



US 20070079969A1

(19) **United States**(12) **Patent Application Publication**
Allenworth(10) **Pub. No.: US 2007/0079969 A1**(43) **Pub. Date: Apr. 12, 2007**(54) **SEGMENTED STEEL TUBE BUNDLE
TERMINATION ASSEMBLY****Related U.S. Application Data**(63) Continuation-in-part of application No. 11/244,465,
filed on Oct. 6, 2005.(75) Inventor: **David Carter Allenworth**, Pearland,
TX (US)**Publication Classification**(51) **Int. Cl.**
E21B 33/035 (2006.01)(52) **U.S. Cl.** **166/368**(57) **ABSTRACT**

A termination and anchorage for steel helical segmented steel tubing bundles includes a set of multiple separable anchor blocks to which the individual tubes in the bundle can be attached and a clamp assembly for securing and supporting the set of anchor blocks. Multiple comating annular arcuate outer anchor blocks for the outer tubes in the tubing bundle surround a central anchor block, for the center tube in the tubing bundle. The aggregation of anchor blocks is compactly assembled and held together by surrounding the assembled blocks with a separable clamp assembly.

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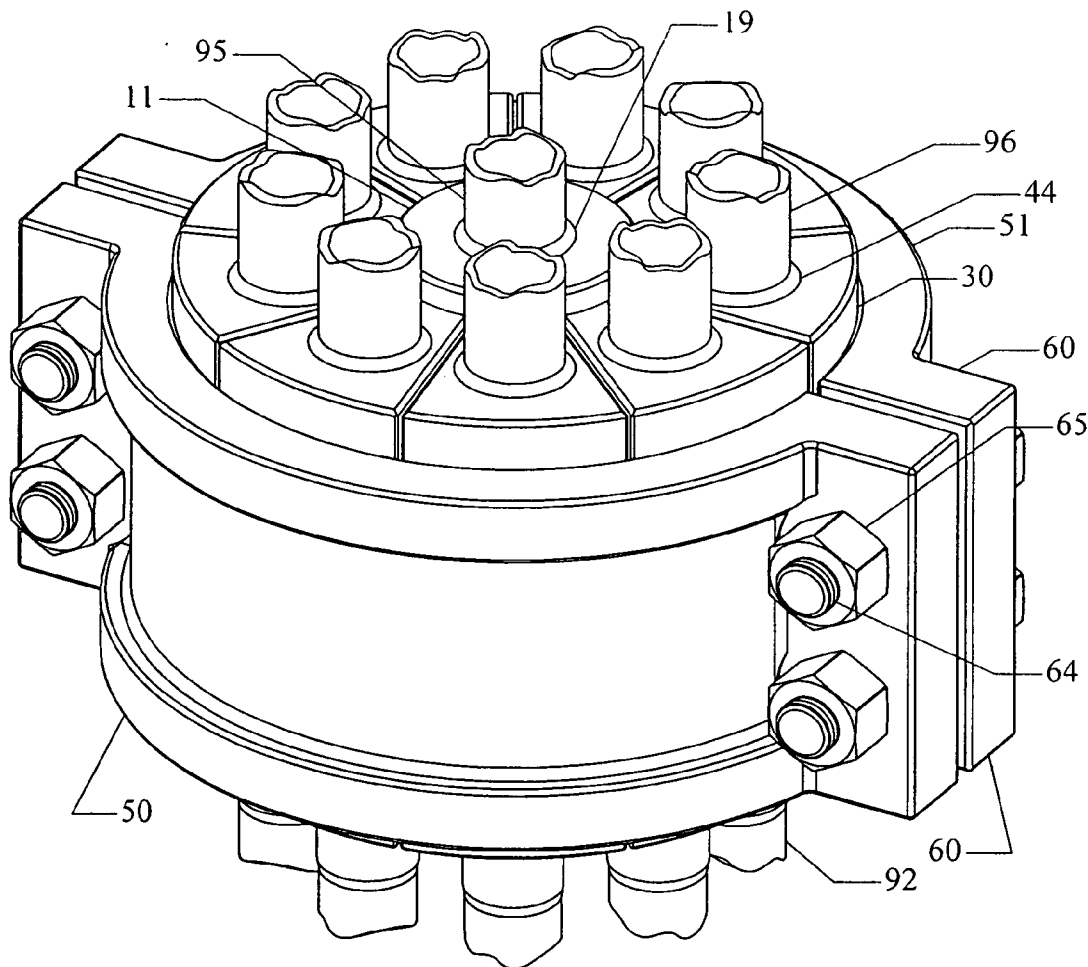
(73) Assignee: **Ocean Works International, Inc.**, Hous-
ton, TX(21) Appl. No.: **11/364,213**(22) Filed: **Feb. 28, 2006****10**

FIGURE 1

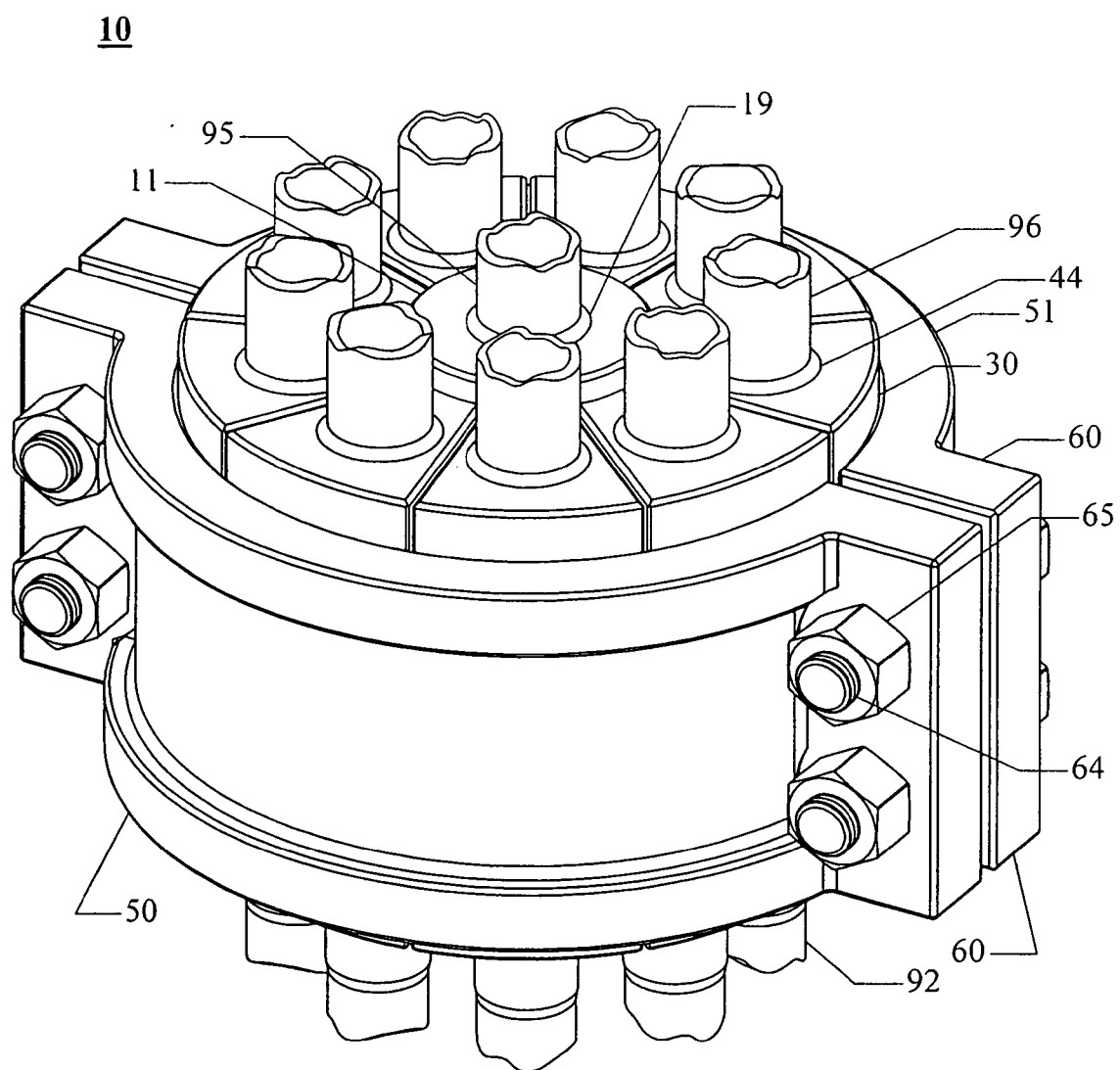


FIGURE 2

10

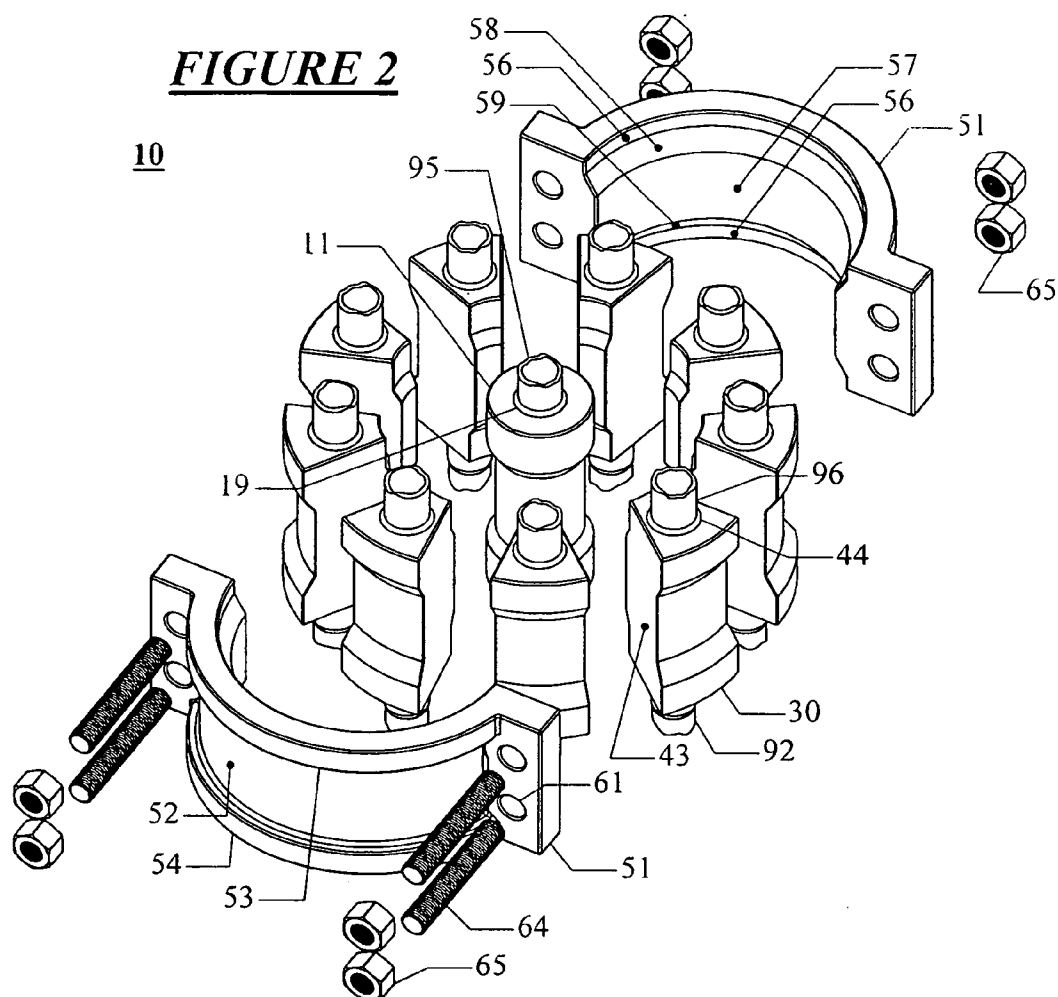


FIGURE 12

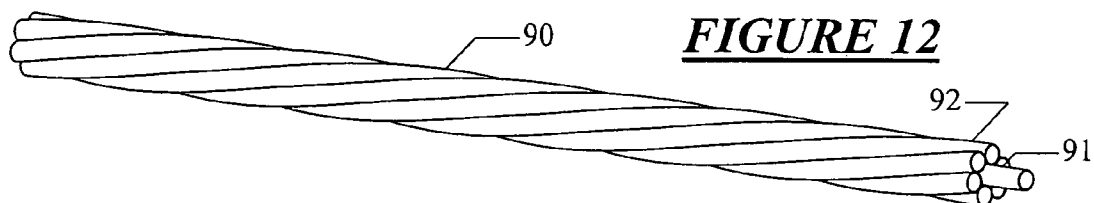


FIGURE 3

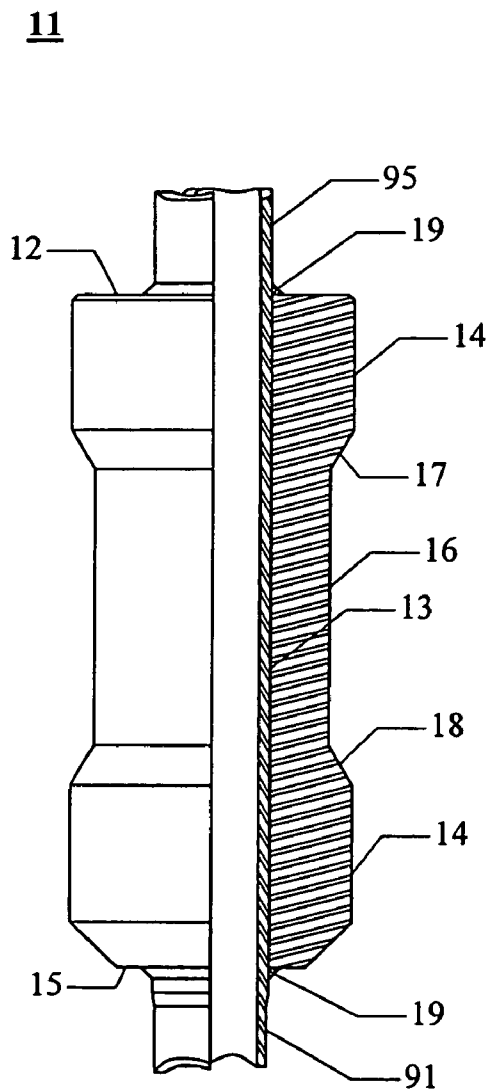
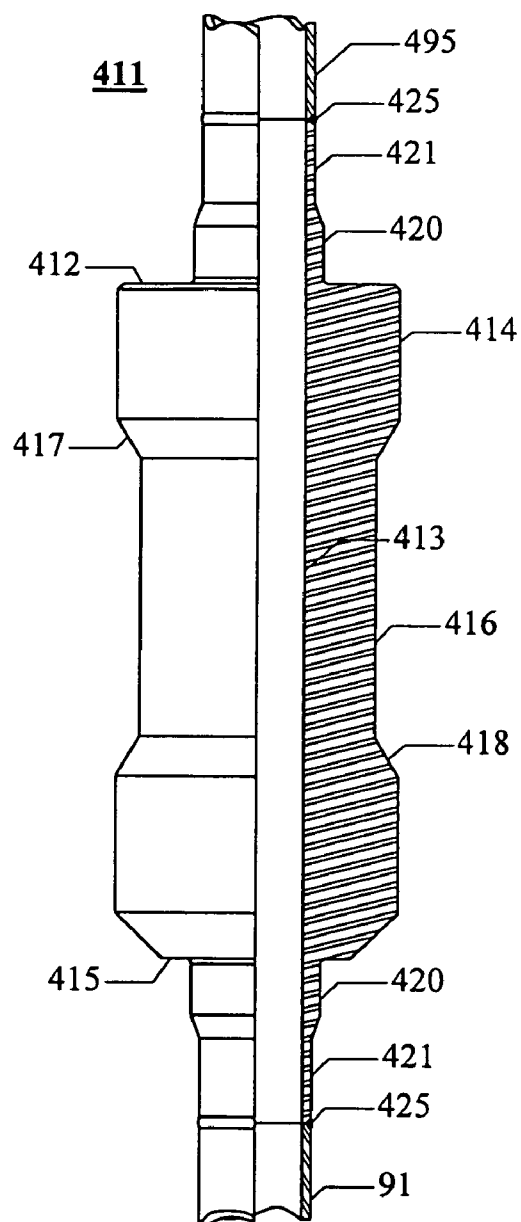


FIGURE 17



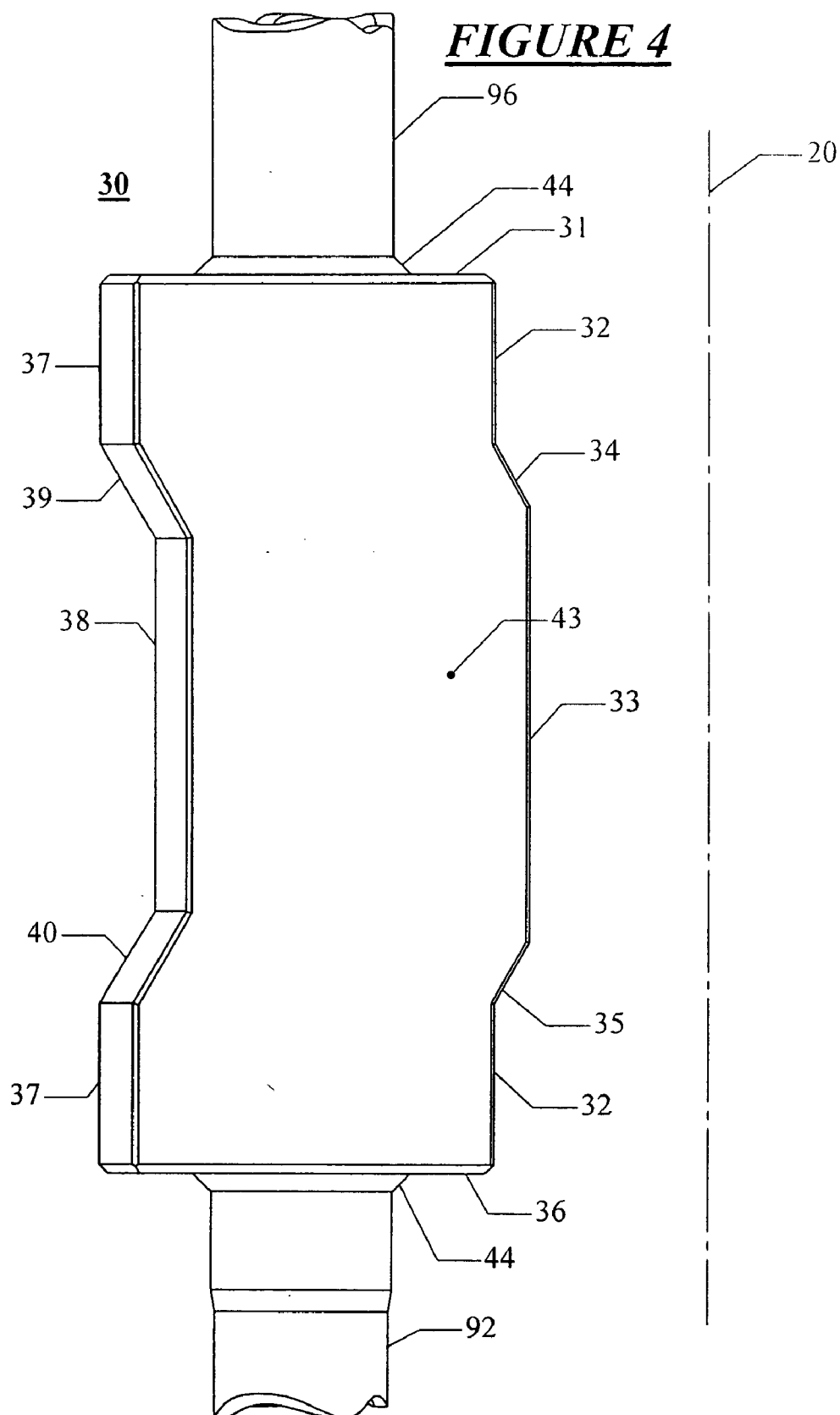
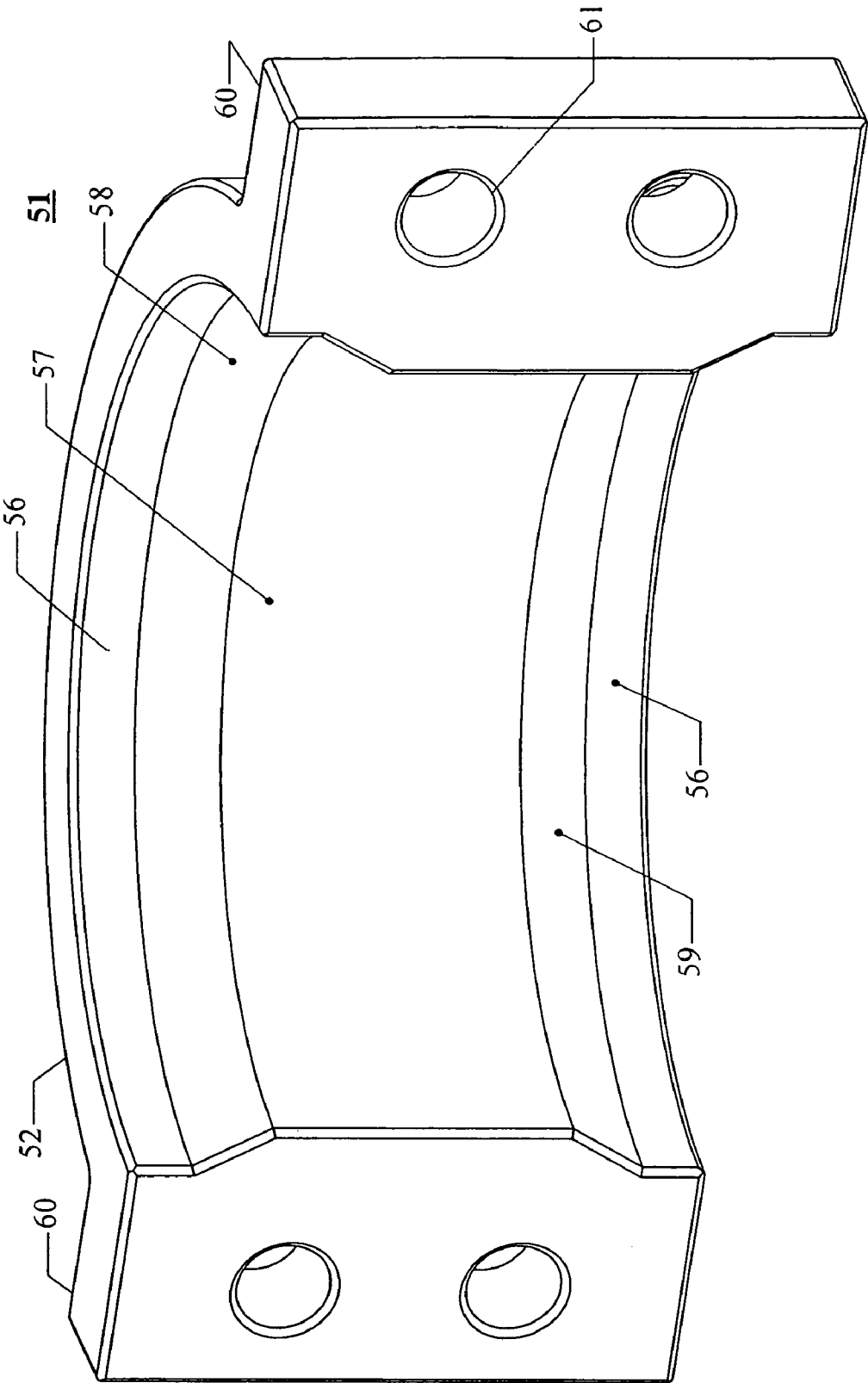
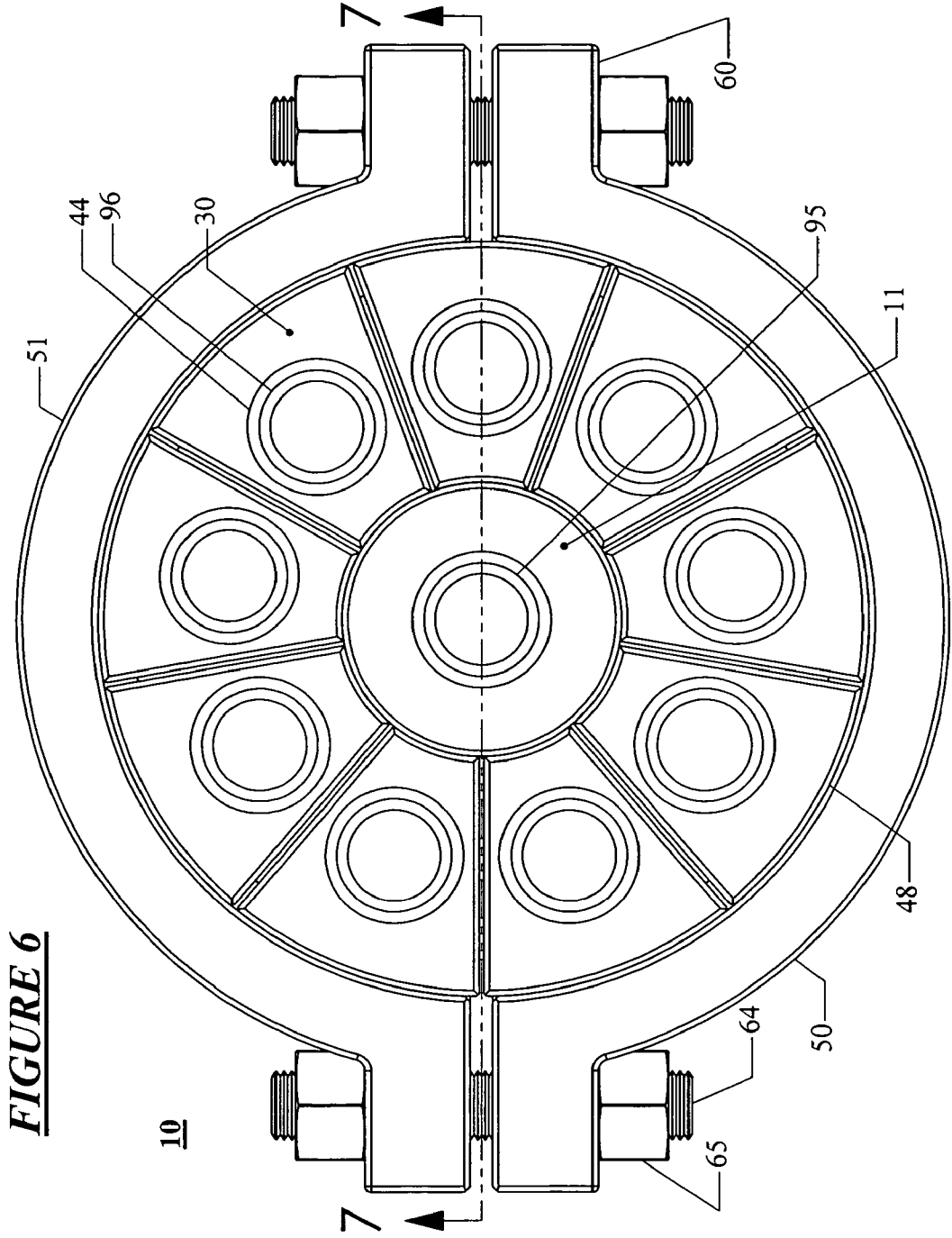


FIGURE 5





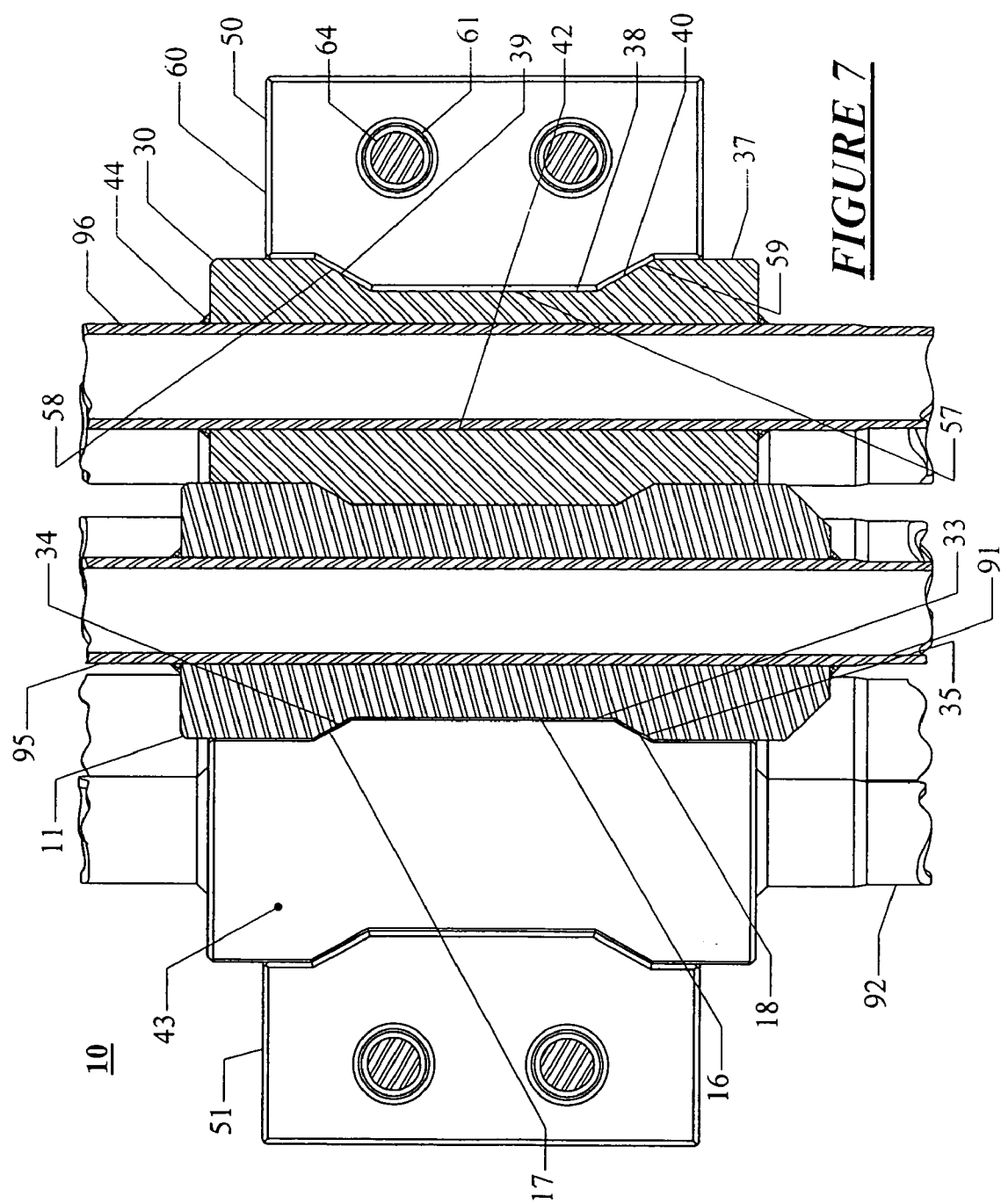


FIGURE 8

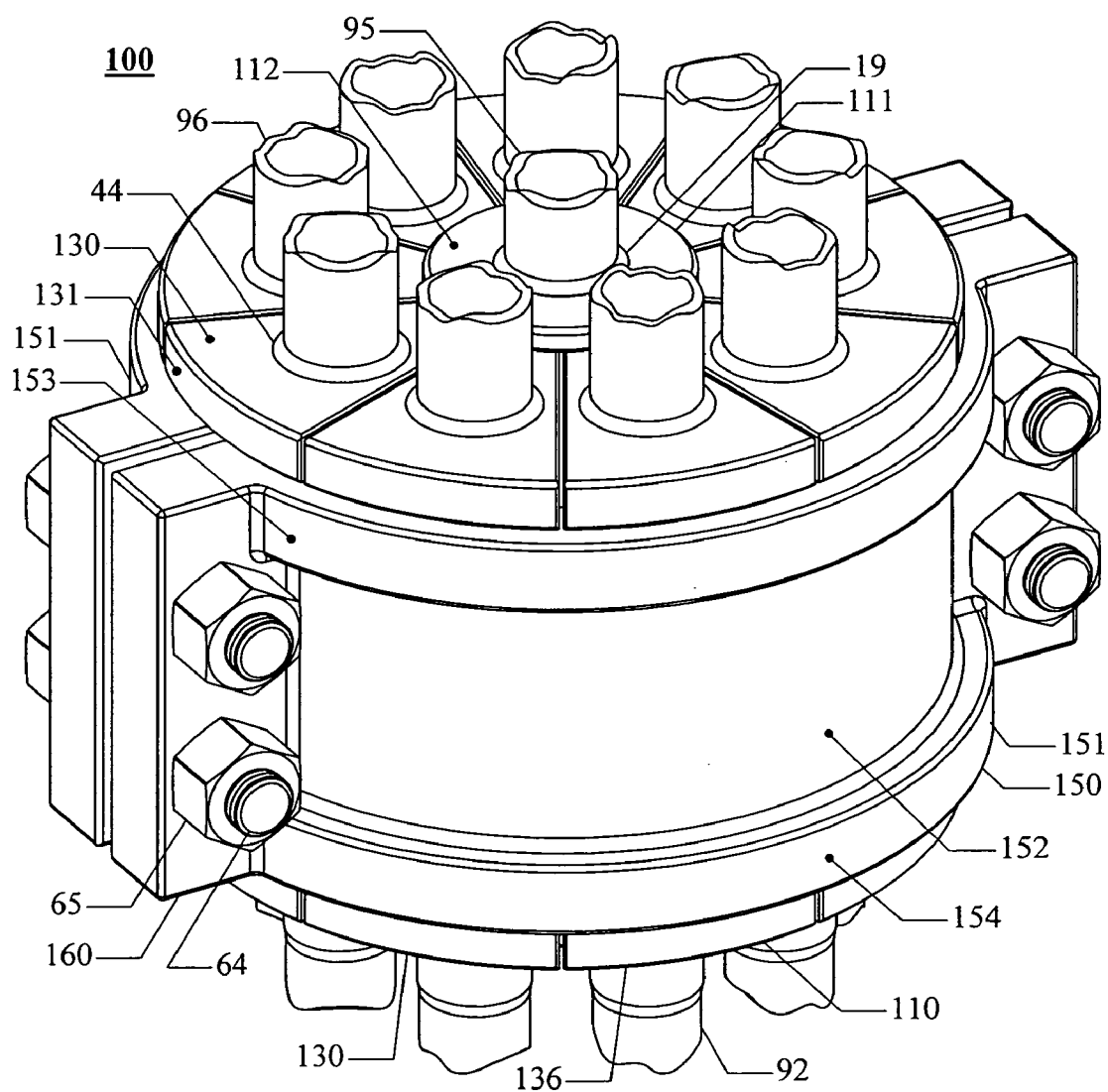
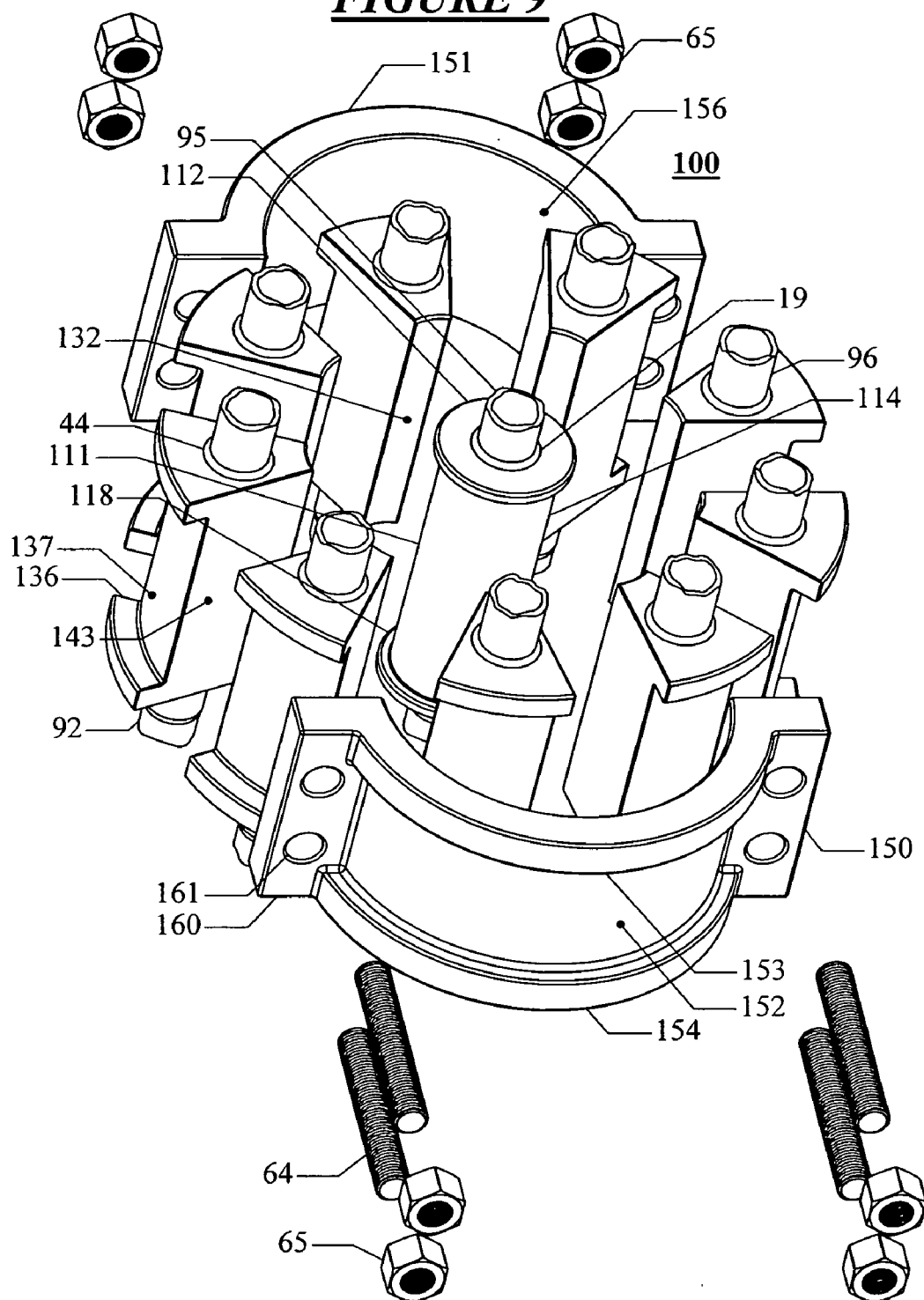


FIGURE 9



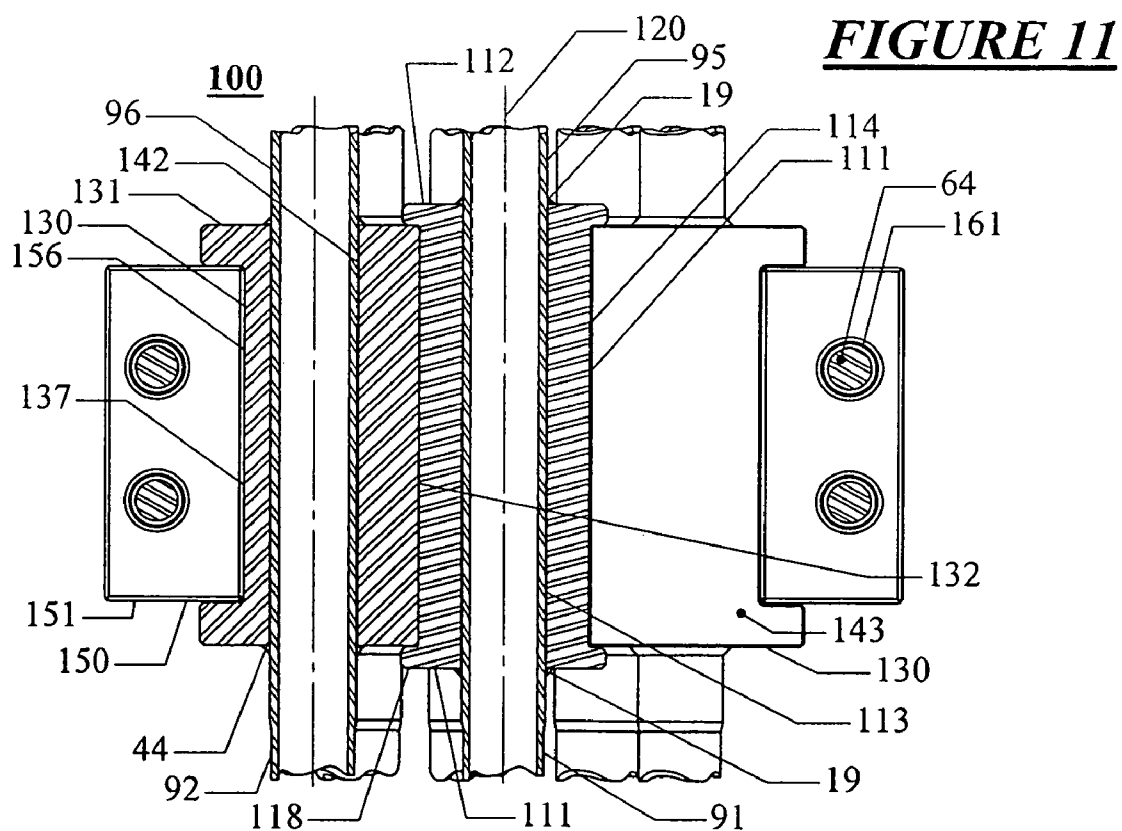
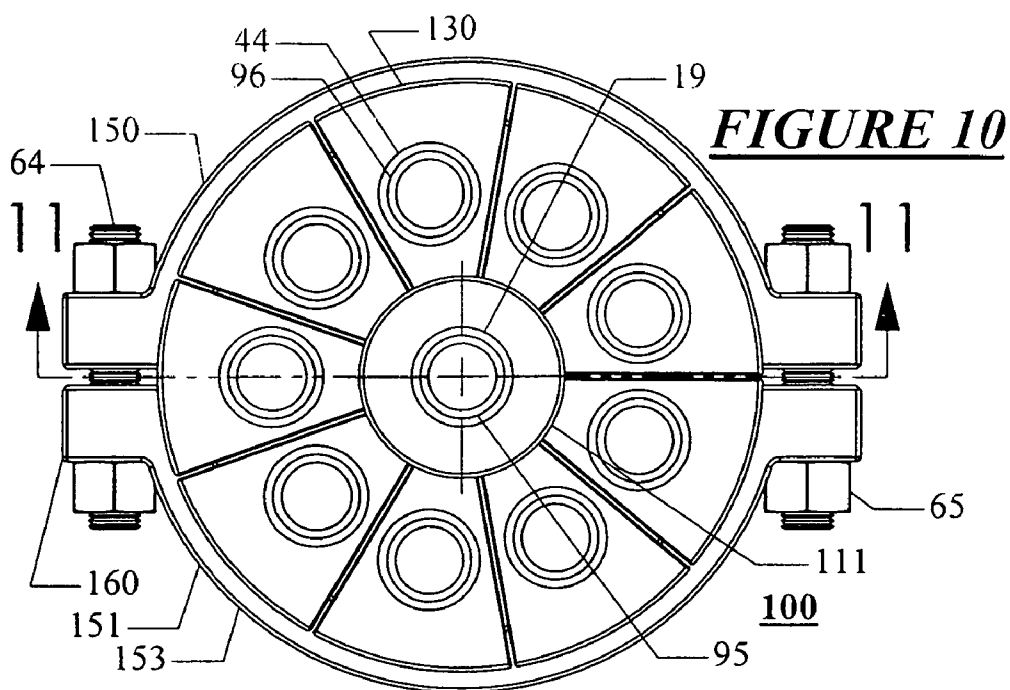
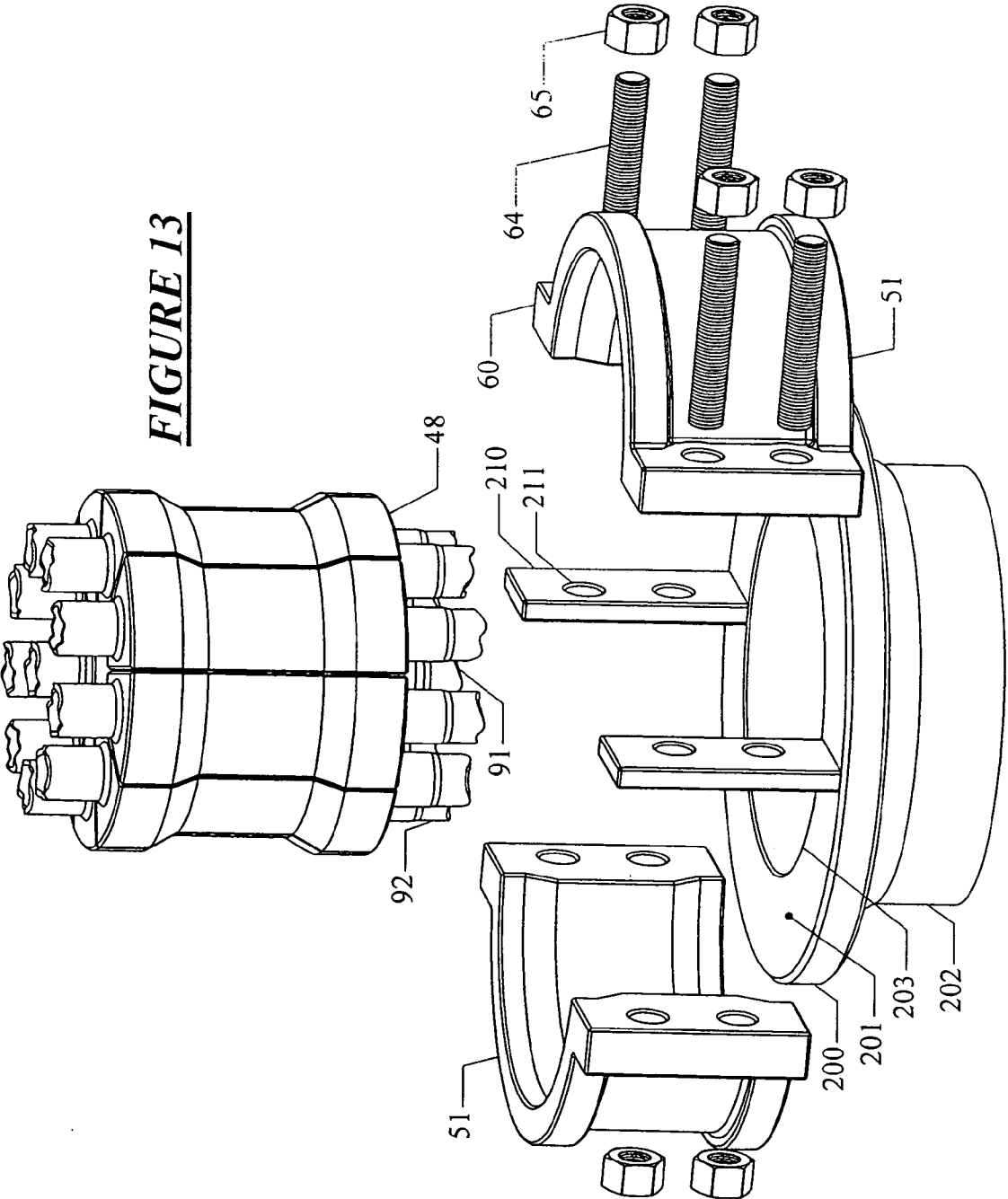
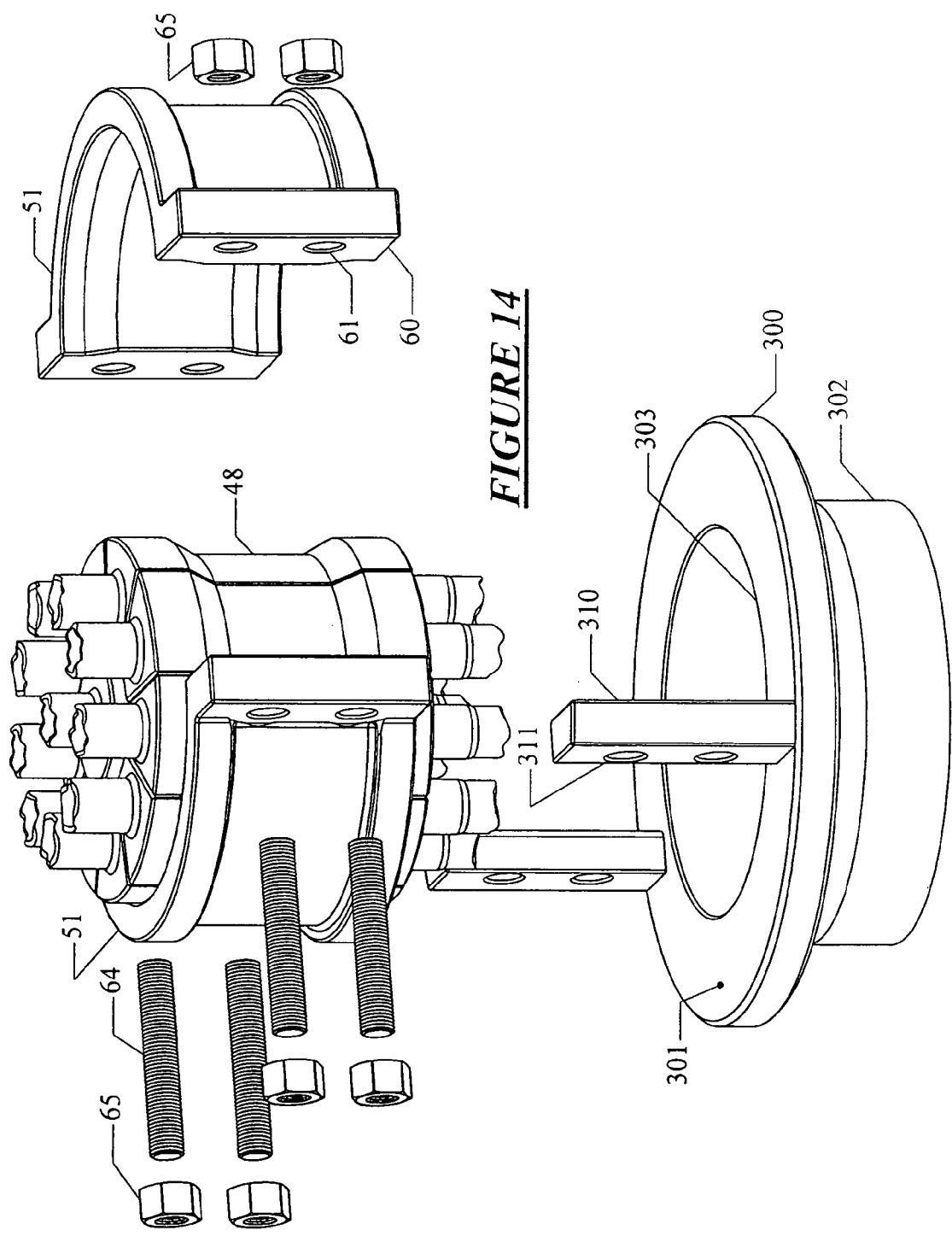
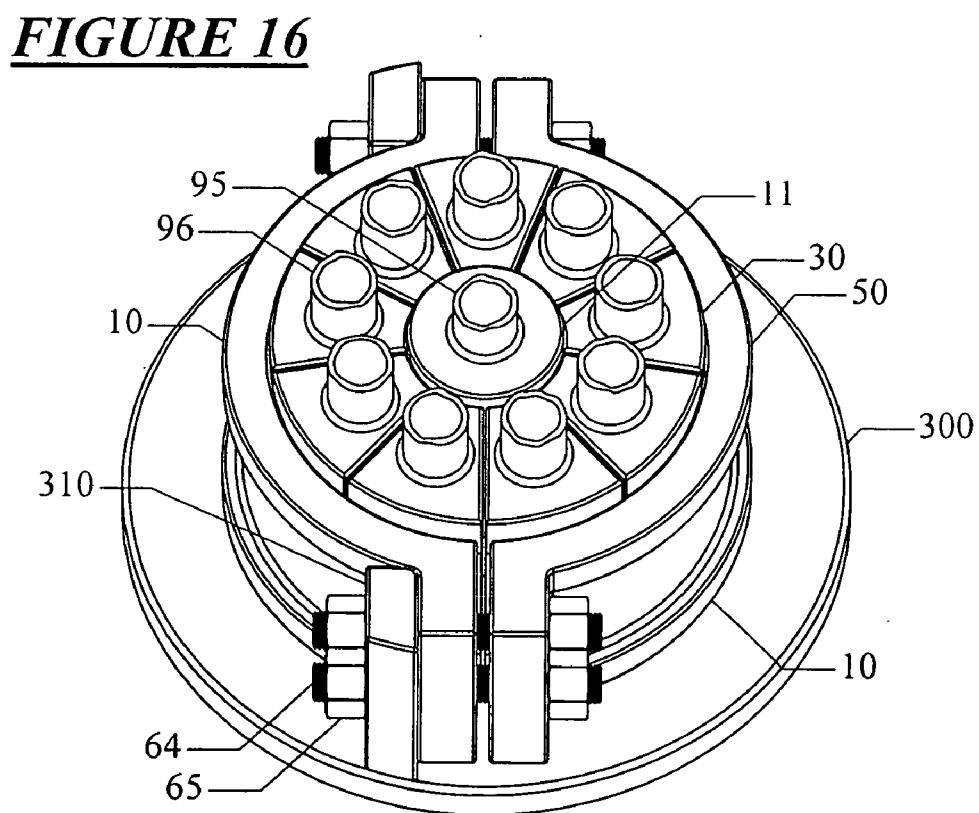
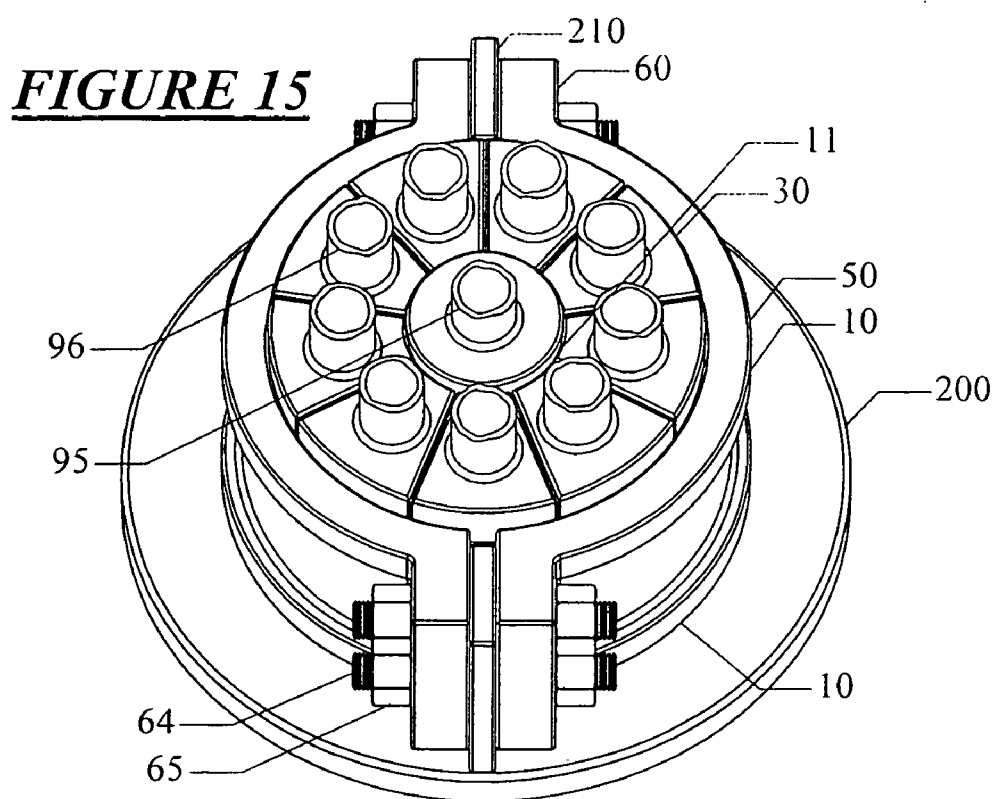


FIGURE 13







SEGMENTED STEEL TUBE BUNDLE TERMINATION ASSEMBLY

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation in part of pending U.S. patent application Ser. No. 11/244,465 (Attorney Docket Number OCEN-P002US), filed Oct. 6, 2005 by inventor David Carter Allensworth and entitled "Termination for Segmented Steel Tube Bundle."

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates in general to a method and apparatus for connectors for subsea operations. More particularly, the invention relates to the termination and axial anchorage of helical steel control tubing bundles used for control lines for subsea wellheads in petroleum production.

[0004] 2. Description of the Related Art

[0005] Helical tubing bundles composed of a multiplicity of steel tubes are used routinely for hydraulic control functions and to convey other fluids to subsea wellheads used in petroleum production. The individual tubes are maintained in constant relative angular positions and are arrayed in a bundle in a helical pattern about a central core tube without torsion in the manner used to lay a torsionally balanced wire cable or fiber rope. These relatively flexible tube bundles in some cases can be subjected to high tensions, particularly during their subsea installation.

[0006] Current means for terminating the ends of the tube bundles are bulky and heavy. Typically, the individual tubes at the end of a bundle are displaced somewhat from the bundle longitudinal axis in order to permit connections to anchorages and other fittings to be made. These currently used end terminations are difficult to assemble, particularly if the tubes are welded into an anchor fitting, since sufficient space between tubes must be provided for the welder to operate. Potted anchorages likewise tend to heavy and bulky.

[0007] There exists a need for an apparatus and method that permits an easily assembled anchorage for subsea tube bundles having high tensile capacity.

SUMMARY OF THE INVENTION

[0008] The present invention relates in general to a method and apparatus for connectors for subsea operations. More particularly, the invention relates to the termination and axial anchorage of helical steel control tubing bundles used for control lines for subsea wellheads in petroleum production.

[0009] The present invention provides a novel type of termination and anchorage for steel helical control tubing bundles. The present invention includes a set of multiple separable anchor blocks to which the individual tubes in the bundle can be attached and a clamp assembly for securing and supporting the set of anchor blocks.

[0010] One aspect of the present invention includes a subsea termination device for a helical tubing bundle comprising: a) a center anchor block attached to a center tube of

a tubing bundle; b) a plurality of outer anchor blocks surrounding the inner anchor block, each outer anchor block attached to an outer tube of the tubing bundle, wherein each outer anchor block has an interior surface abutting an outer surface of the center anchor block and an exterior surface; and c) a selectably removable clamp, wherein the clamp surrounds and engages the exterior surface of the outer anchor blocks.

[0011] Another aspect of the present invention is a termination device comprising: a) an anchor block assemblage having a center anchor block attached to a center tube of a tubing bundle, a plurality of outer anchor blocks surrounding the center anchor block wherein each outer anchor block has an interior surface comateable with an outer surface of the center anchor block; b) a ring clamp engageable around the anchor block assemblage to thereby rigidize the anchor block assemblage; and c) a retaining means for restraining the axial motion of the center and outer anchor blocks.

[0012] Yet another aspect of the present invention A termination device comprising: a) an anchor block assemblage having a center anchor block attached to a center tube of a tubing bundle, a plurality of outer anchor blocks surrounding the center anchor block wherein each outer anchor block has an interior surface comateable with an outer surface of the center anchor block; b) a ring clamp engageable around the anchor block assemblage to thereby rigidize the anchor block assemblage; and c) a retaining means for restraining the axial motion of the center and outer anchor blocks.

[0013] The foregoing has outlined rather broadly several aspects of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and the specific embodiment disclosed might be readily utilized as a basis for modifying or redesigning the structures for carrying out the same purposes as the invention. It should be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

[0015] FIG. 1 is an oblique view of the first embodiment of the tubing termination of the present invention, wherein a tubing bundle consisting of ten steel tubes is anchored. The tubing termination is shown from its first side which serves as the inlet/outlet end for the tubing bundle.

[0016] FIG. 2 is an exploded view of the tubing termination of FIG. 1.

[0017] FIG. 3 is a longitudinal quarter sectional view of the center tubing anchor block of the tubing termination of FIGS. 1 and 2.

[0018] FIG. 4 is a side profile view of an outer anchor block taken normal to a plane through the axis of symmetry of the tubing termination of FIGS. 1, 2, and 3.

[0019] FIG. 5 is an oblique profile view of a split clamp half for the tubing termination of FIG. 1.

[0020] FIG. 6 shows a plan view of the assembled tubing termination of FIG. 1.

[0021] FIG. 7 is a longitudinal section taken along section line 7-7 of FIG. 6 through the axis of symmetry of the first embodiment of the tubing termination.

[0022] FIG. 8 is an oblique view of a second embodiment of the tubing termination of the present invention.

[0023] FIG. 9 is an oblique exploded view of the tubing termination of FIG. 8.

[0024] FIG. 10 is a plan view of the tubing termination of FIGS. 8 and 9.

[0025] FIG. 11 is a longitudinal cross-sectional view of the second embodiment of the tubing termination taken along section line 11-11 of FIG. 10.

[0026] FIG. 12 is an oblique view of a typical helical tubing bundle consisting of seven equisized tubes.

[0027] FIG. 13 is a partially exploded view of the first embodiment of the tubing termination with a first type of mounting structure.

[0028] FIG. 14 is a partially exploded view of the first embodiment of the tubing termination with a second type of mounting structure.

[0029] FIG. 15 is an oblique view of the first embodiment of the tubing termination assembled with the first type of mounting structure shown in the exploded view of FIG. 13.

[0030] FIG. 16 is an oblique view of the first embodiment of the tubing termination assembled with the second type of mounting structure shown in the exploded view of FIG. 14.

[0031] FIG. 17 is a longitudinal quarter sectional view of an alternative center tubing anchor block and tube attachment means for use in the tubing termination of FIGS. 1 and 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0032] The present invention provides an apparatus and method that permits an easily assembled anchorage for subsea tube bundles having high tensile capacity.

[0033] The tubing terminations are intended for use with tubing bundles composed of a multiplicity of steel tubes, wherein the individual tubes are maintained in constant relative angular positions and are arrayed in a bundle in a helical pattern without torsion. In such a tubing bundle, a center tube serves as a core and multiple other tubes are arrayed around the central tube by bending. The tubes need not all be the same size, although for simplicity the tubes shown in the drawings are all the same size. Normally, the center tube is the largest of the tubes in the bundle. The tubes at an end of a section of a tubing bundle are terminated by means of the tubing terminations of the present invention. Connections are made by either mechanical means or by arc welding. However, in the drawings for the present invention, only welded connections between the bundle tubes and the terminations are shown.

[0034] The components of the main structural elements of the tubing termination embodiments of the present invention are typically made of carbon steel, high-strength/low-alloy steel, or stainless steel. A first embodiment 10 of the tubing termination is shown in FIGS. 1 to 7.

[0035] Referring to FIGS. 1 and 2, the tubing termination 10 is shown in an oblique view and an oblique exploded view. As shown in the drawings, the upper side of the termination corresponds to the inlet or outlet side for the anchored tube bundle, while the lower side is where the tubes of the bundle are attached by welding. Strictly for providing a representative example, the tubing bundle 90 in this case consists of ten equisized tubes, with a single center tube 91 and nine outer tubes 92. A greater or lesser number of tubes could be utilized, and the sizes can differ for the individual tubes in a particular bundle.

[0036] FIG. 12 shows a typical tubing bundle 90 with a straight core tube 91 and six helically spiraled tubes 92 closely arrayed around the core tube. For this tubing bundle 90 shown in FIG. 12, all seven tubes are of the same size.

[0037] The first embodiment of the tubing termination 10 includes a set of anchor blocks containing a single center anchor block 11 and multiple comating outer anchor blocks 30, as well as a split clamp assembly 50 which holds the assemblage 48 of anchor blocks together. The center anchor block 11 which supports the center tube 91 of the bundle is a right circular cylindrical tube having a transverse upper face 12, a coaxial right circular through hole 13, an outer cylindrical surface 14, and a transverse lower face 15. A large chamfer is positioned at the lower end of the anchor block 11 at the intersection of the outer cylindrical surface 14 and the lower transverse face 15. Centrally located in the middle of the outer cylindrical surface 14 is a right circular cylindrical coaxial reduced diameter central portion 16 of the center anchor block 11. The reduced diameter central portion 16 is connected to the upper and lower sections of the outer cylindrical surface 14 by upper frustoconical shoulder 17 and lower frustoconical shoulder 18, respectively. The frustoconical shoulder surfaces are inclined from the axis of the center anchor block 11 by similar angles in the range of 30° to 60°.

[0038] The inlet/outlet end 95 of the center tube 91 of the bundle 90 has a right circular cylindrical external upset having at its lower end a conical transition to the normal outer diameter of the center tube. The external upset diameter of the inlet/outlet end 95 is a slip fit to the through hole 13 of the center anchor block 11. The inlet/outlet end 95 is welded to each of the upper 12 and lower 15 transverse faces of the anchor block 11 by circumferential fillet welds 19. The inlet/outlet end 95 is attached to the center tube 91 by a circumferential butt or groove weld (not shown for clarity). Here, the other, upper side of the end 15 is identical to the lower side end and attachment by a circumferential butt or groove weld is made there to a tube of equal size to that of the center tube 91. Alternatively, either or both of the connections could be made by commercially available compressive tube fittings or to a socket weld fitting.

[0039] Each outer anchor block 30 is an arcuate segment of an annular right circular cylindrical having an upper transverse face 31, a right circular partial cylindrical inner face 32, a symmetrically positioned right circular through bore 42 parallel to the axis of anchor block 30, a lower

transverse face 36, and a right circular partial cylindrical outer face 37. The radius of the inner face 32 has the same radius as and is comatable with the outer cylindrical surface 14 of the center anchor block 11. Centrally located in the middle of the inner cylindrical surface 32 is a right circular cylindrical coaxial reduced diameter inner central section 33 of the outer anchor block 30. The reduced diameter central portion 33 is connected to the upper and lower sections of the inner cylindrical surface 32 by inner upper frustoconical shoulder 34 and inner lower frustoconical shoulder 35, respectively. The frustoconical shoulder surfaces 34 and 35 are inclined from the axis 20 of the outer anchor block 30 by the same angle as are the frustoconical shoulders 17 and 18 of the center anchor block 11 so that the shoulders 34 are comatable with the shoulder 17 and the shoulders 35 are comatable with the shoulder 18. The diameter of the reduced diameter central portion 33 is the same as or slightly larger than the diameter of the reduced diameter central portion 16 of the center anchor block 11 in order to permit the mating of the frustoconical faces. The outer anchor blocks 30 are able to mate with the center anchor block 11 so that the inner cylindrical surfaces 32 of the outer anchor blocks abut the outer cylindrical surface 14 of the center anchor block.

[0040] Centrally located in the middle of the outer cylindrical surface 37 of the outer anchor block 30 is a right circular cylindrical coaxial reduced diameter central portion 38. The reduced diameter central portion 38 is connected to the upper and lower sections of the outer cylindrical surface 37 by outer upper frustoconical shoulder 39 and outer lower frustoconical shoulder 40, respectively. The frustoconical shoulder surfaces are inclined from the axis 20 of the outer anchor block 30 by similar angles in the range of 30° to 60°.

[0041] As shown here, all of the outer anchor blocks 30 are the same since the outer tubes 92 of the bundle 90 all have the same size. The planar lateral sides 43 of outer anchor block 30 can be coplanar with the axis of rotation 20 of the block and of the overall anchor block assemblage 48. Alternatively, as shown herein, the individual outer anchor blocks 30 can be made by cutting a solid annular ring with radial saw cuts which have a finite kerf width. The number of outer anchor blocks 30 corresponds to the number of outer tubes 92 in the tubing bundle 90.

[0042] The inlet/outlet end 96 for the attached outer bundle tube 92 supported by outer anchor block 30 is structurally identical to the inlet/outlet end 95 for the center tube 91. The connections of the inlet/outlet end 96 to the tube 92 and the tube on the opposed end are typically made by circumferential butt or groove welds (not shown herein for clarity). The inlet/outlet end 96 has a close slip fit to the through bore 42 and is attached to the upper 31 and lower 36 transverse faces of the anchor block 30 by circumferential fillet welds 44. Again, either or both of the connections alternatively could be made by commercially available compressive tube fittings or socket weld fittings.

[0043] The split clamp assembly 50 consists of a pair of clamp halves 51 and the clamp studs 64 with clamp nuts 65 required to draw the clamp halves together. Sufficient space is provided between the clamp halves 51 so that they do not abut prior to fully clamping together the assemblage 48 of anchor blocks 11 and 30. The split clamp assembly 50 surrounds and retains the anchor block assemblage 48 consisting of the center anchor block 11 and its surrounding

set of outer anchor blocks 30. The clamp halves 51 each have a right circular nearly semicylindrical annular body 52 with its diameters greater than its axial length. At the upper transverse side of each clamp half, an outwardly extending nearly semiannular transverse upper reinforcing flange 53 is located, with a mirror image transverse lower reinforcing flange 54 located at the lower transverse side.

[0044] For the first embodiment of the tubing termination 10, the inner side of a clamp half 51 has an inner nearly semicylindrical face 56 with a symmetrically positioned inner reduced diameter semicylindrical face 57 at its mid-height. Mirror-image frustoconical shoulders 58 and 59 cojoin the two nearly semicylindrical faces 56 and 57. The inner nearly semicylindrical face 57 is a close fit to the outer cylindrical surface sections 37 of the assembled group of outer anchor blocks 30. The upper frustoconical shoulder 58 of the clamp half 51 has the same slope as the outer upper frustoconical shoulder 39 of the outer anchor blocks 30 so that the two shoulders are comatable. Likewise, the lower frustoconical shoulder 59 of the clamp half 51 is similarly comatable with the outer lower frustoconical shoulder 40 of the outer anchor blocks 30. The inner reduced diameter semicylindrical face 57 of the clamp half has a diameter equal to or greater than the diameter of the outer reduced diameter central section 38 of the outer anchor blocks 30.

[0045] Extending outwardly parallel to and slightly offset from the diametrical plane perpendicular to the vertical plane of symmetry for each clamp half 51 on each side are thick rectangular clamping ears 60. On each clamping ear 60, two through clamping bolt holes 61 are drilled horizontally perpendicular to the inner face of the clamping ears and placed symmetrically about the horizontal midplane of the clamp half. When the clamp halves 51 are assembled around the anchor blocks 11 and 30, the clamp studs 64 are extended through the clamping bolt holes 61 and then clamp nuts 65 are used to draw the clamp halves together so that the tubing termination 10 is rigidized. At assembly, the upper 17 and lower 18 frustoconical shoulders of the center anchor block 11 respectively can bear on the comatable inner upper 34 and inner lower 35 frustoconical shoulders of the outer anchor blocks 30. At the same time, the outer upper 39 and outer lower 40 frustoconical shoulders of the outer anchor blocks 30 respectively can bear against the inner upper 57 and lower 58 frustoconical shoulders of the clamp halves 51 of the assembled split clamp assembly 50.

[0046] The second embodiment tubing termination 100, shown in FIGS. 8 through 11, is in most respects very similar to the first embodiment 10. The difference resides in the approaches to retaining the tube bundle 90 and its attached assemblage 110 of one inner 111 and the outer 130 anchor blocks in the split clamp assembly 150 whenever there is an compressive thrust on the tube bundle. In the case of tubing termination 100, the anchor blocks 111 and 130 are both restrained in axial motion in either direction by flanges on both ends of the anchor blocks.

[0047] Referring particularly to FIGS. 9 and 11, tubing termination 100 is seen to consist of a set of comating anchor blocks 111 and 130, as well as a split clamp assembly 150 that holds the anchor blocks together. The split clamp assembly is the same in most details as is used for the first embodiment 10. The center anchor block 111 supports the center tube 91 of the tube bundle 90. The center anchor

block **111** is a right circular cylinder having a transverse upper flange **112**, a coaxial right circular through hole **113**, and a transverse lower flange **118** which is a mirror image of the upper flange **112**. The outer cylindrical surface **114** of the center anchor block **111** is comateable with the outer anchor blocks **130** that support the outer tubes **92** in the tube bundle **90**.

[0048] The inlet/outlet end **95** of the center tube **91** of the bundle **90** has a right circular cylindrical external upset having at its lower end a conical transition to the normal outer diameter of the center tube. The external upset diameter is a slip fit to the through hole **113** of the center anchor block **111**. Here, the bore of the inlet/outlet end **95** matches the bore of the center tube **91**. The inlet/outlet end **95** is welded to each of the upper and lower transverse ends of the anchor block **111** by circumferential fillet welds **19**. The inlet/outlet end **95** is attached to the center tube **91** by a circumferential butt or groove weld (not shown for clarity). Here, the other, upper side of the end **95** is identical to the lower side end and attachment by a circumferential butt or groove weld is made there to a tube of equal size to that of the center tube **91**. Alternatively, either or both of the connections could be made by commercially available compressive tube fittings.

[0049] Each outer anchor block **130** is an arcuate segment of an annular right circular cylinder having an outwardly extending upper transverse flange **131**, a right circular partial cylindrical inner face **132**, a symmetrically positioned right circular through bore **142** parallel to the rotational axis of symmetry **120** of anchor block **130**, a right circular partial cylindrical outer face **137**, and an outwardly extending transverse lower flange **136**. The radius of the inner face **132** has the same radius as and is comateable with the outer cylindrical surface **114** of the center anchor block **111**. The upper transverse face of the outer anchor block **130** abuts the lower side of the upper flange **112** of the center anchor block **111** when the tubing termination is assembled. Likewise, the lower transverse face **136** of the outer anchor block **130** abuts the upper side of the lower flange **118** of the center anchor block **111** when the tubing termination **100** is assembled. As shown here, all of the outer anchor blocks **130** are the same since the outer tubes **92** of the bundle **90** all have the same size.

[0050] The planar lateral sides **143** of outer anchor block **130** can be coplanar with the axis of rotation **120** of the block. Alternatively, as shown herein, the individual outer anchor blocks **130** can be made by cutting a solid annular ring with radial saw cuts which have a finite kerf width. The number of outer anchor blocks **130** corresponds to the number of outer tubes **92** in the tubing bundle **90**.

[0051] The inlet/outlet end **96** for the attached outer bundle tube **92** supported by outer anchor block **130** is structurally identical to the inlet/outlet end **95** for the center tube **91**. The connections of the inlet/outlet end **96** to the tube **92** and the tube on the opposed end are again made by circumferential butt or groove welds (not shown for clarity). The inlet/outlet end **96** has a close slip fit to the through bore **142** and is attached to the upper **131** and lower **136** transverse flanges of the anchor block by circumferential fillet welds **44**. Again, either or both of the connections alternatively could be made by commercially available compressive tube fittings.

[0052] The split clamp assembly **150**, seen best in FIGS. **8** and **9**, consists of a pair of clamp halves **151** and the clamp studs **64** with clamp nuts **65** required to draw the clamp halves together. Sufficient space is provided between the clamp halves **151** so that they do not abut prior to fully clamping together the assemblage **110** of anchor blocks **111** and **130**. The split clamp assembly **150** surrounds and retains the anchor block assemblage **110** consisting of the center anchor block **111** and its surrounding set of outer anchor blocks **130**. The clamp halves **151** each have a right circular nearly semicylindrical annular body **152** with its diameters greater than its axial length. At the upper transverse side of each clamp half, an outwardly extending nearly semiannular transverse upper reinforcing flange **153** is located, with a mirror image transverse lower reinforcing flange **154** located at the lower transverse side.

[0053] For the second embodiment of the tubing termination **100**, the inner side of a clamp half **151** has an inner nearly semicylindrical face **156** extending its full height. The inner nearly semicylindrical face **156** is a close fit to the outer cylindrical surface sections **137** of the assembled group of outer anchor blocks **130**. The height of the split clamp half **151** is such that it is a close fit between the inside faces of the upper **131** and lower **136** transverse flanges of the outer anchor blocks **130**.

[0054] Extending outwardly parallel to and slightly offset from the diametrical plane perpendicular to the vertical plane of symmetry for each clamp half **151** on each side are thick rectangular clamping ears **160**. On each clamping ear **160**, two through clamping bolt holes **161** are drilled horizontally perpendicular to the inner face of the clamping ears and placed symmetrically about the horizontal midplane of the clamp half. When the clamp halves **151** are assembled around the anchor blocks **111** and **130**, the clamp studs **64** are extended through the clamping bolt holes **61** and then clamp nuts **65** are used to draw the clamp halves together so that the tubing termination **100** is rigidized. At assembly, the upper **112** and lower **118** flanges of the center anchor block **111** respectively bear on the outer transverse ends of the upper **131** and lower **136** flanges of the outer anchor blocks **130**. At the same time, the inner sides of the upper **131** and lower **136** transverse flanges of the outer anchor blocks **130** respectively bear against the upper and lower transverse ends of the clamp halves **151** of the assembled split clamp assembly **150**.

[0055] It is generally necessary to mount the tubing terminations for helical tube bundles so that the tube bundles are supported against lateral and axial displacements. A wide array of types of supports are used for various applications, but two types are shown herein in FIGS. **13** to **16** by way of example so that the mounting arrangements for the first and second tubing terminations can be described. The first embodiment **10** of the tubing termination is shown in FIGS. **13** to **16** for illustration purposes, but the second embodiment **100** could likewise be used, since the split clamp assemblies **50** and **150** are substantially structurally identical in most respects.

[0056] Referring to FIG. **13**, the first mounting **200** consists of a short right circular tubular section **202** with an outwardly extending transverse right circular cylindrical annular flange **201** at its upper end. The flange **201** has a frustoconical transition section between its lower side and

the exterior of the tubular section **202** to reduce stress concentrations between the two primary elements. The first mounting **200** has a right circular cylindrical coaxial through hole **203** extending vertically through its length. The diameter of the through hole **203** is selected to be such that the tubing bundle **90** can readily pass through the hole. If so desired, the diameter of the through hole **203** can be made sufficiently large that it can pass the assembled anchor block assemblage **48** of the first tubing termination embodiment **10** or the assembled anchor block assemblage **110** of the second tubing termination **100**. However, the size of hole **203** should not be so large that at least a portion of the nearly semicylindrical transverse end of the split clamp assembly **50** or **150** would not bear on the flange **201** when the clamp assembly is concentrically mounted on the mounting **200**. The mounting **200** typically would be attached to a supporting structure by the welding of the lower end of its tubular section **202** to the support.

[0057] Diametrically opposed, radially extending vertical plate mounting tabs **210** extend upwardly normal to the upper face of flange **201**. The thickness of the tabs **210** is such that they are a close fit to the gap between the ears **60** or **160** of the tubing terminations **10** or **100**, respectively, when the split clamp assemblies **50** or **150**, respectively, are assembled around their anchor block assemblies **48** or **110**. Symmetrically positioned mounting holes **211** normal to the diametrical plane of the mounting tabs **210** penetrate the tabs with a hole pattern the same as for the clamping bolt holes **61** or **161** of the split clamp halves **51** or **151**, respectively. The spacing of the mounting holes **211** from the upper face of the flange **201** is such that the lower face of the clamp halves **51** or **151** of the tubing terminations **10** or **100**, respectively, will bear on the upper face of the flange **201** at assembly of the clamp as indicated in FIGS. **13** and **15**.

[0058] Referring to FIG. **14**, the second mounting **300** can be seen to be structurally very similar to the first mounting **200** in most regards. Second mounting **300** consists of a short right circular tubular section **302** with an outwardly extending transverse right circular cylindrical annular flange **301** at its upper end. The flange **301** has a frustoconical transition section between its lower side and the exterior of the tubular section **302** to reduce stress concentrations between the two primary elements. The first mounting **300** has a right circular cylindrical coaxial through hole **303** extending vertically through its length. The diameter of the through hole **303** is selected to be such that the tubing bundle **90** can readily pass through the hole. If so desired, the diameter of the through hole **303** can be made sufficiently large that it can pass the assembled anchor block assemblage **48** of the first tubing termination embodiment **10** or the assembled anchor block assemblage **110** of the second tubing termination **100**. However, the size of hole **303** should not be so large that at least a portion of the nearly semicylindrical transverse end of the split clamp assembly **50** or **150** would not bear on the flange **301** when the clamp assembly is concentrically positioned on the mounting **300**. The mounting **300** typically would be attached to a supporting structure by the welding of the lower end of its tubular section **302** to the support.

[0059] Coplanar opposed, outwardly extending vertical plate mounting tabs **310** extend upwardly normal to the upper face of flange **301**. The mounting tabs **310** are offset from the axis of symmetry of the second mounting **300** so

that their coplanar faces closest to the axis of symmetry are spaced apart from that axis. The distance of separation from the axis is the same as that of the externally facing coplanar faces of the clamping ears **60** or **161** of the split clamps **50** or **150**, respectively, from their axes of symmetry. Symmetrically positioned mounting holes **311** normal to the plane of the mounting tabs **310** penetrate the tabs with a hole pattern the same as for the clamping bolt holes **61** or **161** of the split clamp halves **51** or **151**, respectively. The spacing of the mounting holes **311** from the upper face of the flange **301** is such that the lower face of the clamp halves **51** or **151** of the tubing terminations **10** or **100**, respectively, will bear on the upper face of the flange **301** at assembly of the clamp as indicated in FIGS. **14** and **16**.

[0060] FIG. **17** shows an alternative arrangement of the center anchor block **411** in which the center tube **91** of the tubing bundle **90** and the inlet/outlet end **495** for the center tube are butt welded to tubular extensions **420** protruding from the center anchor block. The center anchor block **411** which supports the center tube **91** of the tubing bundle **90** is a right circular cylindrical tube having a transverse upper face **412**, a coaxial right circular through hole **413**, an outer cylindrical surface **414**, and a transverse lower face **415**.

[0061] The diameter of the through hole **413** is a match to the inner diameter of the center tube **91**. A large chamfer is positioned at the lower end of the anchor block **411** at the intersection of the outer cylindrical surface **414** and the lower transverse face **415**. Centrally located in the middle of the outer cylindrical surface **414** is a right circular cylindrical coaxial reduced diameter central portion **416** of the center anchor block **411**. The reduced diameter central portion **416** is connected to the upper and lower sections of the outer cylindrical surface **414** by upper frustoconical shoulder **417** and lower frustoconical shoulder **418**, respectively. The frustoconical shoulder surfaces are inclined from the axis of the center anchor block **411** by similar angles in the range of 30° to 60°.

[0062] Coaxial with the through bore **413** and extending outwardly from the upper **412** and lower **415** transverse faces are tubular connection extensions **420**. Each tubular connection extension **420** has a through bore which matches the through bore **413** of the center anchor block **411**, a heavy wall section joined to the transverse face of the anchor block by a fillet for stress relief, and a reduced wall section **421** which matches the wall thickness of the tube **91** or **495** to which it is joined by a butt weld **425**. In this case, the inlet/outlet end **495** of the center tube is another tube. Similarly, the outer anchor blocks can be modified, as described for the center anchor block **411**, with the same type of tubular connection extensions for the attachment by butt welding of the outer tubes **92** and outer tube inlet/outlet tubes.

Operation of the Invention

[0063] The operation of the tube bundle terminations of the present invention is primarily concerned with the assembly of the structures, since the apparatus is stationary and passive following assembly. The characteristic of the construction of the tube bundle **90** which facilitates the use of the type of structural arrangement used in the present invention is the lack of torsion induced in the individual tubes when the bundle is fabricated. The outer tubes **92** in the bundle **90** are laid into their helical pattern utilizing only

bending, rather than torsion, while the center tube **91** is neither bent nor twisted. This causes the maintenance of alignment between the tube ends of the bundle and the elements of the tube bundle termination to be much easier when the anchor blocks of the termination are separated to attach the tubes. Generally, following the attachment of the tube bundle terminations to the tubes, only elastic bending of the separated outer tubes **92** is required to reestablish the desired compact bundle geometry at the end of the bundle **90**.

[0064] The assembly of the tube bundle termination **10** proceeds as follows. The ends of the outer tubes **92** at the end of the bundle **90** are separated sufficiently so that there is sufficient room for a welder to operate around any one of the tubes in the bundle. At this point, a circumferential butt or groove weld is made to align and join each of the outer tubes **92** and the inner tube **91** to an outer tube inlet/outlet end **96** or an inner tube inlet/outlet end **95**, respectively. Following this, the inner tube inlet/outlet end **95** and each of the outer tube inlet/outlet ends **96** is slipped into the through bore **13** of center anchor block **11** or the through bore **42** of outer anchor block **30**, as appropriate.

[0065] At this point, the anchor blocks **11** and **30** are reassembled by elastically bending the tubes **92** into the packed pattern of their assemblage **48** as shown in FIGS. **1**, **6**, and **7** or in FIGS. **13** and **14**, where the assemblage can be seen more clearly. Following this, the split clamp assembly **50** is assembled around the assembled anchor block pattern by engaging the clamp halves **51** around the assemblage **48** of anchor blocks **11** and **30** and then tightening the nuts **65** on the studs **64** after insertion of the studs through the clamping bolt holes **61** in the clamping ears **60**. At this point, match marks between each tube inlet/outlet end **95** or **96** and its corresponding anchor block can be made for both radial alignment and axial positioning. Alternatively, tack welds of the tube inlet/outlet ends **95** or **96** with their respective anchor blocks **11** or **30** can be made to hold the desired alignment therebetween. At this point, the clamp assembly **50** can be removed, the anchor blocks re-separated, and the circumferential fillet welds **19** and **44** made to rigidly affix the inlet/outlet ends **95** or **96** to their respective blocks **11** or **30**. If tack welds are not used to hold alignment, then following anchor block separation, the blocks are aligned with their respective tubes using the marks prior to the making of the final welds **19** or **44**.

[0066] When the connecting fillet welds **19** and **44** are completed, the anchor blocks **11** and **30** can be recombined into the anchor block assemblage **48**. Final assembly is completed by clamping the assembly **10** together using the split clamp assembly **50**. The split clamp halves **51** tightly grip the anchor block assemblage **48** when the threaded studs **64** and their nuts **65** are tightened. After this assembly operation, the tube bundle termination **10** is fully rigidized and can resist axial loads in either direction of the tube bundle **90**. When the axial load is tension in the tube bundle **90**, the axial load is resisted by abutment of the frustoconical shoulder **17** of the center anchor block **11** on the comated frustoconical shoulders **34** of the outer anchor blocks **30** and the abutment of the frustoconical shoulders **39** of the outer anchor blocks **30** on the upper frustoconical shoulders **58** of the split clamp assembly **50**.

[0067] Mounting of the tubing termination embodiments **10** and **100** by means of either of the mountings **200** or **300**

may be understood by reference to FIGS. **13** through **16**. By means of example, the use of the mountings is shown for the first tubing termination **10**, but the same arrangements are used for the second tubing termination **100**.

[0068] Referring to FIGS. **13** and **15**, for the first mounting **200** the tube bundle **90** is positioned in the hole **203** so that the anchor block assembly **48** of the tubing termination **100** is on the flange side of the mounting. The split clamp assembly **50** is separated at this point. The clamp bolt holes **61** of the clamp halves **51** of the split clamp **50** are then aligned with the mounting holes **211** of the mounting tabs **210** of the mounting **200**. The clamp halves **51** are on opposed sides of the mounting tabs **210** at this point, and the anchor block assembly **48** is also aligned to be concentric with the mounting **200** and in axial alignment with the clamp halves. At this point, the studs **64** are engaged through both the mounting holes **211** of the mounting tabs **210** and the clamping bolt holes **61**. The clamp halves **51** are then pulled together by means of tightening the nuts **65** on the studs **64** so that the clamp halves rigidly clamp the anchor block assembly **48** and also closely engage the mounting tabs **210**. When the assembly is complete, the lower transverse side of the split clamp assembly **50** abuts the top surface of the flange **201** of the mounting **200**.

[0069] For the second mounting **300**, again illustrated with the first tubing termination **10** in FIGS. **14** and **16**, the tube bundle **90** is positioned in the hole **303** so that the anchor block assembly **48** of the tubing termination **100** is on the flange side of the mounting. The nuts **65** are removed and the studs **64** are at least partially withdrawn. The clamp bolt holes **61** of the clamp halves **51** of the split clamp **50** are then aligned with the mounting holes **311** of the mounting tabs **310** of the mounting **300**. The clamp halves **51** are on the same side of the mounting tabs **310** as the axis of symmetry of the mounting **300** at this point, and the anchor block assembly **48** is also aligned to be concentric with the mounting **300** and in axial alignment with the clamp halves. The studs **64** then are engaged through both the mounting holes **311** of the mounting tabs **310** and the clamping bolt holes **61**. The clamp halves **51** are then pulled together by means of tightening the nuts **65** on the studs **64** so that the clamp halves rigidly clamp the anchor block assembly **48** and also closely engage the mounting tabs **310**. When the assembly is complete, the lower transverse side of the split clamp assembly **50** abuts the top surface of the flange **301** of the mounting **300**.

[0070] Generally, it is desirable to mount the completed tubing termination **10** so that it is adequately anchored and hence able to resist axial loadings. Various types of mountings are suitable for this purpose, including fixed mountings such as **200** or **300** or ball jointed, flex jointed, or trunnion mountings. Herein, for sake of example, the attachment of the split clamp assembly **50** of the tubing termination **10** to a fixed mounting such as either the first mounting **200** or the second mounting **300**, as shown respectively in FIGS. **15** and **16**, completes the mounting of the assembly.

[0071] Resistance by the tubing termination **10** to axial compressive loads in the tube bundle **90** is then provided by abutment of the frustoconical shoulder **18** of the center anchor block **11** on the comated frustoconical shoulders **35** of the outer anchor blocks **30** and the abutment of the frustoconical shoulders **40** of the outer anchor blocks **30** on

the lower frustoconical shoulders **59** of the split clamp assembly **50**. For the case of tension loadings in the tubing bundle **90**, the lower transverse side of the split clamp **50** will bear directly on respectively the upper transverse surface **201** or **301** of the first **200** or second **300** mounting. In the case of compression loadings in the tubing bundle **90**, transverse shear from the split clamp halves **51** of the clamp assembly **50** is transferred from the clamping bolt holes **61** to the clamp studs **64** and thence respectively to the mounting holes **211** or **311** of the support tabs **210** of first mounting **200** or tabs **310** of second mounting **300**.

[0072] The assembly and operation of the second embodiment of the tube termination **100** is very similar to that of the first embodiment tube termination **10**. Slightly more care is required in maintaining proper alignment between the anchor blocks and the inlet/outlet tube ends during fitup and welding in order to nest the outer anchor blocks **130** within the flanges **112** and **118** of the center anchor block **111**. The difference between the two embodiments is related to the means for resisting axial loads produced by axial loadings induced by the tube bundle **90**. The tube termination **100** is assembled in a manner identical to that used for the termination **10**. Thus, the alignment marking and the welding follow the same procedures as used for the first embodiment.

[0073] For this embodiment **100** when axial tension is induced in the tube bundle **90**, the upper flange **112** of the center anchor block **111** abuts the upper transverse faces of the upper flanges **131** of the outer anchor blocks **130**, while the upper flanges **131** of the anchor blocks **130** abut the upper side of the split clamp assembly **150**. For thrust loads from the tube bundle **90**, the lower flange **118** of the center anchor block **111** abuts the lower transverse faces of the flanges **136** of the outer anchor blocks **130**, while the lower flanges **136** of the anchor blocks **130** abut the lower side of the split clamp assembly **150**.

[0074] The operation of the alternative center anchor block **411** shown in FIG. 17 is substantially identical to that of the anchor block **11** of the first embodiment of the tubing termination **10**. The only difference for anchor block **411** is in the use of butt welds **425** without a through tube **95** for the connections and the provision of strain relief by means of tapered wall sections and fillets for the tubular extensions **420**. Moving the butt welds **425** away from the transverse end faces **412** and **415** also improves the access for the welder.

Advantages of the Invention

[0075] A major advantage of the present invention is the ability to physically separate the anchor blocks of the tube bundle terminations by sufficient space that the necessary connecting welds **19** and **44** respectively between the center anchor block **11** (or **111**) and the outer anchor blocks **30** (or **130**) and the respective inlet/outlet tube ends **95** and **96** of tubes **91** and **92** of the helical tube bundle **90** can be readily made. This ability directly results from the segmentation of the anchor block assemblage **48** (or **110**) to which the tubes are joined by welding into a set of discrete, separable, but comatable anchor blocks wherein one block is provided for each tube in the tube bundle.

[0076] Because of this ability to separate the anchor blocks, the center-to-center spacing of the tubes in the assembled tubing termination can be decreased significantly,

since welding does not have to be done in the inter-tube spaces of the assembled terminations of the present invention. Consequent to the compactness of the present invention, its weight and cost for construction as well as the assembly cost are significantly reduced.

[0077] The present invention provides a more flexible means for terminating helical tubing bundles than the conventional welding or potting of the tubes into a socket with a plastic. Should there be a problem with one tube, the termination assembly can be readily disassembled, repaired, and reassembled. This flexibility greatly improves the ability to maintain the termination.

[0078] The tubing termination **10** can be assembled with particular ease, so that it offers the quickest assembly of the set of terminations of the present invention. This ease of assembly is due to the interaction of the frustoconical shoulders of the center tube anchor **11**, the outer tube anchors **30**, and of the split clamp assembly **50**. The wedging interaction of the abutting frustoconical shoulders when the anchor block assemblage **48** is circumferentially pulled together causes good relative axial alignment of anchor blocks of the tubing termination **10** with the split clamp **50**. The abutment of adjacent frustoconical shoulders in the assembled tubing termination **10** offers very high resistance to axial loads imposed by the tubing bundle **90**. Likewise, the positioning of the tubing termination **10** on a mounting such as the first **200** or the second mounting **300** permits the assembled tubing termination to support high axial loads, particularly in the case of tube bundle tension.

[0079] The second tubing termination embodiment **100** offers substantially the same advantages as the first embodiment **10** such as ease of assembly and reduction in size and cost of the termination. The tubing termination **100** also is relatively easy to assembly if reasonable care is taken both to make accurate alignment marks for the inlet/outlet ends of the tubes and the anchor blocks and also to ensure that the welds between the inlet/outlet ends and the anchor blocks maintain that alignment. In such an event, the outer anchor blocks **130** readily may be engaged between the upper **112** and lower **118** flanges of the center anchor block **111**, while the upper **131** and lower flanges **136** of the outer anchor blocks **130** engage the upper and lower transverse faces of the split clamp assembly **150**. This second embodiment of the tubing termination **100** is also highly resistant to axial loads from the helical tubing bundle **90** when the termination is fixed to a mounting structure like the first **200** or the second **300** mounting.

[0080] Referring to FIG. 17, the outer anchor blocks can likewise be modified similarly to the center anchor block **411** with the same type of tubular connection extensions for the attachment by butt welding of the outer tubes **92** and outer tube inlet/outlet tubes. Although construction of the anchor blocks is more difficult, use of this approach permits overly high bending stress concentrations from occurring in the tubes adjacent to the transverse end faces of the anchor blocks.

[0081] As readily may be understood by those skilled in the art, the present invention may be varied in its details without departing from the spirit of the invention. For example, the configuration of the inlet/outlet tube ends may be varied. In some cases when the helical tubing in the bundle **90** has thick walls, it may be possible to directly weld

the tubes to the anchor blocks without using special inlet/outlet tube ends. Likewise, compression tube fittings may be utilized as an alternative to welded connections between the tubes of the tube bundle and the terminations of the present invention. The split clamp halves can be made without having the upper and lower reinforcing flanges. Different types of mountings than those shown herein may be used without departing from the spirit of the invention. The frustoconical shoulders for the first embodiment may extend from the central cylindrical sections to the transverse end faces without changing the basic functionality of the present invention. Likewise, the choice is arbitrary of which side should be male with the other side female for a comating pair of surfaces for a center anchor block to outer anchor block mate or for an outer anchor block to split clamp assembly mate. These and other variations all can be made without changing the spirit of the invention.

What is claimed is:

1. A subsea termination device for a helical tubing bundle comprising:

- a) a center anchor block attached to a center tube of a tubing bundle;
- b) a plurality of outer anchor blocks surrounding the inner anchor block, each outer anchor block attached to an outer tube of the tubing bundle, wherein each outer anchor block has an interior surface abutting an outer surface of the center anchor block and an exterior surface; and
- c) a selectably removable clamp, wherein the clamp surrounds and engages the exterior surface of the outer anchor blocks.

2. The subsea termination device of claim 1, wherein the interior surface of the outer anchor blocks is comatable with the outer surface of the center anchor block.

3. The subsea termination device of claim 1, wherein the outer anchor blocks constitute a segmented ring.

4. The subsea termination device of claim 1, wherein the center anchor block is attached to the center tube by welding.

5. The subsea termination device of claim 1, wherein the outer anchor blocks are attached to the outer tubes by welding.

6. The subsea termination device of claim 1, wherein the clamp is a split clamp assembly having a first clamp half and a second clamp half cojoined by threaded fasteners.

7. The subsea termination device of claim 6, wherein a flange on each outer anchor block engages the first or second clamp half.

8. The subsea termination device of claim 1, wherein the center anchor block and the outer anchor blocks have comating frustoconical surfaces.

9. The subsea termination device of claim 1, wherein each outer anchor block is retained within two opposed transverse flanges of the center anchor block.

10. The subsea termination device of claim 1, wherein each outer anchor block comprises: a transverse flange, a right circular partial cylindrical inner face, a symmetrically positioned right circular through hole, and a right circular partial cylindrical outer face.

11. The subsea termination device of claim 10, wherein a radius of the inner face of the outer anchor block is substantially similar to a radius of an outer cylindrical surface of the center anchor block.

12. The subsea termination device of claim 1, wherein an upper transverse face of the outer anchor block abuts a flange of the center anchor block.

13. The subsea termination device of claim 1, wherein the center anchor block and the outer anchor blocks have a radially outwardly extending transverse flange and wherein the flange of the center anchor block abuts a side of each of the outer anchor blocks and the flange of the outer anchor blocks engages the clamp.

14. The subsea termination device of claim 1, wherein the clamp is mounted on a mounting structure comprising a tubular section having an outwardly extending transverse flange.

15. The subsea termination device of claim 14, wherein the transverse flange has a frustoconical transition section where the flange joins the tubular section of the mounting structure.

16. The subsea termination device of claim 14, wherein the mounting structure has a through hole with a diameter sufficiently large for the tubing bundle to pass through the through hole.

17. The termination device of claim 1, wherein

- a) the outer surface of the center anchor block is frustoconical with a taper in a first direction;
- b) the interior surface of each outer anchor block is frustoconical with a taper in the same direction as the frustoconical outer surface of the center anchor block and comateable with the outer surface of the center anchor block;
- c) the exterior surface of each outer anchor block is frustoconical with a taper in the same direction as the frustoconical outer surface of the center anchor block; and
- d) an inner face of the clamp is frustoconical with a taper in the same direction as the frustoconical outer surface of the center anchor block and comateable with the exterior surface of the outer anchor blocks, thereby permitting the inner and outer anchor blocks to resist axial movement.

18. A termination device comprising:

- a) an anchor block assemblage having a center anchor block attached to a center tube of a tubing bundle, a plurality of outer anchor blocks surrounding the center anchor block wherein each outer anchor block has an interior surface comateable with an outer surface of the center anchor block;
- b) a ring clamp engageable around the anchor block assemblage to thereby rigidize the anchor block assemblage; and
- c) a retaining means for restraining the axial motion of the center and outer anchor blocks.

19. The termination device of claim 18, wherein the retaining means includes a pair of opposed flanges on the inner and the outer anchor blocks.

20. The termination device of claim 18, wherein the retaining means includes:

- a) a pair of opposed center anchor block flanges, one flange extending radially outward from a first end of the center anchor block and a second flange extending radially outward from a second end of the center anchor block;
- b) a pair of opposed outer anchor block flanges, one flange extending radially outward from a first end of each outer anchor block and a second flange extending radially outward from a second end of each outer anchor block;
- c) the flange at the first end of the center anchor block abuts the first end of each of the outer anchor blocks;
- d) the flanges at the first end of the outer anchor blocks abut a one end of a first side of the ring clamp;
- e) the flange at the second end of the center anchor block abuts the second end of each of the outer anchor blocks; and
- f) the flanges at the second end of the outer anchor blocks abut a second end of the first side of the ring clamp.

21. The termination device of claim 18, wherein the outer anchor blocks constitute a segmented ring.

22. The subsea termination device of claim 18, wherein the retaining means includes the center anchor block and the outer anchor blocks have comating frustoconical surfaces.

23. The termination device of claim 18, wherein the retaining means includes

- a) a first taper on the outer surface of the center anchor;
- b) a second taper on the interior surface of each outer anchor block, wherein the first and second tapers are comateable;
- c) a third taper on the exterior surface of each outer anchor block; and
- d) a fourth taper on the exterior surface of the outer anchor blocks, wherein the third and fourth tapers are comateable.

24. The subsea termination device of claim 18, wherein the clamp is mounted on a mounting structure comprising a tubular section having an outwardly extending transverse flange.

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