provide for  
2 complete self-tapping. Therefore, cut-out portions 58 are also formed  
3 along thread 14 in order to add further self-tapping features.  
4 Additionally, thread 14 within the region of taper 56 also forms an  
5 undercut 26 so that progressive formation of complementary  
6 corresponding undercut female threads can be formed within bone beds  
7 of adjacent vertebrae receiving the implant.

8 Alternatively, fenestrations 22 can be provided immediately adjacent  
9 to leading end 50, eliminating the need for cut-out portions 58  
10 altogether when providing self-tapping features on implant 10. For  
11 cases where female threads 66 are preformed into beds 28 and 30 with  
12 undercut, there is little or no apparent need for such self tapping  
13 features. In such cases, fenestrations 22 can be placed anywhere along  
14 implant 10, and cut-out portions 58 (Figure 5) can be eliminated (i.e.  
15 No other self-tapping needed).

16 Referring to Figure 3, leading or advancing end 50 of implant 10  
17 is clearly shown. Cut-out portions 58 can be clearly seen in this view.  
18 Additionally, taper 56 progressively decreases the height of thread 14 as  
19 it extends helically toward leading end 50, until it merges into base  
20 body 12. Furthermore, a plurality of axially extending through holes 60  
21 cut through thread 14 are clearly shown. Through holes 60 facilitate  
22 early stage ingrowth of bone with implant 10 following implantation.  
23 As shown in Figure 3, through holes 60 are also formed in thread 14  
24 in the region of taper 56, thereby interrupting thread 14 in the region

1 of taper 56 so as to impart even further self-tapping features there  
2 along. Alternatively, through holes 60 can be omitted in the region of  
3 taper 56.

4 Opening 48 in leading end 50 is sized smaller in diameter than  
5 an inner wall 62 of the implant base body 12, as shown in Figure 3.  
6 In this manner, a structure enforcing bulkhead is provided at the  
7 leading end. Additionally, a similar centrally positioned bulkhead 54 is  
8 also provided intermediate of the advancing and driving ends 50 and 46,  
9 respectively, within central chamber 18. Central bulkhead 54 has an  
10 oval slot 52 extending completely therethrough for mating with a  
11 fingered end of a driver (not shown). The slot mates with the finger,  
12 allowing torquing of threaded implant 10 into the bony beds of adjacent  
13 vertebrae. Typically, such a driver construction is required in order to  
14 impart large forces necessary to insert implant 10 into the lumbar  
15 region of a patient's spine. Alternatively, a driver can be configured  
16 to mate with trailing end 46 via a plurality of dowels on the driver.  
17 The dowels are received in complementary corresponding receiving holes  
18 (not shown) of the implant there along. Such a construction is well  
19 suited to an implant that is sized to be received also in the cervical  
20 region of the spine where less torque is required to insert implant 10  
21 therein.

22 A further alternative construction calls for formation of an oval  
23 slot (similar to slot 52 of Figures 3 and 4) in place of opening 44 in  
24 trailing end 46. Provision of the slot in the trailing end will enable

1 driver engagement suitable to insert as well as remove the implant.  
2 Hence, the same tool can be used to remove the implant.  
3 Furthermore, the leading end can have a similar slot, allowing for  
4 surgical removal of an implant where a posteriorly inserted implant  
5 needs to be removed from the anterior for surgical reasons.

6 As shown in Figures 3 and 4, axially extending through holes 60  
7 are provided in implant 10 in locations that correspond with the vertical  
8 and horizontal planes of a patient receiving the implant. Additional  
9 through holes 60 are provided between the holes positioned along the  
10 vertical and horizontal planes, enabling further initial ingrowth there  
11 along. For holes 60 that are positioned in locations along the vertical  
12 and horizontal planes, such holes are provided adjacent small  
13 fenestrations 24 which further facilitates ingrowth and through growth  
14 there along.

15 As shown in Figure 4, trailing or driving end 46 has opening 44  
16 which is sized similarly to opening 48 in leading end 50 (of Figure 3).  
17 In this manner, opening 44 is sized smaller than inner wall 62, forming  
18 an enforcing flange from a portion of trailing end 46 extending there  
19 along. Additionally, Figure 4 illustrates termination of undercut thread  
20 14 along trailing end 46 of implant 10. Preferably, axially extending  
21 through holes 60 are machined through the helically extending thread  
22 14 progressively from the trailing end 46 toward the leading end 50.  
23 In this manner, a drill bit received there along to cut holes 60 can be  
24

1 axially advanced, short of drilling through thread 14 in the region of  
2 taper 56 if such a construction is so desired.

3 According to Figure 5, outer surface 16 of implant 10 is shown  
4 in an unrolled plan view to better depict layout of thread 14,  
5 fenestrations 22 and 24, through hole 60, and self-tapping cutout  
6 portions 58. The particular layout leads to the various above described  
7 benefits. Various alternative layouts can be readily envisioned for  
8 thread 14, fenestrations 22 and 24, through hole 60 and self-tapping  
9 cutout portions 58, and fall within the claimed subject matter of this  
10 invention. Additionally, any one or more of such features can be  
11 eliminated, with the exception of an undercut spline, or thread, yet still  
12 remain within the claimed scope of this invention.

13 Figure 6 depicts implant 10 of Figures 1 through 5 immediately  
14 after implantation within prepared bone beds 28 and 30 of vertebrae  
15 32 and 34, respectively. According to the depicted implantation of  
16 Figure 1, bone beds 28 and 30 are prepared by forming female threads  
17 66 therein, prior to receiving implant 10. Subsequently, implant 10 is  
18 inserted by threading in into the beds with a driver.

19 As shown in Figure 6, a bore 68 is cut into vertebrae 32 and 34  
20 (partially shown) by progressively enlarging the bore with a series of  
21 reamers received through a hollow guide tube (not shown).  
22 Subsequently, a tap is inserted through the guide tube to cut thread 66  
23 into each vertebrae 32 and 34. In the embodiment of Figure 6, female  
24 threads 66 are cut to have a square cross-sectional configuration, after

1 which the self cutting features of thread 14 enlarge the square female  
2 threads during insertion of the implant. Hence, complementary  
3 corresponding undercut female threads 66 are formed that are configured  
4 to receive undercut thread 14 in snug and inter-locking engagement  
5 there along. By pretapping a square (or some other closely configured)  
6 thread into the bone bodies, the self tapping implant 10 can complete  
7 the tap, which interlocks the implant with each bone body. In this  
8 manner, implant 10 when inserted, interlocks vertebrae 32 and 34  
9 together immediately upon implantation, instantly stabilizing articulation  
10 38. Subsequently, bone ingrowth and through growth occurs via through  
11 hole 60 and fenestrations 22 and 24, by way of enhanced development  
12 via bone grafts 20 packed into central chamber 18. Therefore, with  
13 such a construction, the prior art reliance on a wedging effect to  
14 stretch disc annulus 40 in order to stabilize the joint until bone fusion  
15 occurs there between is eliminated. However, it is still desirable to  
16 prepare beds 28 and 30 such that distraction occurs across disc 40,  
17 further stabilizing articulation 38 there between. Additionally, a bone  
18 distractor can also be used during preparation of bone beds and implant  
19 insertion to pull apart the vertebrae, putting the disc annulus on stretch  
20 in the final implanted configuration.

21 Implant 10 according to the construction of Figures 1-5 facilitates  
22 staged stabilization and a bone fusion between vertebrae 32 and 34.  
23 Figure 6 illustrates the first stage of stabilization across articulation 40,  
24 wherein undercut thread 14 interlocks in female threads 66 of each

1 vertebra, imparting instant fixation and frictional stabilization there  
2 between. Furthermore, annulus 40 further cooperates with the implant  
3 to control distraction. A second stage of stabilization is depicted in  
4 Figure 7, wherein new bone from the living female bone threads 66  
5 through grows into through hole 60. A third stage of stabilization is  
6 depicted in Figure 7, wherein bone grows through small fenestrations 24  
7 enjoins with bone growing from the same vertebra through an adjacent  
8 fenestration, and can further incorporate a portion of bone graft  
9 material contained within the implant. Furthermore, such ingrowth can  
10 occur through large fenestrations (not shown). A fourth stage of  
11 stabilization is depicted in Figures 9 and 10, wherein initial bone growth  
12 occurs through the implant, connecting vertebrae 32 and 34. Such a  
13 condition forms an initial bone fusion. A fifth and final stage of fusion  
14 is depicted in Figures 11 and 12, wherein the fused bone of Figure 11  
15 has reorganized according to Wolff's law. The trabeculae relocate  
16 through large fenestrations 22 to form a mature strengthening of the  
17 trabeculae. Additional reorganization can be facilitated outside of the  
18 implant by providing bone graft material thereabout at the time of  
19 implantation. Such a staged stabilization enables instant fixation  
20 between vertebrae 32 and 34, after which the articulation 38 is  
21 stabilized and stress protected by shifting load-bearing from the implant  
22 to newly formed and reorganized bone occurring there between. For  
23 cases where staged stabilization and bone fusion is not allowed to occur,  
24 stress protection osteopenia can result from normal physiologic stress

1 through the bone being removed via the implant, which can cause  
2 localized osteoporosis.

3 Figure 7 is a fragmentary and enlarged cross-sectional view taken  
4 generally on line 7-7 of Figure 5 illustrating an initial stage of bone  
5 ingrowth with arrows. Bone ingrowth occurs early on through axially  
6 extending through holes 60 due to their short length and proximity to  
7 healthy developed bone in living beds 28 and 30. Since holes 60 are  
8 cut in thread 14 immediately adjacent base body 12, holes 60 are  
9 shallow, and bone growth from living bone beds 28 and 30 need only  
10 progress a short distance in order to extend completely through holes  
11 60. Therefore, early through growth can occur through holes 60, which  
12 further fixes and stabilizes implant 10 to vertebrae 32 and 34. Such  
13 early ingrowth within holes 60 provides fixation above and beyond that  
14 provided by the interlocking fit of undercut thread 14 within female  
15 threads 66. Additionally, through growth of bone into holes 60 prevents  
16 any loosening or "unscrewing" of implant 10 from within female threads  
17 66 of beds 28 and 30. Holes 60 impart a cotter-pin effect, locking  
18 implant 10 within threaded beds 28 and 30. A typical time for  
19 complete through growth of holes 60 in an active and healthy patient  
20 ranges from about two weeks to four weeks.

21 Figure 8 schematically depicts a cross-sectional view of implant 10  
22 taken generally on line 8-8 of Figure 4. The arrows of Figure 8  
23 schematically represent bone ingrowth in the form of arrows that occurs  
24 through adjacent fenestrations 24 by way of the same vertebral body 32

1 or 34. The ingrowth through fenestrations 24 of Figure 8 occurs  
2 somewhat later in time than the ingrowth through holes 60 of Figure  
3 7. The typical time for through growth is from one month to 3  
4 months. Ingrowth by way of fenestrations 24 further ensures fixation  
5 of implant 10 to vertebrae 32 along a top portion, and to vertebrae 34  
6 along a bottom portion. At this stage of stabilization, implant 10 still  
7 holds vertebrae 32 and 34 together in structural relation. Furthermore,  
8 the ingrowth depicted in fenestrations 24 in Figure 8 also occurs  
9 through fenestrations 22 (not depicted).

10 Figure 9, taken later in time than Figures 7 and 8, depicts  
11 complete through growth (arthrodesis) of implant 10 by healing bone  
12 following earlier ingrowth. According to Figure 9, a simplified and  
13 somewhat schematic cross-sectional configuration shows large fenestrations  
14 22 and omits small fenestrations 24 for clarity. Furthermore, through  
15 growth is depicted in the form of arrows extending between vertebra 32,  
16 along a top portion, and vertebra 34, along a bottom portion. At this  
17 stage of bone fusion, bone graft material 20 that was initially placed in  
18 chamber 18 has fused with healing bone from vertebrae 32 and 34.  
19 The fused bone provides a continuous path of structural bone there  
20 between. Furthermore, an additional pathway of bone not depicted in  
21 Figures 7-9 is bone growth outside of and around the implant. Such  
22 an initial bone fusion tends to have a somewhat random or directionally  
23 uniform bone cell orientation. The bone cells lack any optimized or  
24 reorganized structural orientation there through, other than that dictated

1 by passageways that originally allowed for the bone growth. As shown  
2 in Figures 9 and 10, the general characteristics of such initial bone  
3 fusion lacks any substantial reorganization. Hence, bone cell geometry  
4 has not been structurally oriented to optimize structural loading.

5 Figure 10 depicts histologic bone cell geometry in greater detail,  
6 corresponding in time to that depicted in Figure 9. Lacunae and canals  
7 or voids 69 are formed between the bone 67. The lacunae represent  
8 the voids between the bone where soft tissue, blood vessels, and fatty  
9 deposits reside.

10 According to Figure 11, reorganization of fused bone material  
11 through implant 10 is shown generally occurring between vertebrae 32  
12 and 34. The fused bone consists of bone ingrowth and through growth  
13 of holes 60, fenestrations 22 and 24, and openings 44 and 48.  
14 According to this simplified schematic representation depicting  
15 fenestrations 22, the bone cells of Figure 11 have remodeled so as to  
16 optimize the substantially vertical loading. Such loading represents the  
17 vertical weight bearing that a patient will impart on the implant system  
18 as surgically placed in the configuration of Figures 10 and 11. In such  
19 a manner, bone cells have remodeled to form a definite elongated  
20 configuration extending between vertebrae 32 and 34 through  
21 fenestrations 22. Such remodelled bone through growth can be seen  
22 between fenestrations on same sides of a patient, occurring from  
23 cephalad to caudad, as well as between fenestrations along a diagonal  
24 configuration of the patient, from cephalad to caudad. The large

fenestrations 22 allows nature (by Wolff's law) to locate and strengthen large trabeculae. The latter also occurs around the outside of the implant between the vertebrae, as shown in Figures 10 and 11.

Figure 12 depicts an alternatively constructed bone joining implant 70 implanted between vertebrae 32 and 34, but in a totally fused together and remodelled bone configuration. Such a final state of fusion transfers loading through the remodelled bone resulting from arthrodesis and remodelling. Hence, the need for implant 70 to carry load is greatly diminished, or even eliminated. In some cases, the implant can be subsequently removed where arthrodesis has occurred along the outside of the implant without reversing the bone fusion. According to Figure 12, bone union can be clearly seen around the outside of the implant.

Implant 70 of Figure 12 has a modified form of thread 72 having an undercut 74 formed by enlarging the radial outermost portion of thread 72. Alternatively, a bead having a cylindrical, oval, or semi-circular cross-sectional configuration can be affixed to the base to form thread 72. Fenestrations 24 are also depicted on implant 70. Additionally, large fenestrations 22 (not shown) substantially similar to those depicted in the device of Figures 1 through 11 are also present.

Figure 13 is a fragmentary and enlarged center line sectional view of a further alternative construction for a thread 76 on implants 78 substantially similar to that depicted in Figures 1 through 11. However, thread 76 is constructed to have a substantially vertical first face 80

1 and a substantially undercut second face 82. When implanted, faces 80  
2 and 82 cooperate to engage in interlocking relation with a  
3 complementary corresponding female receiving thread. Upon  
4 implantation of the device, the resulting undercut thread construction is  
5 trapped in the female receiving thread. The construction of Figure 13  
6 provides the benefits of undercut, while decreasing the cost of producing  
7 a thread having an undercut along both faces.

8 Figure 14 is yet another alternative construction of a thread 84  
9 having undercut features 86 on an implant 88. Undercut 86 is provided  
10 by through holes substantially similar to through hole 60 of implant 10  
11 pursuant to Figures 1 through 11. However, the undercut 86 of Figure  
12 14 is less preferred since immediate fixation is difficult, if not  
13 impossible to impart immediately after implantation of implant 88 within  
14 a bone bed. One technique for enabling immediate fixation is to also  
15 provide bone cement, such as polymethyl methacrylate (PMMA) which  
16 is inserted into the prepared bed as well as into holes 86 so that  
17 immediate fixation can occur via undercut 86 with the bone bed upon  
18 implantation of implant 88 there along. Additionally, or alternatively,  
19 undercut 86 can take on the form of a localized, or discreet undercut  
20 that extends into a base portion of thread 84 along only a discrete  
21 portion(s). Even furthermore, through holes 60 can alternatively extend  
22 between a side face of thread 84 and the radial outermost face of the  
23 thread. Such a configuration will provide for undercut fixation.

Alternatively, the thread constructions depicted in Figures 1-14 can be formed by any of a number of cross-sectional configurations of one or more splines extending from a base body, and having an undercut portion. Further examples would include a spline having a vertical first face and an opposite undercut face. The undercut can have a face that is flat, concave, convex or some combination thereof. Furthermore, the first face can be sloped, essentially the opposite of undercut, thinning the spline in locations away from the base body. However, a corresponding undercut must be provided on the second face, in order to ensure interlocking between the implant and a bone bed instantly upon fixation. Another alternative construction has a pair of threads extending about the implant. With such a dual thread construction, the threads start 180 degrees apart, such that cutting forces produced by self-tapping threads will substantially offset one another. Hence, a self-tapping implant will tend to rotate into a pilot hole in a balanced manner, tending to follow the pilot hole. Furthermore, the balanced forces lead to a compact and stable implant that is more readily implanted in close relation with a solid bone bed. Such a relation enhances osteogenic effect, and allows a surgeon to deliver the implant on a long and thin driver. Hence, a smaller incision can be used to perform the surgery (via laparoscopy and thoroscope), resulting in much less trauma and less recovery time to a patient.

Figure 15 illustrates a bone joining implant 106 suitable for use in performing a vertebral corpectomy. A corpectomy involves removal

1 of a vertebral body from the posterior arch of a vertebra. Implant 106  
2 has splines 118 and 120 configured on a top and bottom most outer  
3 surface for interlocking in bone beds of vertebrae adjacent to the  
4 vertebra to be removed. Implant 106 is first inserted into the bone  
5 beds of the vertebrae above and below the corpectomy after they are  
6 prepared. This option allows stabilizing the two healthy vertebrae 90  
7 and 94 before removing the vertebral body of vertebra 92. Otherwise,  
8 vertebra 92 would be dangerously destabilized. The implant has an  
9 open central receiving cavity 114 that envelopes the vertebra to be  
10 removed. Following implantation, the vertebra is remove, after which  
11 a reinforcing brace, or medial cruciate baffle 136 is mounted within  
12 implant 106 to strengthen the structural bridging resulting there between.

13 Figure 16 illustrates a portion of vertebral column 36 wherein a  
14 middle vertebra 92 has a cancerous tumor 96. Such a condition is a  
15 suitable candidate for a corpectomy, which requires complete removal  
16 of the vertebral body to extract cancerous tumor 96, and removal of  
17 discs 98 and 100. However, it is very difficult to perform such an  
18 operation without stabilizing the healthy vertebra first due to the  
19 tendency of surrounding muscles and soft tissue to compressively set the  
20 spine, driving vertebral bodies 90 and 94 closer together. The main  
21 body portion of vertebra 92 is removed, and a posterior portion forming  
22 the arch is left intact, thereby removing significant protection to the  
23 spinal cord and nerve structures. Therefore, it becomes necessary to  
24 maintain the positions of vertebrae 90 and 94 during removal of

1 vertebra 92 until suitable implant material and/or implants can be  
2 inserted there between.

3 According to Figure 17, vertebrae 90 and 94 are cut to prepare  
4 bone beds 102 and 104 for receiving the bone bridging implant 106  
5 (Figure 16) of this invention. Each of beds 102 and 104 is formed  
6 from a single, centrally located and axially extending undercut groove  
7 108 and a pair of laterally positioned and axially extending smaller  
8 grooves 110. Grooves 108 and 110 are preferably cut into vertebrae  
9 90 and 94 with a saw or milling head, forming beds 102 and 104,  
10 respectively. Undercuts 112 in each groove ensure interlocking of  
11 implant 106 as discussed below. Preferably, beds 102 and 104 are  
12 prepared while vertebra 92 is left in position.

13 According to Figure 18, implant 106 is inserted into interlocking  
14 and fixed relation with vertebrae 90 and 92, along beds 102 and 104.  
15 Subsequently, vertebra 92, which is contained within the receiving cavity  
16 114 of implant 106 is cut from the arch extending posteriorly there  
17 along, and removed from the implant.

18 Implant 106 of Figure 18 has a hoop shaped somewhat-rectangular  
19 base body 116, defining receiving cavity 114 therein. An elongated and  
20 axially extending large spline 118 and neighboring adjacently disposed  
21 small splines 120 are configured on a top most 122 and bottom most  
22 124 face of body 116. Splines 118 and 120 both have an undercut 126  
23 constructed and arranged to engage in dove-tailed relation with undercut  
24 grooves 108 and 110 respectively. In this manner, implant 106 is mated

1 in immediate fixed relation between vertebrae 90 and 94, forming a  
2 structural bridge there between. Subsequently, the vertebral body of  
3 vertebra 92 is removed therefrom.

4 Implant 106 also has horizontally extending through holes 128  
5 formed in each spline 118 and 120. Additionally, vertically extending  
6 fenestrations 130, as well as horizontally extending fenestrations 132 are  
7 provided in base body 116 for facilitating bony ingrowth and through  
8 growth there through. Furthermore, a plurality of brace receiving  
9 grooves 134 are provided, one at each corner of cavity 114 for  
10 receiving a reinforcing brace (Figures 15 and 19) subsequent to removal  
11 of vertebra 32 there from.

12 According to Figure 19, reinforcing brace 136 is inserted within  
13 implant 106 so as to structurally enforce the box-shaped base body  
14 configuration. Preferably, brace 136 includes fenestrations 138 for  
15 facilitating bony ingrowth and through growth there along. Preferably,  
16 bone graft material 20 is also inserted in the remaining portions of  
17 cavity 114, along brace 136. The bone graft material further facilitates  
18 ingrowth and through growth between vertebra 90 and 94, and with  
19 graft material 20. Additionally, a cavity 139 is shown optionally in  
20 Figure 19, in which bone graft material 20 can be packed to facilitate  
21 ingrowth and through growth.

22 Figure 15 also discloses an interrupted configuration for each of  
23 splines 118 and 120. Interruptions 140 prevent inadvertent axial  
24 displacement of implant 106 subsequent to implantation. Interruptions

1 140 in splines 118 and 120 serve to prevent axial motion of each spline  
2 within each groove 108 and 110, respectively. Additionally, or  
3 alternatively PMMA can also be inserted between the splines and  
4 grooves during implantation. The PMMA, or bone cement facilitates  
5 fixation between the implant and grooves 108 and 110. PMMA can  
6 partially fill through holes 128 and/or fenestrations 130 and 132, further  
7 joining with the vertebral bodies 90 and 94 to prevent motion there  
8 between.

9 In compliance with the statute, the invention has been described  
10 in language more or less specific as to structural and methodical  
11 features. It is to be understood, however, that the invention is not  
12 limited to the specific features shown and described, since the means  
13 herein disclosed comprise preferred forms of putting the invention into  
14 effect. The invention is, therefore, claimed in any of its forms or  
15 modifications within the proper scope of the appended claims  
16 appropriately interpreted in accordance with the doctrine of equivalents.

**CLAIMS:**

1. A bone joining implant comprising:

a rigid , implantable base body having an outer surface with at least one bone bed engaging portion configured for engaging between bone beds on a pair of bone bodies to be joined; and

at least one spline comprising a thread provided by the bone bed engaging portion, the spline constructed and arranged to extend outwardly of the body and having at least one tapering undercut portion to produce a cross-sectional configuration with a radial outer portion having a dimension sized larger than a radial inner portion, the undercut portion configured to engage the spline in interlocking relation with a bone bed provided in each of the bone bodies to be joined.

2. The implant of claim 1 wherein the base body comprises a generally cylindrical body and the spline comprises a thread.

3. The implant of claim 2 wherein the thread comprises a generally helical structure configured on the generally cylindrical body to provide a bone bed engaging structure there along.

4. The implant of claim 3 further comprising a hollow portion provided in the body, the hollow portion configured to receive bone graft material therein.

5. The implant of claim 4 further comprising a plurality of fenestrations provided in the body, extending from the hollow portion to the outer surface.

1           6.     The implant of claim 5 wherein the fenestrations comprise  
2     a large bore sized to interrupt at least one portion of the helically  
3     nested together thread, the large bore suitably sized for bone  
4     remodelling.

5  
6           7.     The implant of claim 6 wherein the fenestrations further  
7     comprise a small bore sized to fit between adjacent portions of the  
8     helically nested together thread.

9  
10          8.     The implant of claim 2 wherein the thread is undercut  
11     generally along a radial inner portion, the undercut thread configured  
12     to engage in interlocking relation upon implantation with at least one  
13     of the bone beds to be joined.

14  
15          9.     The implant of claim 8 wherein the bone bed of each bone  
16     body to be joined is prepared with a complementary undercut female  
17     receiving thread, and the undercut threads of the implant are received  
18     in interlocking threaded assembly therein.

19  
20          10.    The implant of claim 1 wherein the spline comprises a strip  
21     of material extending from the base body.

22  
23          11.    The implant of claim 10 wherein the strip of material is  
24     discontinuous, having interruptions there along.

1           12. The implant of claim 1 wherein the base body comprises a  
2 frusto-cylindrical body and the spline comprises a thread.

3  
4           13. The implant of claim 1 wherein the spline is tapered in  
5 height from an advancing end, the implant further comprising  
6 interruptions provided in the spline along the tapered advancing end,  
7 such interruptions in the spline enabling self-tapping of the implant.

8  
9           14. The implant of claim 13 further comprising at least one  
10 fenestration having a large bore sized to interrupt at least one portion  
11 of the spline, such interrupted portion of the spline providing at least  
12 in part such self-tapping.

13  
14           15. The implant of claim 13 further comprising at least one  
15 cutout portion provided in the spline, the cutout portion configured to  
16 interrupt at least one portion of the spline, such cutout portion of the  
17 spline providing at least in part such self-tapping.

18  
19           16. The implant of claim 13 further comprising holes extending  
20 through the spline generally transverse thereto, such holes imparting  
21 interruptions along the tapered advancing end, such interruptions  
22 providing at least in part such self-tapping.

1           17. The implant of claim 1 wherein the implant comprises a  
2 vertebral interbody fusing device.

3  
4           18. The implant of claim 1 wherein the implant comprises a  
5 vertebral interbody prosthesis.

6  
7           19. The implant of claim 18 wherein the base body comprises  
8 a bridging portion having a central chamber therein, the central chamber  
9 constructed and arranged to substantially encircle a vertebral body to  
10 be removed therefrom, a top-most and a bottom-most portion defining  
11 at least one of the bone bed engaging portions there along, the  
12 top-most and the bottom-most portions being mated in interlocking  
13 assembly with bone beds of neighboring associated vertebra there along,  
14 wherein the implant is mated in interlocking engagement with top-most  
15 and bottom-most neighboring vertebra while encircling a mid-most  
16 vertebral body to be removed.

17  
18           20. The implant of claim 19 wherein the bridging portion further  
19 comprises a plurality of receiving grooves provided along an inner-most  
20 surface along the central chamber and an enforcing bulkhead, the  
21 receiving grooves constructed and arranged to receive the enforcing  
22 bulkhead therein so as to enforce the bridging portion following removal  
23 substantially of the mid-most vertebral body therefrom.

1        21. A vertebral interbody implant comprising:

2        an implantable body sized to be received between a pair of  
3 adjacent vertebrae to be joined;

4        an outer surface formed by the body having at least one bone  
5 bed engaging portion configured to be engaged with a bone bed on  
6 each of a pair of vertebrae to be joined;

7        at least one thread formed by the bone bed engaging portion,  
8 extending radially outward of the body, and configured in a generally  
9 helical configuration, the thread being configured to engage in assembly  
10 with each adjacent vertebra; and

11        an undercut portion provided on a radial inner portion of the  
12 thread, the undercut portion engaging in interlocking relation with the  
13 bone bed in each vertebra;

14        wherein, in assembly the implant engages in interlocking relation  
15 with a pair of vertebrae joined there along.

16  
17        22. The implant of claim 21 wherein the body is generally  
18 cylindrical.

19  
20        23. The implant of claim 21 wherein the thread is discontinuous,  
21 having interruptions there along.  
22  
23  
24

1        24. The implant of claim 23 further comprising a hollow portion  
2 provided in the body, the hollow portion configured to receive bone  
3 graft material therein, and a plurality of fenestrations provided in the  
4 body, extending from the hollow portion to the outer surface, at least  
5 one of the fenestrations positioned and arranged to provide the  
6 interruption in the thread there along.

7  
8        25. The implant of claim 21 wherein the undercut extends along  
9 the entire length of the thread.

10  
11       26. The implant of claim 21 wherein the undercut comprises a  
12 through hole extending generally transverse to the thread between  
13 opposed faces.

14  
15       27. The implant of claim 21 wherein the thread has a pair of  
16 side faces configured in generally opposed relation, the undercut being  
17 provided in one of the faces.

18  
19       28. The implant of claim 21 wherein the thread has a pair of  
20 side faces configured in generally opposed relation, the undercut being  
21 provided in both faces.

1           29. The implant of claim 21 further comprising a transverse  
2 through hole provided between opposed faces of the thread, the through  
3 hole configured to promote early physiological ingrowth so as to interlock  
4 the implant within each bone bed to be joined.

5  
6           30. The implant of claim 21 further comprising a hollow portion  
7 provided in the body, the hollow portion configured to receive bone  
8 graft material therein, and a plurality of fenestrations provided in the  
9 body, extending from the hollow portion to the outer surface, the  
10 fenestrations configured to promote physiological implant fixation.

11  
12           31. The implant of claim 21 wherein the thread is tapered in  
13 height from an advancing end of the implant, the implant further  
14 comprising interruptions provided in the thread along the tapered  
15 advancing end, such interruptions in the thread enabling self-tapping  
16 within the bone beds to be joined.

17  
18           32. The implant of claim 31 wherein the bone beds are  
19 prepared with a female square thread having a width corresponding to  
20 the narrowest width of the thread along the undercut, the self-tapping  
21 thread enlarging the female thread in each bone bed upon implantation,  
22 interlocking the implant to each vertebra to be joined.

33. The implant of claim 21 wherein the thread has a cross-sectional configuration with a radial outer portion having a dimension sized larger than a radial inner portion.

34. A vertebral bridging implant configured for use in performing a corpectomy, comprising:

an implantable body having an inner dimension sized to be received about a vertebral body to be removed, and an outer dimension sized to be received between a pair of vertebrae to be joined adjacent thereto;

an outer surface provided by the body has a bone bed engaging portion configured to be engaged with bone beds on each vertebra to be joined;

an undercut spline provided by the bone bed engaging portion, the spline extending outwardly of the body, the spline in assembly mating in interlocking engagement with the bone bed of each vertebra; and

a bridging portion having a central chamber therein, providing the inner dimension sized to be received about a vertebral body to be removed, the central chamber constructed and arranged to substantially encircle a vertebral body to be removed therefrom, a top-most and a bottom-most portion of the bridging portion defining at least one of a pair of the bone bed engaging portions there along;

upon implantation of the spline within each prepared bone, the top-most and the bottom-most portions being mated in interlocking assembly with bone beds of neighbouring associated vertebra there along, wherein the implant is mated in interlocking engagement with top-most and bottom-most neighbouring vertebral while encircling a mid-most vertebral body to be removed.

35. The implant of claim 36 wherein the bridging portion further comprises a plurality of receiving grooves provided along an inner-most surface along the central chamber and an

## 43

enforcing bulk head, the receiving grooves constructed and arranged to receive the enforcing bulk head therein so as to enforce the bridging portion following removal substantially of the mid-most vertebral body therefrom.

36. The implant of claim 34 wherein the spline comprises a strip of material extending from the base body along the outer surface.

37. The implant of claim 36 wherein the strip of material is discontinuous, having interruptions there along.

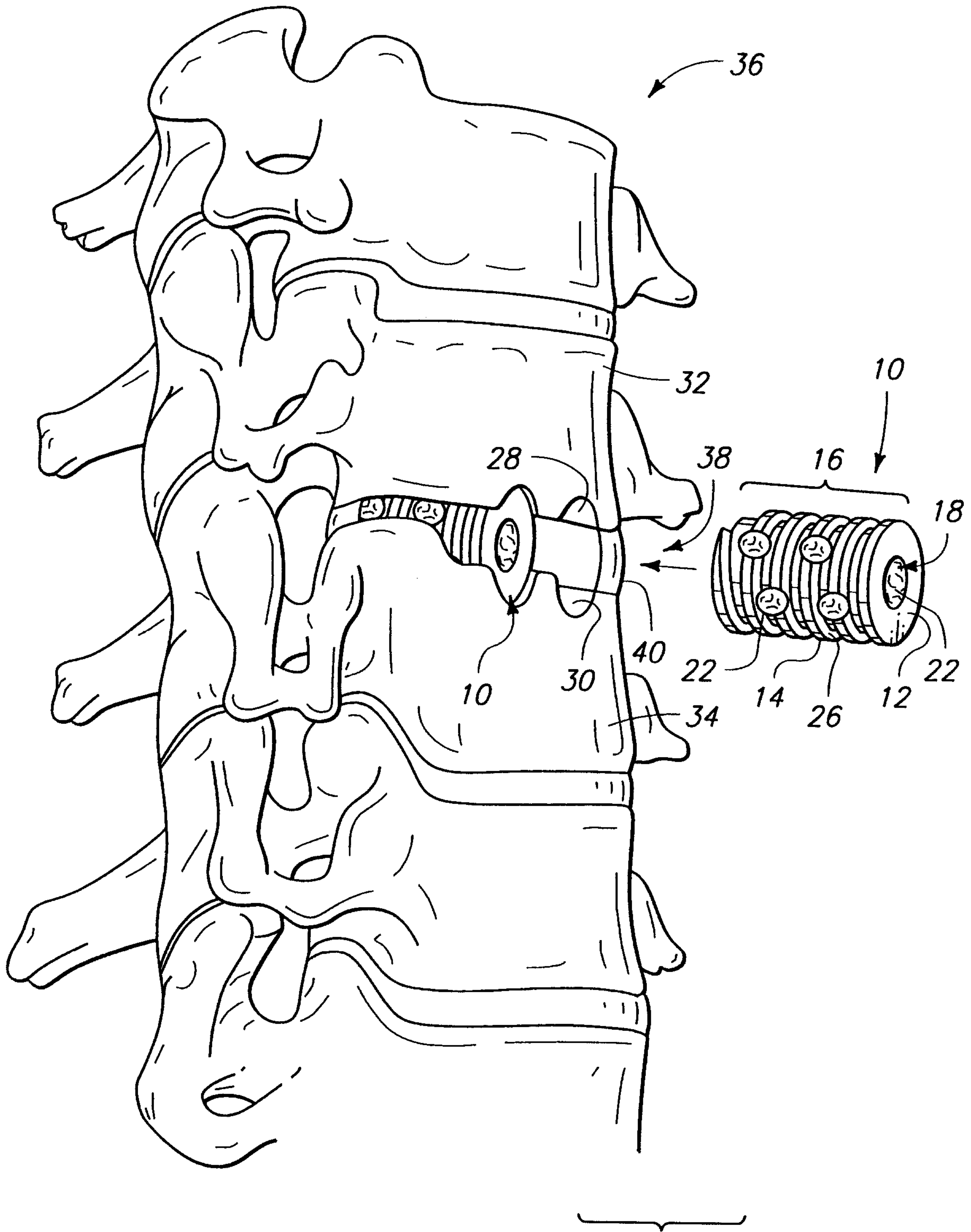
38. A bone joining member comprising:

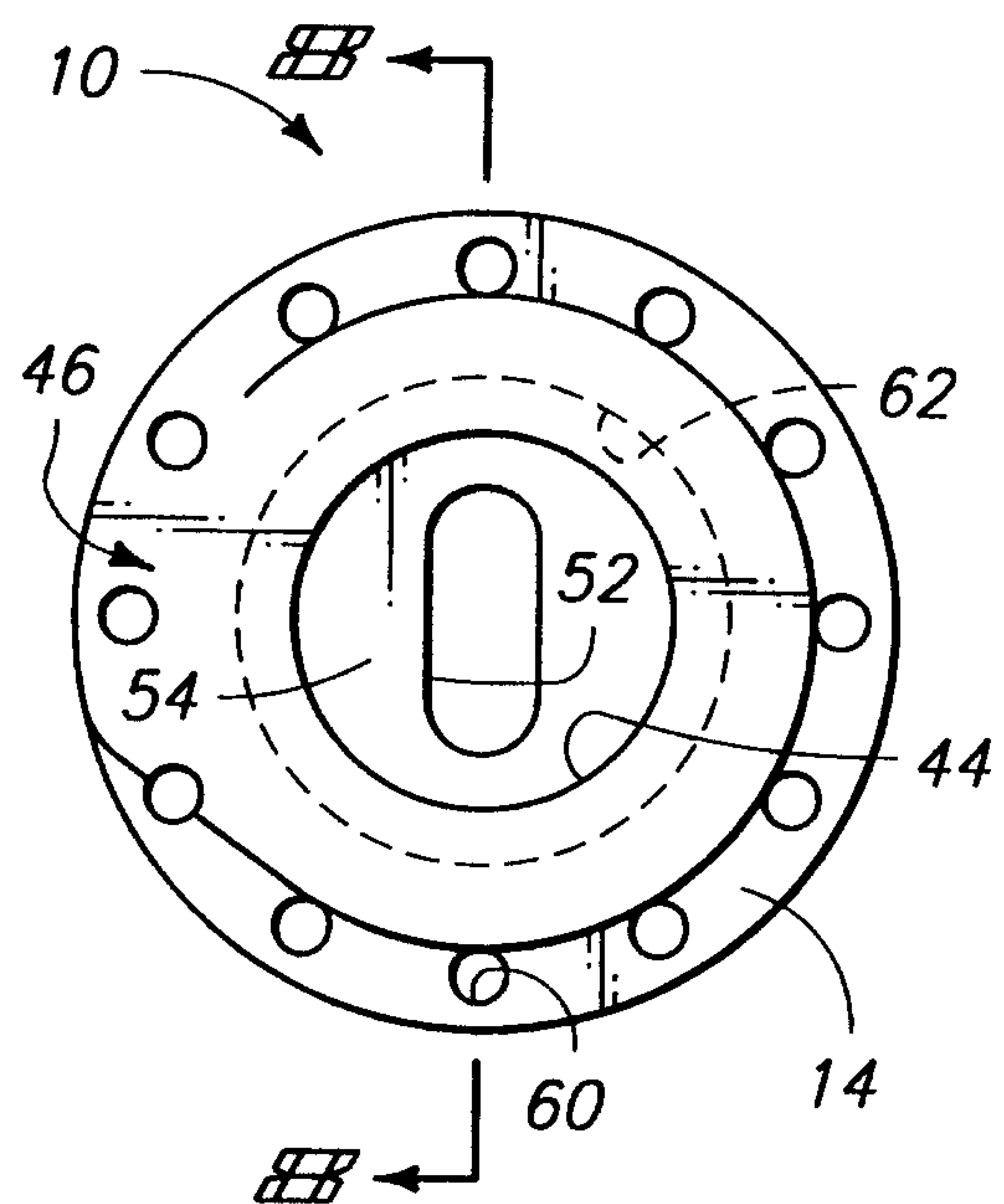
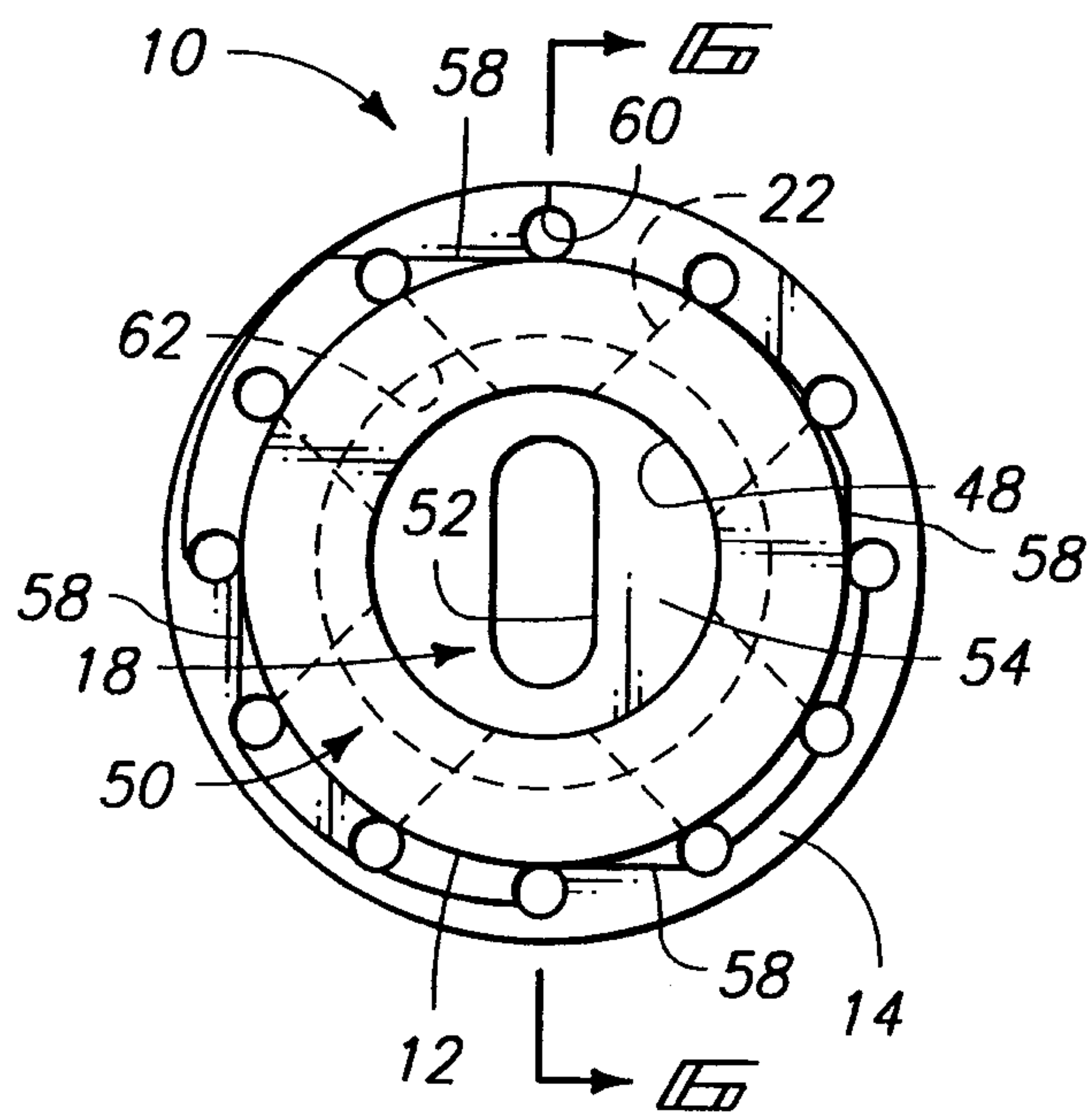
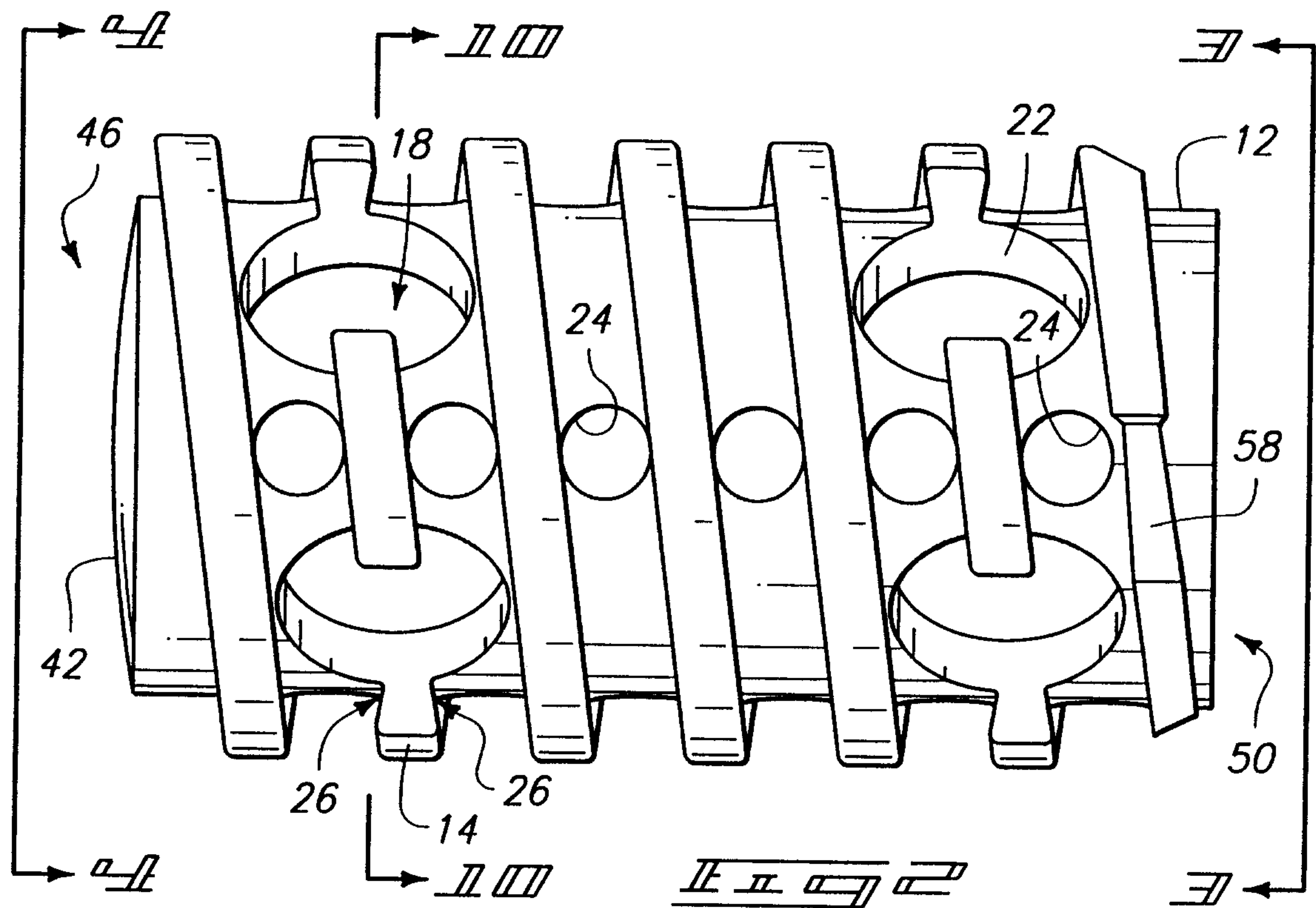
a tubular body having an outer dimension sized to be received between a pair of adjacent bone bodies to be joined and a thread extending about the body configured to engage in assembly with each adjacent bone body, the thread being undercut along a radial inner portion to engage with a correspondingly prepared bed in each bone.

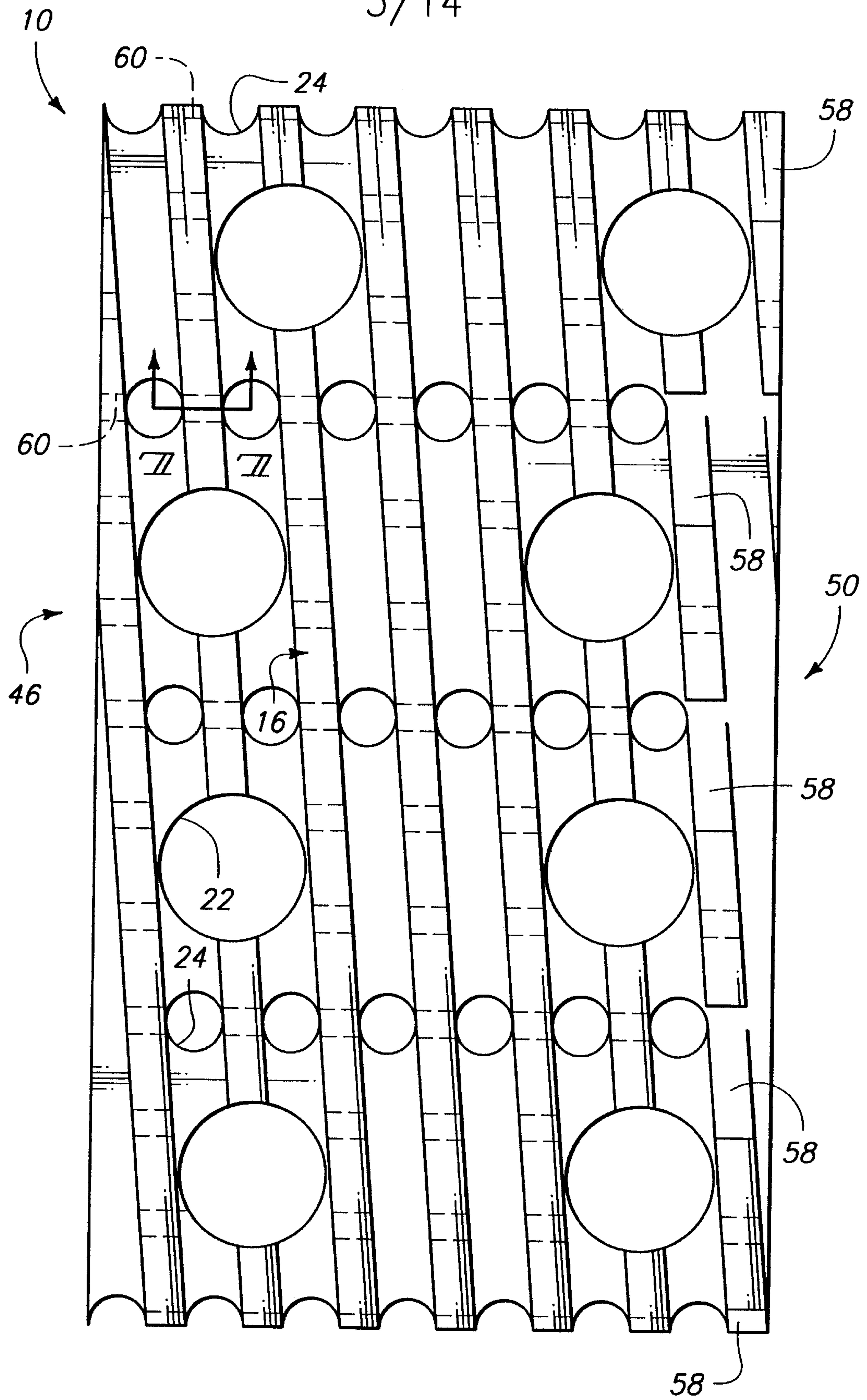
39. The bone joining member of claim 38 further comprising a through bore extending laterally of the thread, the bore configured to impart an undercut to the thread, and further provide for bone through-growth subsequent to implant.

40. The bone joining member of claim 38 wherein the thread comprises a pair of faces, at least one face having an undercut portion.

41. The bone joining member of claim 38 wherein the thread has a cross-sectional configuration with a radial outer portion having a dimension sized larger than a radial inner portion.







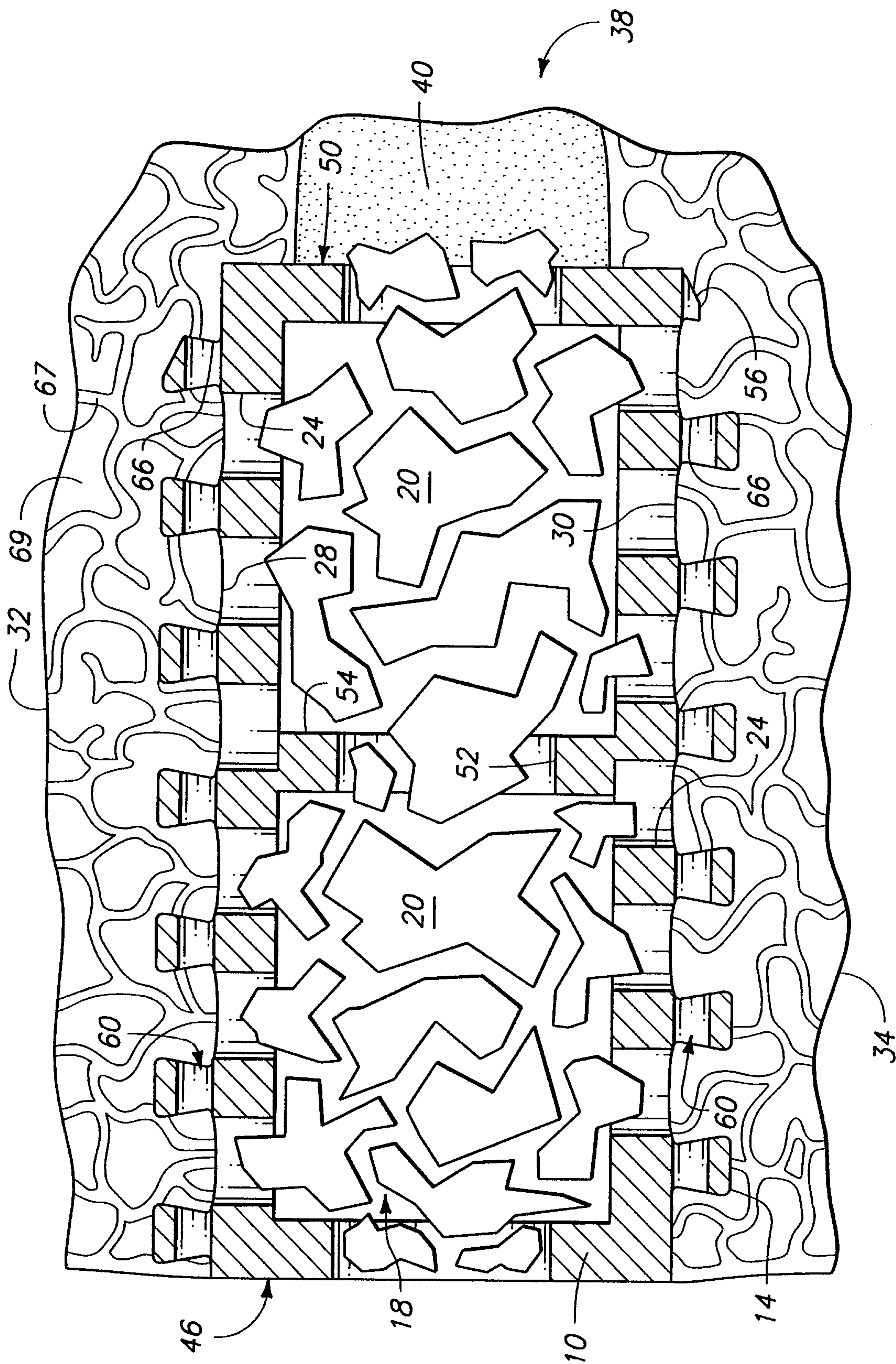
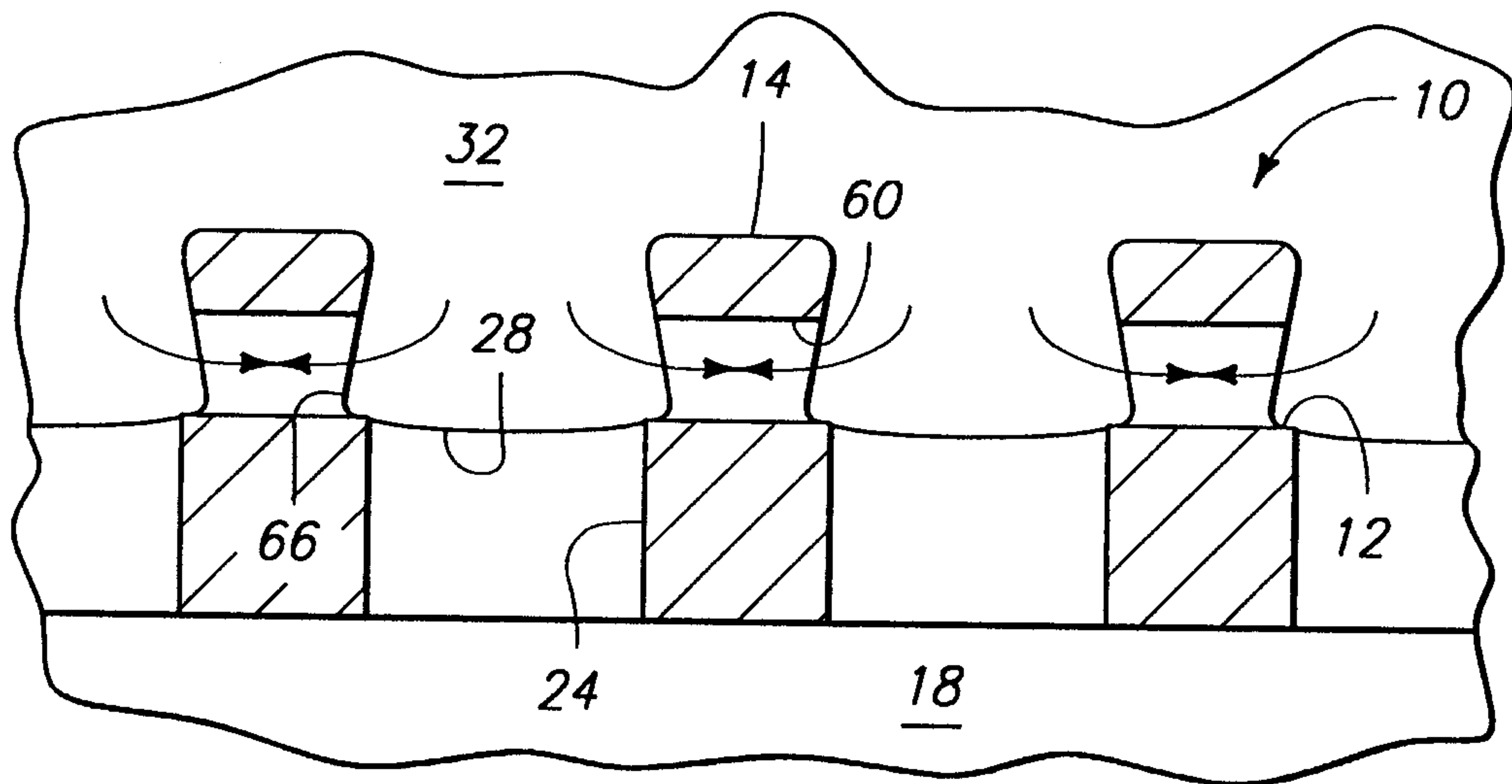
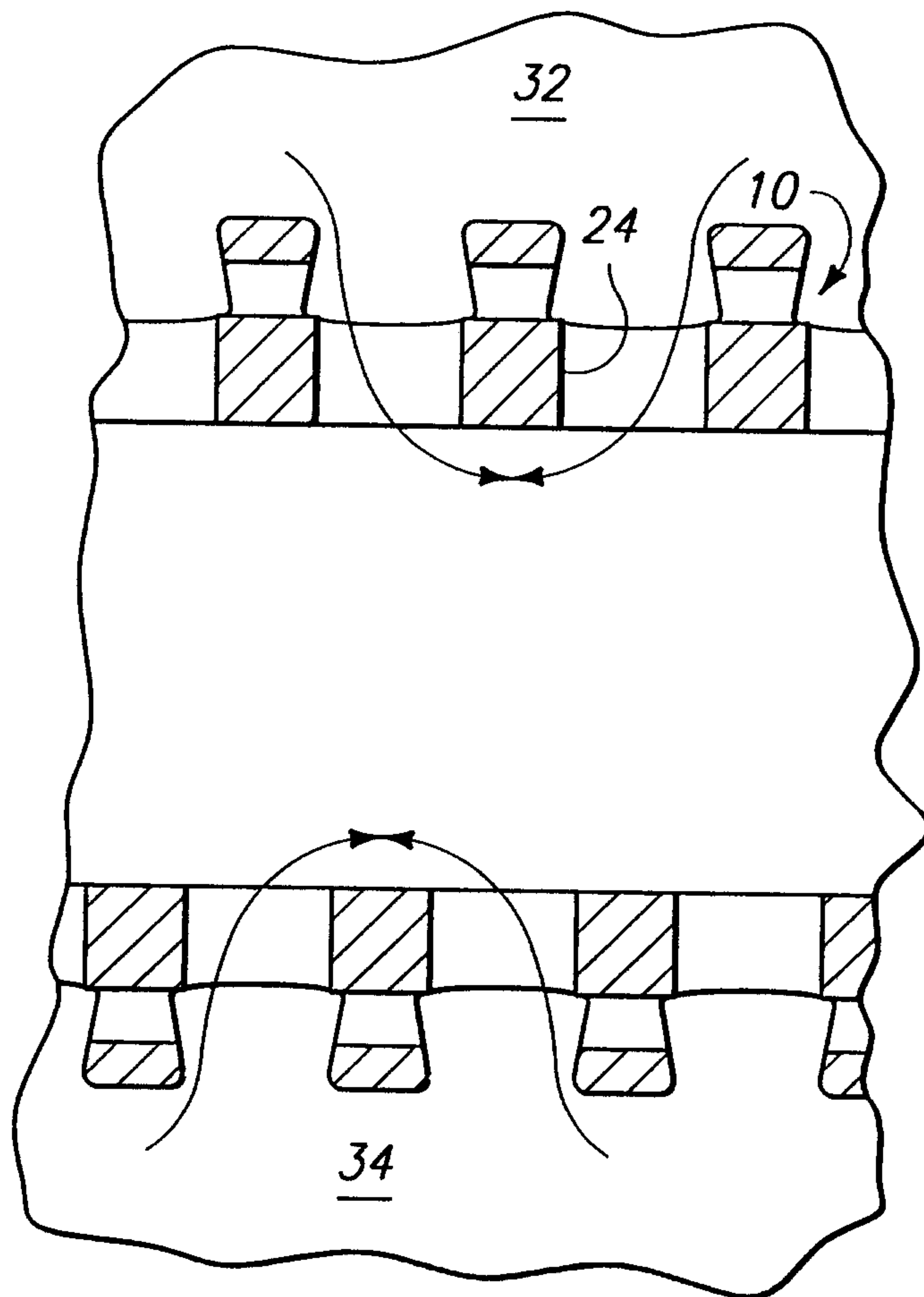


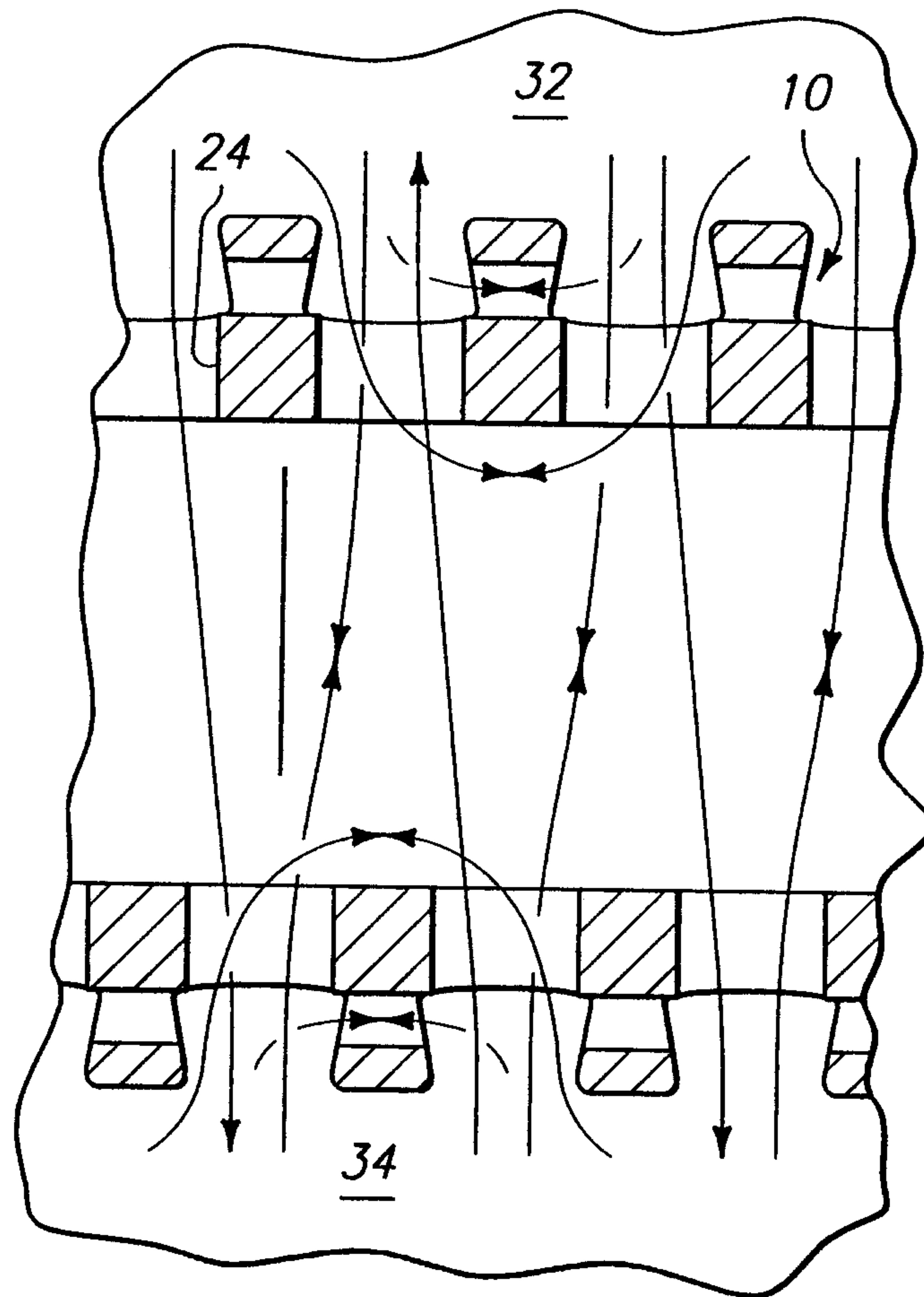
FIG. 4



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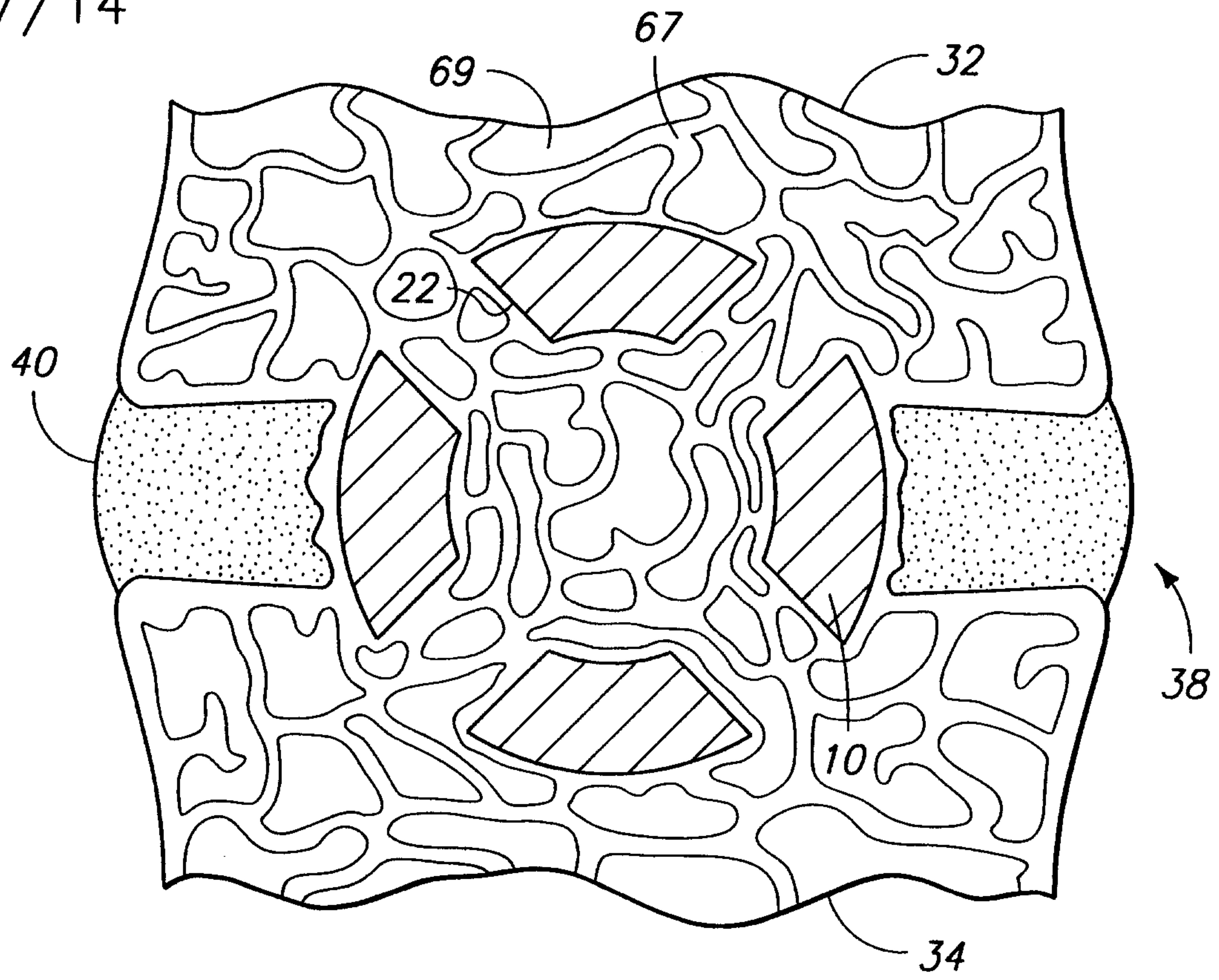


II II II II

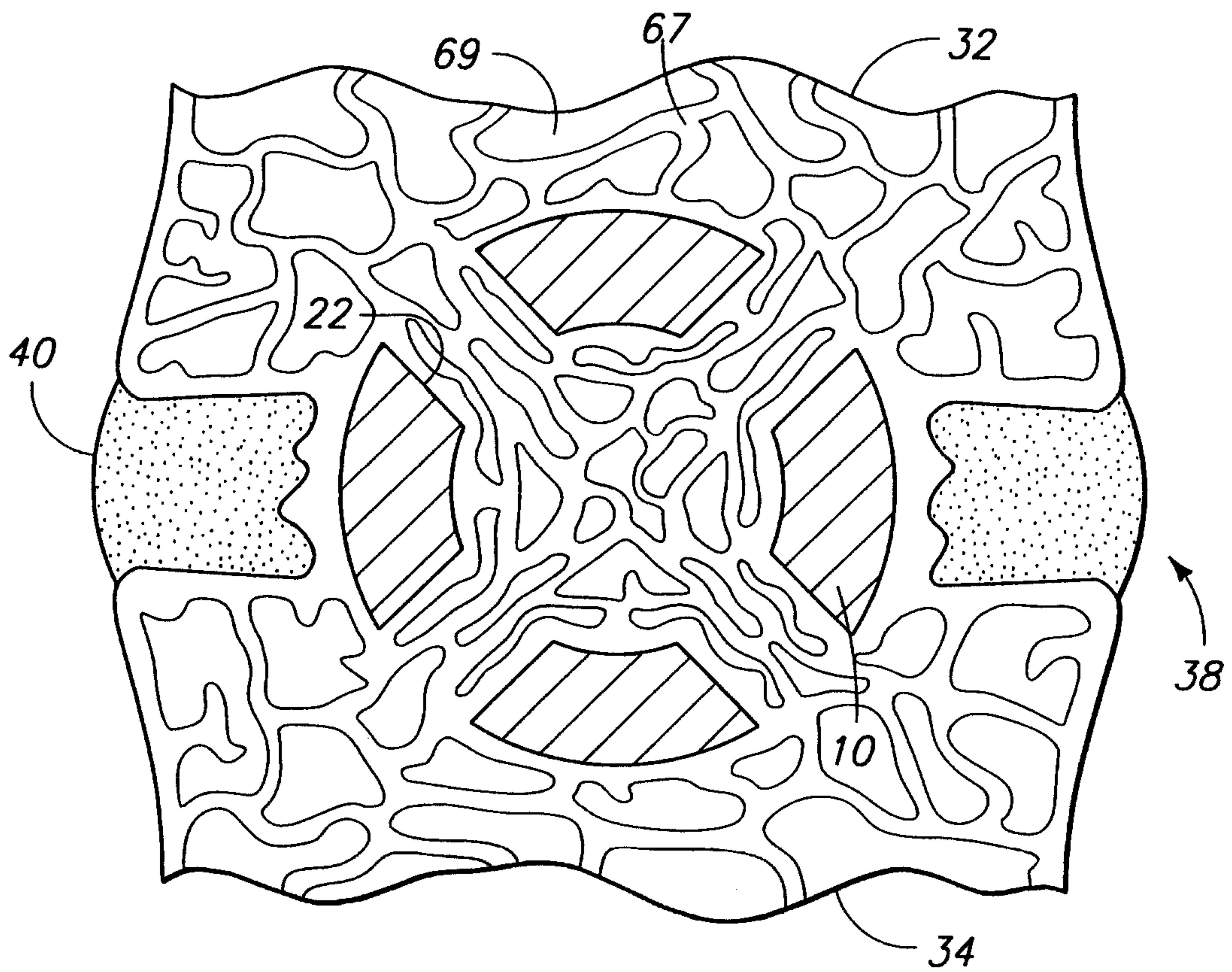


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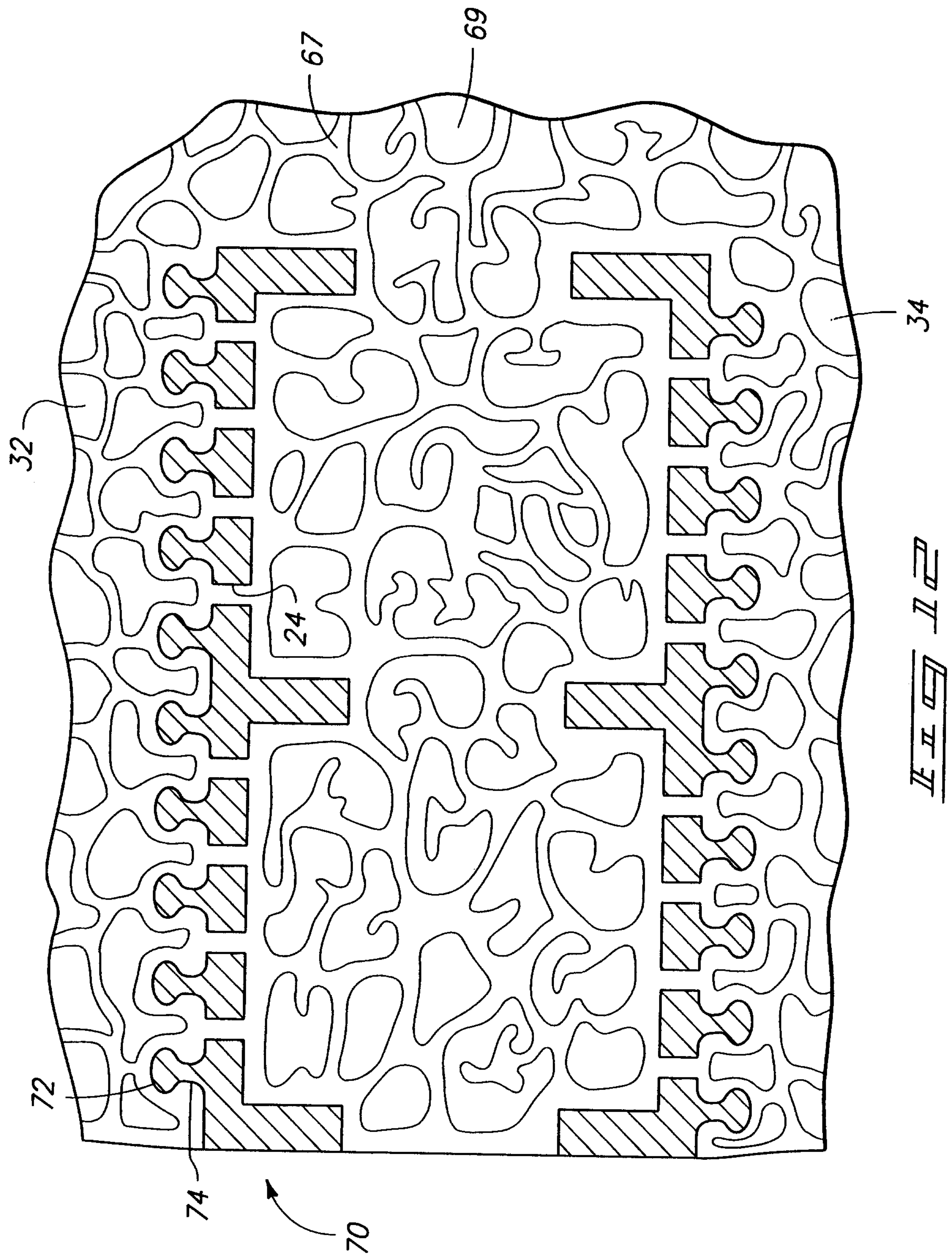
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II II II II II



II II II II II



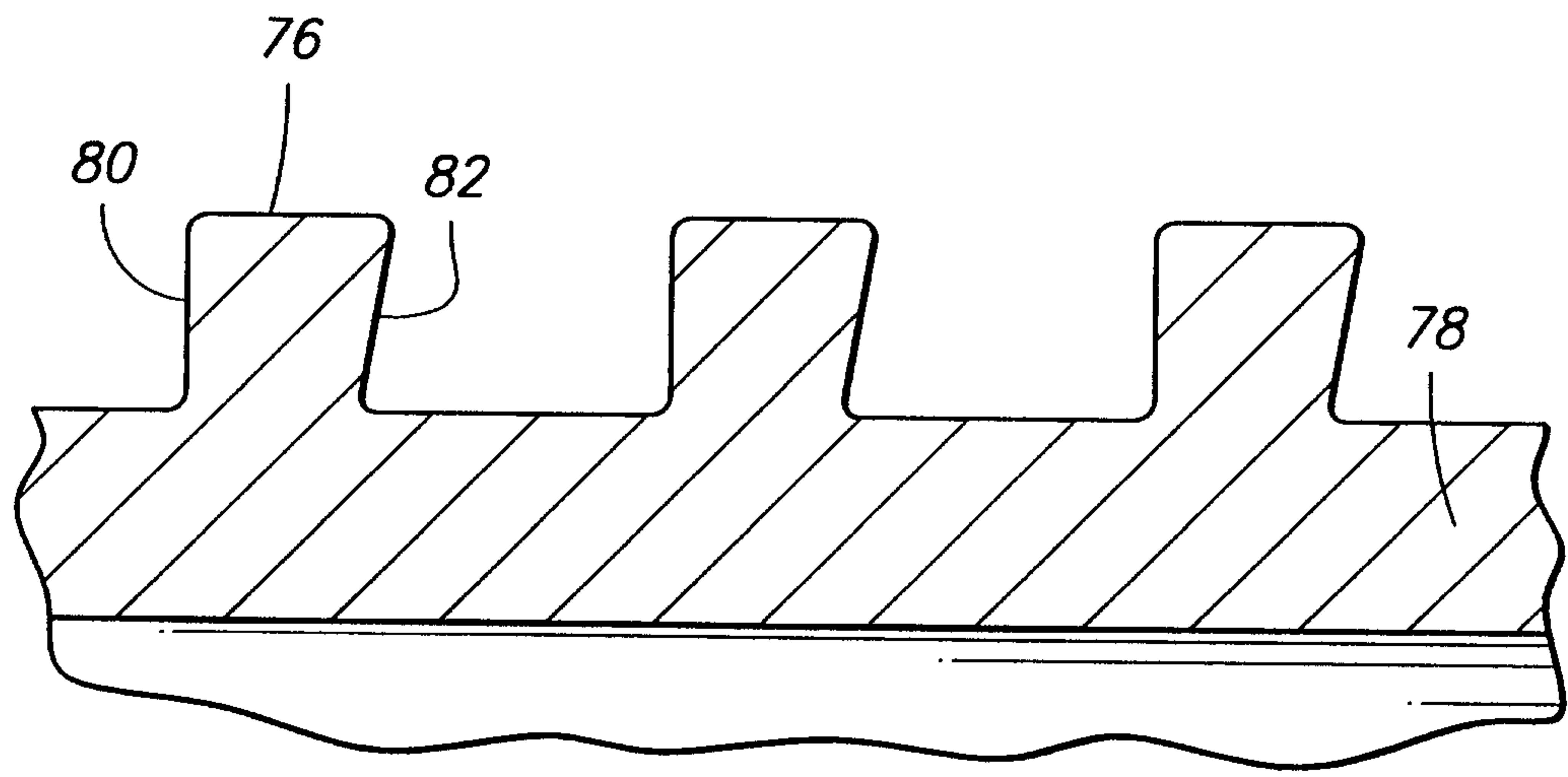


FIG. 1

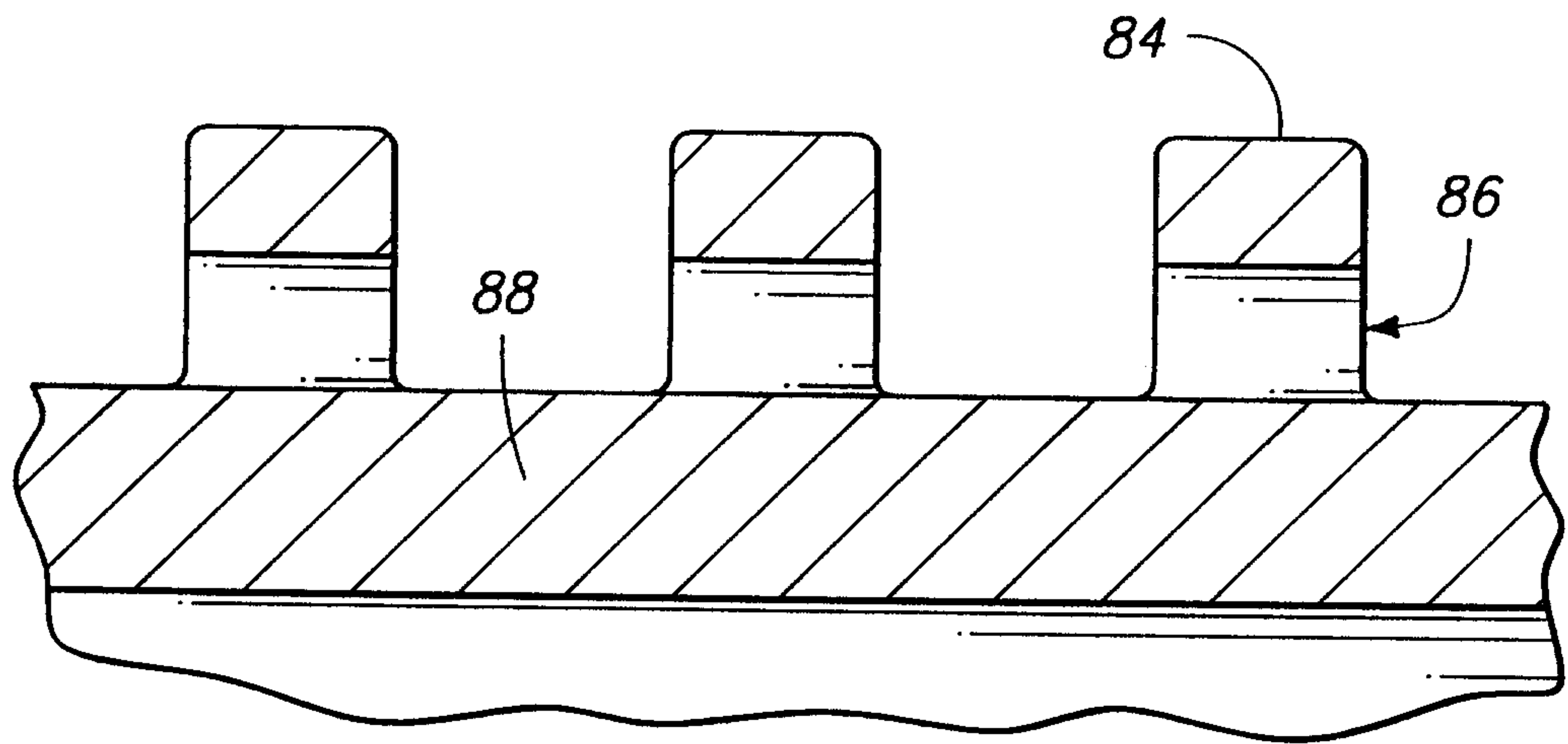


FIG. 2

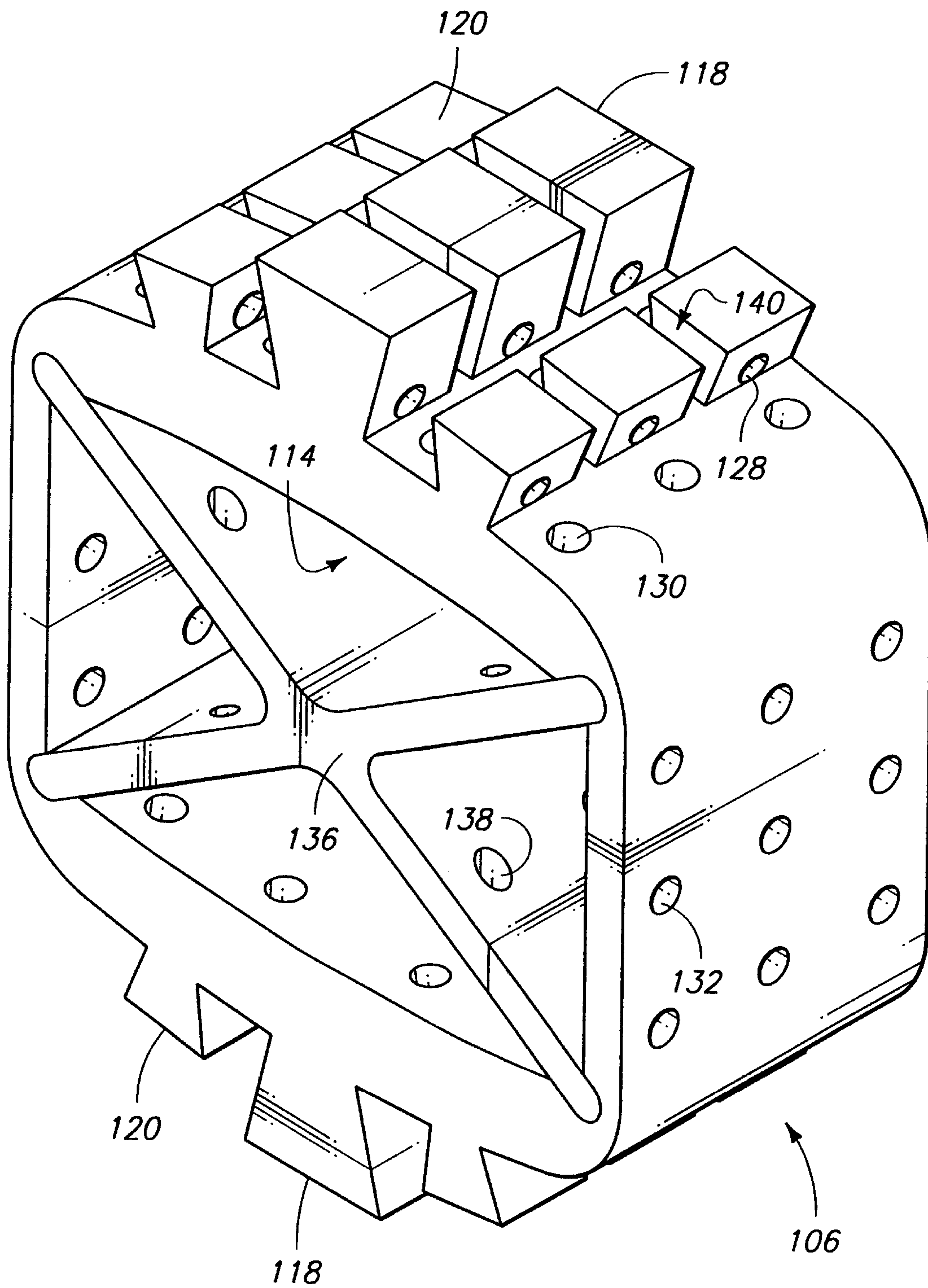


FIG. 15

