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Buoyancy module

Abstract

Disclosed herein are novel buoyancy modules for attachment to a cable, pipe, or umbilical. The buoyancy modules include a pair of module bodies adapted to mate with each other. Each module body has a recess adapted to engage a single bolt tensioner and at least one of the module bodies includes a longitudinal channel running the length of the module body. Further, the module bodies include one or more pads positioned within a pad containment channel. A plurality of single bolt tensioners may be positioned within the recesses of the module bodies and tensioned to impart a compressive force such that the module bodies contact each other, generating a predetermined displacement of the pad and thereby imparting a known clamping force that results in a desired clamping pressure being applied by the pad to the cable pipe or umbilical.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application claims the benefit of U.S. Provisional Application No. 63/315,313, filed Mar. 1, 2022, the disclosure of which is herein incorporated by reference.

BACKGROUND
1. Field of the Invention
(1) The present invention pertains to the field of buoyancy modules. Specifically, this invention relates to a novel buoyancy module and method that facilitates accurate and efficient installation of the buoyancy module in connection with a range of offshore applications.
2. Discussion of Background Information
(2) Buoyancy modules are a critical component of offshore activities. For example, offshore floating oil and gas platforms, and floating offshore wind platforms all require buoyancy modules in connection with components such as cables, umbilicals, and flow lines.
(3) In offshore wind applications, buoyancy modules are installed in a precise manner to provide distributed buoyancy for cables and umbilicals. For example, buoyancy modules hold cables in a desired geometric configuration and can reduce top tension loads as well as support compliance in the cable during movement of a floating platform. Once installed, buoyancy modules are expected to remain in service for up to 30 years. Thus, they must be installed with great precision and must retain their installation specifications despite the unrelenting subsea environment.
(4) Existing buoyancy module designs fall generally within two categories: buoyancy modules that utilize a separate clamping mechanism and buoyancy modules with an integrated clamping mechanism. Further, it is customary for buoyancy modules to be comprised of a plurality of bodies, which are secured together during the installation process. However, to achieve the desired performance and longevity, the clamping mechanism of the buoyancy modules must be secured to the cable, pipe, or umbilical with a precise tensioning force. Typically, this tensioning force is achieved by utilizing a large hydraulic tool and then maintained via bolts, crimped corrosion-resistant metal bands, such as an INCONEL™ bands, or high-tension fiber straps coupled with single or double bolt tensioners.
(5) Given the nature of the required tooling, installation of buoyancy modules is completed on land whenever possible. However, where installation must occur at sea, the process is cumbersome and labor intensive and significantly complicates the process of deploying the required cables, pipes, and umbilicals. In addition, the difficulties associated with offshore buoyancy module installation are known to increase the duration of the deployment process and cause frequent vessel stoppages, both of which can significantly increase project costs. While other devices and methods have been proposed for buoyancy modules, none of these inventions, taken either singly or in combination, adequately address or resolve the aforementioned problems. Therefore, a need exists for an improved buoyancy module that accurately and efficiently attaches to a cable, pipe, or umbilical.
SUMMARY OF THE INVENTION
(6) The present invention solves the problems associated with the installation of buoyancy modules and provides a device and method facilitates accurate and efficient installation of the buoyancy module in connection with a range of offshore applications.
(7) The invention is directed to a buoyancy module that facilitates accurate and efficient installation of the buoyancy module in connection with a range of offshore applications. The buoyancy module comprises a first and second module body, the first module body adapted to mate with the second module body, wherein each module body includes at least one recess comprising an upper portion and a bolt channel; a longitudinal channel running the length of at least the first module body, the longitudinal channel having a pad containment channel located therein; a pad positioned within the

pad containment channel; and at least one single bolt tensioner, the at least one single bolt tensioner comprising a bolt, a cylindrical washer, and a cylindrical nut, wherein the at least one single bolt tensioner is positioned such that the bolt lies within the bolt channel of the first module body and the bolt channel of the second module body.

(8) The present invention is also directed to a buoyancy module comprising a module body having at least one recess comprising an upper portion and a bolt channel; a longitudinal channel running the length of the module body, the longitudinal channel having a pad containment channel located therein; a pad positioned within the pad containment channel; at least one single bolt tensioner comprising a bolt, a cylindrical washer, and a cylindrical nut, the cylindrical washer or the cylindrical nut captured within a recess bore in the at least one recess of the module body.

(9) The present invention is also directed to a method for accurately and efficiently installing a buoyancy module in connection with a range of offshore applications. The method comprises a first step of providing a buoyancy module comprising a first and second module body, the first module body adapted to mate with the second module body, wherein each module body includes a plurality of recesses, each recess comprising an upper portion and a bolt channel; a longitudinal channel running the length of at least the first module body, the longitudinal channel having a pad containment channel located therein; a pad positioned within the pad containment channel; and a first and second single bolt tensioner, each of the first and second single bolt tensioner comprising a bolt, a cylindrical washer, and a cylindrical nut. A second step includes positioning the first and second module body about a cable, pipe, or umbilical such that the cable, pipe, or umbilical lies within the longitudinal channel of the first module body and contacts the pad. A third step includes positioning the first and second single bolt tensioner such that each bolt is located within the bolt channel of the first and second module body and each cylindrical nut is positioned in a recess of one of the first and second module body and each cylindrical washer is positioned in a recess of the other of the first and second module body. A fourth step includes tensioning the first and second single bolt tensioner.

(10) The present invention is also directed to a method for accurately and efficiently installing a buoyancy module comprising a first step of providing a buoyancy module comprising a first and second module body, the first module body adapted to mate with the second module body, wherein each module body includes at least one recess comprising an upper portion and a bolt channel; a longitudinal channel running the length of at least the first module body, the longitudinal channel having a pad containment channel located therein; a pad positioned within the pad containment channel; and a single bolt tensioner comprising a bolt, a cylindrical washer, and a cylindrical nut, and a hinge single bolt tensioner comprising a bolt, a cylindrical washer, and a cylindrical nut wherein where the cylindrical washer of the hinge single bolt tensioner is captured in a recess bore in the recess of the first module body and the cylindrical nut of the hinge single bolt tensioner is captured within a recess bore in the recess of the second module body. A second step includes positioning the cable, pipe, or umbilical within the longitudinal channel of the first module body and in contact with the pad. A third step includes rotating the second module body to mate with the first module body and positioning the single bolt tensioner such that the bolt is located within the bolt channel of the first and second module body, the cylindrical washer is positioned within the recess of the first module body, and the cylindrical nut is positioned within the recess of the second module body. A fourth step includes tensioning the single bolt tensioner and the hinge single bolt tensioner.

(11) The present invention is also directed to a method for accurately and efficiently installing a buoyancy module comprising a first step of providing a buoyancy module comprising a first, second, and third module body, the first, second, and third module body adapted to mate with each other to form a desired geometric shape, each of the first, second, and third module body including a plurality of recesses, each recess comprising an upper portion and a bolt channel; a longitudinal channel running the length of each of the first, second, and third module body, the longitudinal

channel having a pad containment channel located therein; a pad positioned within each containment channel; and a first and second single bolt tensioner, each of the first and second single bolt tensioner comprising a bolt, a cylindrical washer, and a cylindrical nut; a hinge single bolt tensioner, the hinge single bolt tensioner comprising a bolt, a cylindrical washer and a cylindrical nut, wherein the cylindrical washer is captured within a recess bore in the recess of either the first module body or the second module body and the cylindrical nut is captured within a recess bore in the recess of the other of the first module body or the second module body. A second step includes positioning the cable, pipe, or umbilical within the longitudinal channel of the first module body and in contact with the pad. A third step includes rotating the second module body such that the cable, pipe, or umbilical is positioned within the longitudinal channel and in contact with the pad of the second module body. A fourth step includes positioning the third module body in an orientation that mates with the first and second module body to form the desired geometric shape. A fifth step includes positioning the first single bolt tensioner such that the bolt is located within the bolt channel of the first module body and the bolt channel of the third module body, the cylindrical washer is positioned within the recess of one of the first and third module body, and the cylindrical nut is positioned within the recess of the other of the first and third module body. A sixth step includes positioning the second single bolt tensioner such that the bolt is located within the bolt channel of the second module body and the bolt channel of the third module body, the cylindrical washer is positioned within the recess of one of the second and third module body, and the cylindrical nut is positioned within the recess of the other of the second and third module body. A seventh step includes tensioning the first and second single bolt tensioner and the hinge single bolt tensioner.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) These and other features, aspects and advantages of the present invention will become better understood with reference to the following description, appended claims, and accompanying drawings where:

(2) FIG. **1** is a perspective view of a buoyancy module of the present invention.

(3) FIG. **2** is a perspective exploded view of a single bolt tensioner of the present invention.

(4) FIG. **3** is a perspective view of a single bolt tensioner of the present invention.

(5) FIG. **4** is a perspective view of a single bolt tensioner of the present invention.

(6) FIG. **5** is a front view of a single bolt tensioner of the present invention.

(7) FIG. **6** is a perspective view of a single bolt tensioner of the present invention.

(8) FIG. **7** is a perspective view of a single bolt tensioner of the present invention.

(9) FIG. **7***a* is a perspective view of a single bolt tensioner of the present invention.

(10) FIG. **8** is a front view of a module body of the present invention.

(11) FIG. **9** is a side view of a module body of the present invention.

(12) FIG. **10** is a bottom view of a module body of the present invention.

(13) FIG. **11** is a top view of a module body of the present invention.

(14) FIG. **12** is a perspective bottom view of a module body of the present invention.

(15) FIG. **13** is a perspective top view of a module body of the present invention.

(16) FIG. **14** is a bottom perspective view of a module body of the present invention.

(17) FIG. **15** is a bottom perspective view of a module body of the present invention.

(18) FIG. **16** is a cross section view of a buoyancy module of the present invention.

(19) FIG. **17** is a cross section view of a buoyancy module of the present invention.

(20) FIG. **18** is a cross section view of a buoyancy module of the present invention.

(21) FIG. **19** is a cross section view of a buoyancy module of the present invention.

(22) FIG. **20** is a side view of a buoyancy module of the present invention.
(23) FIG. **21** is a side view of a buoyancy module of the present invention.
(24) FIG. **22** is a detail cross section view of the recess portion of a buoyancy module of the present invention.
(25) FIG. **23** is a detail cross section view of the recess portion of a buoyancy module of the present invention.
(26) FIG. **24** is a detail cross section view of the recess portion of a buoyancy module of the present invention.
(27) FIG. **25** is a detail cross section view of the recess portion of a buoyancy module of the present invention.
(28) FIG. **26** is a top view of a buoyancy module of the present invention.
(29) FIG. **27** is a front view of a buoyancy module of the present invention.
(30) FIG. **28** is a perspective view of a buoyancy module of the present invention.
(31) FIG. **29** is a perspective view of a buoyancy module of the present invention.
(32) FIG. **30** is a perspective view of a buoyancy module of the present invention.
(33) FIG. **31** is a cross section view of a buoyancy module of the present invention.
(34) FIG. **32** is a cross section view of a buoyancy module of the present invention.
(35) FIG. **33** shows the steps of one method of the present invention.
(36) FIG. **34** shows the steps of one method of the present invention.
(37) FIG. **35** shows the steps of one method of the present invention.
(38) FIG. **36** shows the steps of one method of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

(39) The present device and method is directed to the problem of accurately and efficiently connecting buoyancy modules to cables, pipes, and umbilicals in offshore applications. Specifically, the present invention provides a device comprised of a pair of module bodies secured together using a plurality of single bolt tensioners, and a method of use that efficiently and accurately secures the buoyancy module to a cable, pipe, or umbilical.
(40) The present invention addresses the problems surrounding the installation of buoyancy modules. Offshore environments, such as oil and gas platforms and offshore wind farms rely on buoyancy modules to impart engineered shapes into subsea components such as cables, pipes, and umbilicals. These buoyancy modules must be installed to precise specifications in order to function as required during the operational life of the attached subsea component. The present invention addresses these needs by providing a device that accurately and efficiently attaches to subsea components such as cables, pipes, and umbilicals.
(41) Turning to FIG. **1**, a buoyancy module **100** of the present invention is shown. The buoyancy module **100** includes a pair of module bodies **10** and a pair of single bolt tensioners **50**. As depicted in FIGS. **2**-**5**, the single bolt tensioner **50** includes a bolt **52**, a cylindrical washer **54** and a cylindrical nut **56**. The bolt **52** passes through a bore **55** in the cylindrical washer **54** and is secured to the cylindrical nut **56** via a tapped bore **57**. In some embodiments, the dimensions of the cylindrical washer **54** and the cylindrical nut **56** are the same. The bolt head **53** may be of any head style known in the art and is sized such that the bolt head **53** cannot pass through the bore **55** in the cylindrical washer **54**. As depicted in FIGS. **6**, **7** and **7***a*, it may be advantageous to utilize an extended bolt **52***a*, where the length of the bolt **52** is extended using a threaded extension **51** and a threaded coupler **58**. The threaded coupler **58** may be secured using any form known in the art. For example, the threaded coupler **58** may be secured using a physical lock washer, an adhesive, or a combination of both. As will be understood by a person of skill in the art, an extended bolt **52***a* may be used in lieu of a bolt **52** in any of the embodiments of the single bolt tensioner **50** disclosed herein without deviating from the scope of the invention.
(42) In some embodiments, the bolt tensioner **50** may include an alignment nut **59**. The alignment nut **59** is located along the length of the bolt **52** and is sized and shaped such that sufficient

frictional force exists to restrict the rotation of alignment nut **59** relative to the bolt **52**. Preferably, the alignment nut **59** is unthreaded and maintains its position on the bolt via frictional forces. The alignment nut **59** may be made of any material known in the art. For example, the alignment nut **59** may be made of plastic, nylon, PVC, or an elastomeric material. Further, in some embodiments utilizing an extended bolt **52***a*, it may be advantageous for the alignment nut **59** to surround the bolt **52** and a portion of the threaded coupler **58** such that the alignment nut **59** functions as a stop that limits the ability of the bolt **52** to slide within the bore **55**.

(43) Turning to FIGS. **8-13**, each of the module bodies **10** are shown as substantially semicylindrical in shape and designed to mate with each other to form a buoyancy module **100** with a substantially cylindrical shape as depicted in FIG. **1**. However, the buoyancy module **100** may be shaped in any geometric form as known in the art. For example, the buoyancy module **100** may be substantially spherical, substantially elliptical, or substantially rectangular. The module bodies **10** are sized according to the buoyancy requirements of the application. For example, the module bodies **10** are generally in the range of about three to about six feet in diameter and about three to about six feet in length, with in-air weights in the range from about two hundred to about two thousand pounds.

(44) Although the module bodies **10** are shown as being substantially semicylindrical in shape, the module bodies **10** may be any shape required to achieve the desired geometric form of the buoyancy module **100**. In addition, while the buoyancy module **100** is shown comprising substantially symmetrical module bodies **10**, a person of skill in the art will appreciate that in some embodiments of the invention the module bodies **10** may be different shapes provided they mate to form the desired buoyancy module **100** configuration and geometric shape. For example, a substantially cylindrical buoyancy module **100** may be comprised of a first module body **10** that is substantially u-shaped and a second module body **10** that is designed to mate with the first module body **10** to complete the substantially cylindrical buoyancy module **100**. Further, the buoyancy module **100** may be comprised of any plurality of module bodies **10**. For example, rather than utilizing a u-shaped module body **10** and a second module body **10** designed to complete a substantially cylindrical buoyancy module **100** as described above, it may be advantageous to utilize three module bodies **10** that mate to form the desired buoyancy module **100**.

(45) The module bodies **10** are manufactured as known in the art. For example, the exterior of the module body **10** may be molded plastic, with the interior filled with a foam. The foam may be any foam known to a person of skill in the art. For example, the foam may be syntactic foam. In addition, the module body **10** may include inserts such as handling points **6**. To achieve the desired strength and structural integrity, inserts may be installed in the module body **10** shell prior to filling the interior with foam. By extending the inserts into the interior of the module body **10**, the addition of the foam surrounds the insert, stabilizing the insert and distributing load forces.

(46) Each module body **10** includes a pair of recesses **12** located in the lateral surface area of the module body **10**. The recesses **12** include an upper portion **14**, which has a cradle **16** adapted to engage the cylindrical washer **54** and cylindrical nut **56** elements of the single bolt tensioner **50**. When the cylindrical nut **56** is positioned within the upper portion **14** of the recess **12**, the wall of the recess **12** prevents the cylindrical nut **56** from rotating as the bolt **52** is tightened during the initial stage of bolt **52** tightening. As the bolt **52** is tightened further, the cylindrical nut **56** enters the cradle **16**, which secures the cylindrical nut **56** and generates a compression force between the module bodies **10**. The recess **12** further includes a bolt channel **18**, which extends from the upper portion **14** of the recess **12** to the face **20** of the module body **10**. The bolt channel **18** is an open channel that is sized and shaped to allow the bolt **52** to pass between the cradle **16** to the adjacent buoyancy module **10**. Further, in embodiments where the single bolt tensioner **50** includes an alignment nut **59**, the alignment nut is sized and shaped to fit within the bolt channel **18** such that the alignment nut **59** can slide within the bolt channel **18** without rotating. Accordingly, the frictional forces between the alignment nut **59** and the bolt **52** resist rotation of the bolt **52** relative

to the bolt channel **18**.
(47) As best shown in FIG. **12**, the face **20** of the module body **10** includes a pair of mating surfaces **22**, with a longitudinal channel **28** running the length of the module body **10**. The longitudinal channel **28** is sized and shaped to accept a cable, pipe, or umbilical and may be flared at the ends to accommodate the minimum bend radius of the cable, pipe, or umbilical. Transverse to the longitudinal channel **28** is a pad containment channel **30**. The pad containment channel **30** is sized and shaped to accept a pad **32**. The pad containment channel **30** may be recessed within the longitudinal channel **28** or the pad containment channel **30** may be formed using walls or a series of protrusions extending from the longitudinal channel **28**, provided that the pad containment channel **30** interacts with the pad **32** to maintain the position of the pad **32** and prevents the pad from displacing axially.
(48) Once the buoyancy module **100** is installed, the pad **32** is in direct contact with the cable, pipe, or umbilical and resists axial displacement of the buoyancy module **100** along the cable, pipe, or umbilical during the service life of the buoyancy module **100**. Accordingly, it is desirable for the pad **32** to be an elastomeric pad comprised of a high friction material such as EPDM rubber, neoprene rubber, natural rubber, or polyurethane. The shape and size of the pad **32** may be adapted to the specific application for the buoyancy module **100**. For example, the pad **32** may be a single segment or the pad **32** may be comprised of multiple segments. Further, the pad **32** may be shaped to conform to the cable, pipe, or umbilical upon installation.
(49) The mating surfaces **22** may include one or more alignment protrusions **24** and one or more alignment recesses **25**. The alignment protrusions **24** may be any shape and size known in the art and are preferably intended to mate with a corresponding alignment recess **25** disposed in the mating module body **10**. For example, FIG. **12** depicts an embodiment where each mating surface **22** includes an alignment protrusion **24** and an alignment recess **25**, with the alignment protrusion **24** tapered slightly to facilitate entry of the alignment protrusion **24** into a corresponding alignment recess **25** of the mating module body **10**.
(50) As depicted in FIGS. **14** and **15**, the mating surfaces **22** may include one or more contact surfaces **26**, which are portions of the mating surface **22** that are intended to contact when two module bodies **10** are mated to form a buoyancy module **100**. In some embodiments, the contact surfaces **26** may correspond to the entirety of the mating surfaces **22**. However, in other embodiments, such as the embodiments depicted in FIGS. **14** and **15**, the contact surfaces **26** are a portion of the mating surfaces **22**. Where the contact surfaces **26** are a portion of the mating surfaces **22**, the contact surface **26** may be manufactured to extend above the mating surface **22**. Further, a raised contact surface **26** may be machined to remove material from the contact face **27** of the contact surface **26** to achieve a high degree of precision with regard to the height of the contact surface **26**. In some embodiments, the contact surface **26** may be machined to remove the entire external shell of the module body **10** from the contact face **27**. In these embodiments, the contact face **27** will be comprised of the internal foam, which in the case of syntactic foam, will possess a high compressive strength.
(51) During installation, two module bodies **10** are mated to form the buoyancy module **100**. Several embodiments of the present invention are envisioned, depending on the configuration of the single bolt tensioners **50**.
(52) In one embodiment of the buoyancy module **100**, a pair of module bodies **10** are mated and secured using a pair of free single bolt tensioners **50**. As depicted in FIGS. **16** and **17**, the module bodies **10** are mated such that a cable, pipe, or umbilical is positioned within the longitudinal channel **28** of each module body **10**. As shown, the recesses **12** in each module body **10** are aligned such that the bolt channel **18** of each recess is in communication with the bolt channel **18** of the mated module body **10**. Once the module bodies **10** are so aligned, single bolt tensioners **50** are installed within the recesses **12**, such that the cylindrical washer **54** is located within the upper portion **14** of the recess **12** on one module body **10**, the bolt **52** passing through the communicating

bolt channels **18**, and the cylindrical nut **56** is located within the upper portion **14** of the recess **12** of the mating module body **10**. Upon tightening of the single bolt tensioners **50**, the pair of module bodies **10** are brought together, creating a clamping force. This clamping force displaces the pad as it contacts the cable, pipe, or umbilical, resulting in a clamping pressure being applied to the cable, pipe, or umbilical. While the location of the cylindrical nut **54** and the cylindrical washer **56** are described in specific orientations, a person of skill in the art will appreciate that the arrangement of the cylindrical washer **54** and the cylindrical nut **56** may be reversed in any of the embodiments disclosed herein without deviating from the scope of the invention.

(53) The clamping pressure applied to the cable, pipe, or umbilical is dependent on the physical characteristics of the pad **32**. To properly determine the clamping pressure, the displacement curve of the pad **32** can be derived empirically or calculated based on a known or determined finite element analysis. Once the force displacement curve is determined, a known clamping force will create a known clamping pressure, enabling the determination of the appropriate geometry for the module bodies **10**. In one embodiment of the invention, the single bolt tensioners **50** may be tightened to a predetermined tension, such that the mating surfaces **22** of the module bodies **10** do not contact each other. In this embodiment, adjustment of the tension of the single bolt tensioners **50** will result in adjustment of the clamping force and the corresponding clamping pressure exerted by the pads **32**. Alternatively, in other embodiments of the invention it is desirable to engineer the geometry of the module bodies **10** such that contact between the contact surfaces **26** of the module bodies **10** generates a predetermined displacement of the pad **32**, thereby imparting a known clamping force that results in the desired clamping pressure being applied by the pad **32**. In these embodiments, the single bolt tensioners **50** are tensioned to ensure secure contact between the contact surfaces **26** of the module bodies **10**, with sufficient additional tension applied to the single bolt tensioners **50** as a safety measure.

(54) In embodiments where the module bodies **10** are in direct contact once the single bolt tensioners **50** are tensioned, the clamping pressure on the cable, pipe, or umbilical will be determined by the geometry of the cable, pipe, or umbilical, the geometry of the module body **10**, and the properties of pad **32**. Specifically, the dimensions and shape of the pad **32** and the relative position of the pad to the contact surfaces **26** will generate a known clamping pressure to a cable, pipe, or umbilical with a known outer diameter. For example, based on the known characteristics of a cable, such as diameter, coefficient of friction between the sheath of the cable and the pad **32**, the maximum clamping pressure, and the known characteristics of the pad **32**, a person of skill in the art can calculate the dimensions of the pad **32** and the relationship between the pad **32** and the contact surface **26** required to achieve the desired clamping pressure for the cable. Where precise application of clamping pressure is desired, the integration of a contact surface **26**, with a precisely machined contact face **27** can be implemented to ensure that the required clamping pressure is achieved when the single bolt tensioners **50** are tensioned such that the module bodies **10** are in direct contact.

(55) Further in one embodiment of the buoyancy module **100**, a single buoyancy module **10** may be positioned such that a cable, pipe, or umbilical is positioned within the longitudinal channel **28** of the module body **10**. A single bolt tensioner **50** is placed in the recess of the module body **10**, with the bolt **52** positioned in the bolt channel **18**, and the cylindrical washer **56** is engaged with a strap. The single bolt tensioner **50** may be tensioned to a desired tension in order to tighten the strap and secure the module body **10** to the cable, pipe, or umbilical. Further, in some embodiments a second single bolt tensioner **50** may be positioned in a second recess **12** of the module body **10**, with the bolt **52** of the second single bolt tensioner **50** located in the second bolt channel **18**, and the cylindrical washer **56** of the second single bolt tensioner **50** may engage the opposite end of the strap such that tensioning the first and second single bolt tensioners **50** to the desired tension will secure the module body **10** to the cable, pipe, or umbilical.

(56) In some embodiments of the invention, it may be advantageous to capture the single bolt

tensioner **50** in one or both of the module bodies. For example, FIGS. **18-25** depict an embodiment of the invention where the cylindrical washer **54** is captured within a recess bore **17** in the recess **12** of the module body **10**. The recess bore **17** is sized to act as a bushing for the cylindrical washer **54**, allowing the single bolt tensioner **50** to rotate about the axis of the recess bore **17**. In some embodiments, the recess bore **17** may include an insert, such as a pipe or a tube to form or reinforce the recess bore **17**. For example, a fiber reinforced pipe could be used as an insert during manufacturing to form the recess bore **17**. Prior to mating the module bodies **10**, it may be advantageous to have the single bolt tensioner **50** rotated such that the cylindrical washers **54** and the cylindrical nuts **56** of the single bolt tensioners **50** are both disposed within the recess **12** so that the pair of module bodies **10** can be mated without interference from the single bolt tensioners **50**.
(57) Once the module bodies **10** are mated, the single bolt tensioners **50** can be rotated such that the bolt **52** is disposed within the bolt channel **18** and the cylindrical nut **56** is located within the recess **12** of the mated module body **10**. Upon tensioning of the single bolt tensioner **50**, the cylindrical nut **56** contacts the cradle **16** of the mated module body **10**. As detailed above, in embodiments where the module bodies **10** are designed to contact each other to achieve the desired clamping pressure, the single bolt tensioner **50** is tensioned to ensure secure contact between the contact surfaces **26** of the mating module bodies **10**, with sufficient additional tension applied to the single bolt tensioners **50** as a safety measure. Alternatively, where the buoyancy module **100** is designed to leave a gap between the module bodies **10**, the single bolt tensioner **50** is tensioned to a predetermined tensioning force to achieve the desired clamping pressure.
(58) As shown in FIGS. **18-21**, multiple single bolt tensioners **50** may be captured in the same module body **10**, and the mating module body **10** may be set to receive the cylindrical nuts **56** of the captured single bolt tensioners **50**. Alternatively, both module bodies **10** may include a single bolt tensioner **50**, such that once the module bodies **10** are mated, the single bolt tensioners **50** may be rotated into the recess **12** of the mated module body **10** and each of the single bolt tensioners **50** may be tensioned to achieve the desired clamping pressure. In addition, while the figures depict a pair of single bolt tensioners **50** securing the buoyancy module **100**, a person of skill in the art will appreciate that the module bodies **10** may utilize a plurality of single bolt tensioners **50** depending on factors such as spreading load, managing torque, or redundancy.
(59) It is noted that while the single bolt tensioner **50** is described with the cylindrical washer **54** captured within the recess bore **17**, the arrangement can be reversed and the cylindrical nut **56** may be captured within the recess bore **17** such that the single bolt tensioner **50** can rotate about the axis of the recess bore **17**. In such arrangements, the cylindrical washer **54** will contact the cradle when the single bolt tensioner **50** is tensioned.
(60) Turning to FIGS. **26-32**, an embodiment of the buoyancy module **200** is shown. The buoyancy module **200** includes a pair of module bodies **210** connected by a single bolt tensioner **250** and a hinge single bolt tensioner **251**. The hinge single bolt tensioner **251** having a cylindrical washer **254** captured in the recess bore **217** of a first module body **210** and a cylindrical nut **256** captured in a recess bore **217** of a second module body **210** such that the module bodies **210** may rotate like a clamshell to encircle a cable, pipe, or umbilical. Similar to the module body **10** described previously, the module body **210** may include a contact surface **226**, which may correspond to the entirety of a mating surface **222** or may be a portion of the mating surface **222**. Further, the single bolt tensioner **250** may be either a free single bolt tensioner **50** or a captured single bolt tensioner **50** as described above.
(61) Alternatively, the buoyancy module **200** may utilize a fixed hinge in place of the hinge single bolt fastener **251**. In such embodiments, the fixed hinge may take any form known in the art that fixes the module bodies **210** in a hinged arrangement. For example, the module bodies **210** may include fingers, which interlace and are connected using a rod or pin to create a fixed hinge.
(62) Turning to a first method **300** of installing a buoyancy module **100** on a cable, pipe, or umbilical, a first step S**310** includes providing a pair of module bodies **10** and a pair of single bolt

tensioners **50**. The single bolt tensioners **50** may each be free from the module bodies **10**; both single bolt tensioners **50** may be captured within a bore recess **17** in the same module body; or the first single bolt tensioner **50** may be captured within a recess bore **17** of the first module body **10** and the second single bolt tensioner **50** may be captured within a recess bore **17** of the second module body **10**. A second step S**320** includes positioning the module bodies **10** about the cable, pipe, or umbilical such that the cable, pipe, or umbilical lies within the longitudinal channels **28** and contacts the pads **32**. A third step S**330** includes positioning the single bolt tensioners **50** such that the bolt **52** is located within the bolt channel **18**, with the cylindrical washer **54** positioned within the recess **12** of one module body **10** and the cylindrical nut **56** positioned within the recess **12** of the mated module body **10**. A fourth step S**340** includes tensioning the single bolt tensioners **50** to ensure secure contact between the contact surfaces **26** of the module bodies **10**, with sufficient additional tension applied to the single bolt tensioners **50** as a safety measure.

(63) Turning to a second method **400** of installing a buoyancy module **100** on a cable, pipe, or umbilical, a first step S**410** includes providing a pair of module bodies **10** and a pair of single bolt tensioners **50**. The single bolt tensioners **50** may each be free from the module bodies **10**; both single bolt tensioners **50** may be captured within a bore in the same module body; or the first single bolt tensioner **50** may be captured within a recess bore **17** of the first module body **10** and the second single bolt tensioner **50** may be captured within a recess bore **17** of the second module body **10**. A second step S**420** includes positioning the module bodies **10** about the cable, pipe, or umbilical such that the cable, pipe, or umbilical lies within the longitudinal channels **28** and contacts the pads **32**. A third step S**430** includes positioning the single bolt tensioners **50** such that the bolt **52** is located within the bolt channel **18**, with the cylindrical washer **54** positioned within the recess **12** of one module body **10** and the cylindrical nut **56** positioned within the recess **12** of the mated module body **10**. A fourth step S**440** includes tensioning the single bolt tensioners **50** to a predetermined tension such that a gap exists between the mating surfaces **22** of the module bodies **10**.

(64) Turning to a third method **500** of installing a buoyancy module **200** on a cable, pipe, or umbilical, a first step S**510** includes providing a pair of module bodies **210**, a single bolt tensioner **250**, and a hinge single bolt tensioner **251**, where the cylindrical washer **254** of the hinge single bolt tensioner **251** is captured in the recess bore **217** of the first module body **210** and the cylindrical nut **256** of the hinge single bolt tensioner **251** is captured within the recess bore **217** of the second module body **210**. The single bolt tensioner **250** may be free from the module bodies **210** or the second single bolt tensioner **250** may be captured within a recess bore **217** of either the first or second module body **210**. A second step S**520** includes positioning the cable, pipe, or umbilical within the longitudinal channel **228** and in contact with the pad **232** of the first module body **210**. A third step S**530** includes rotating the second module body **210** such that the cable, pipe, or umbilical is positioned within the longitudinal channel **228** and in contact with the pad **232** of the second module body **210**. A fourth step S**540** includes positioning the single bolt tensioner **250** such that the bolt **252** is located within the bolt channel **218** of the first module body **210** and such that the cylindrical washer **254** and the cylindrical nut **256** are each positioned within the recess of a different module body **210**. A fifth step S**550** includes tensioning the single bolt tensioner **250** and the hinge single bolt tensioner **251** to ensure secure contact between the contact surfaces **226** of the module bodies **210**, with sufficient additional tension applied to the single bolt tensioners **250** as a safety measure. Alternatively, the fifth step S**550** may include tensioning the single bolt tensioner **250** and the hinge single bolt tensioner **251** to a predetermined tension such that a gap exists between the mating surfaces **222** of the module bodies **210**.

(65) Turning to a fourth method **600** of installing a buoyancy module **200** on a cable, pipe, or umbilical, a first step S**610** includes providing a plurality of module bodies **210**, a plurality of single bolt tensioners **250**, and at least one hinge single bolt tensioner **251**, where the cylindrical washer **254** of the hinge single bolt tensioner **251** is captured in the recess bore **217** of a first

module body **210** and the cylindrical nut **256** of the hinge single bolt tensioner **251** is captured within the recess bore **217** of a second module body **210**. The plurality of single bolt tensioners **250** may be free from the module bodies **210** or each of the plurality of single bolt tensioners **250** may be captured within a recess bore **217** of any of the plurality of module bodies **210**. A second step S**620** includes positioning the cable, pipe, or umbilical within the longitudinal channel **228** and in contact with the pad **232** of the first module body **210**. A third step S**630** includes rotating the second module body **210** such that the cable, pipe, or umbilical is positioned within the longitudinal channel **228** and in contact with the pad **232** of the second module body **210**. A fourth step S**640** includes positioning a third module body **210** in an orientation that mates with the first and second module bodies **210** to form the desired geometric shape of the buoyancy module **200**. A fifth step S**650** includes positioning a first single bolt tensioner **250** such that the bolt **252** is located within the bolt channel **218** of the first module body **210** and the cylindrical washer **254** and the cylindrical nut **256** are each positioned within the recess of a different module body **210**. A sixth step S**660** includes positioning a second single bolt tensioner **250** such that the bolt **252** is located within the bolt channel **218** of the second module body **210** and the cylindrical washer **254** and the cylindrical nut **256** are each positioned within the recess of a different module body **210**. A seventh step S**670** includes tensioning each of the single bolt tensioners **250** and the hinge single bolt tensioner **251** to ensure secure contact between the contact surfaces **226** of the module bodies **210**, with sufficient additional tension applied to the hinge single bolt tensioner **251** and the single bolt tensioners **250** as a safety measure. Alternatively, the seventh step S**670** may include tensioning each of the single bolt tensioners **250** and the hinge single bolt tensioner **251** to a predetermined tension such that a gap exists between the mating surfaces **222** of the module bodies **210**.

(66) It is noted that the foregoing examples have been provided merely for the purpose of explanation and are in no way to be construed as limiting of the present invention. While the present invention has been described with reference to exemplary embodiments, it is understood that the words, which have been used herein, are words of description and illustration, rather than words of limitation. Changes may be made, within the purview of the appended claims, as presently stated and as amended, without departing from the scope and spirit of the present invention in its aspects. Although the present invention has been described herein with reference to particular means, materials and embodiments, the present invention is not intended to be limited to the particulars disclosed herein; rather, the present invention extends to all functionally equivalent structures, methods and uses, such as are within the scope of the appended claims.

Claims

1. A buoyancy module comprising: a first and second module body, the first module body adapted to mate with the second module body, wherein each module body includes at least one recess comprising an upper portion and a bolt channel; the first and second module body each further comprising a contact face, the contact face of the first module body positioned and configured to align with the contact face of the second module body when the first and second module bodies are mated, wherein the first and second module body are each machined to remove material such that the contact face of the first module body and the contact face of the second module body are both comprised of a foam; a longitudinal channel running the length of at least the first module body, the longitudinal channel having a pad containment channel located therein; a pad positioned within the pad containment channel; and at least one single bolt tensioner, the at least one single bolt tensioner comprising a bolt, a cylindrical washer, and a cylindrical nut, wherein the at least one single bolt tensioner is positioned such that the bolt lies within the bolt channel of the first module body and the bolt channel of the second module body.

2. The buoyancy module of claim 1, wherein the bolt is an extended bolt.

3. The buoyancy module of claim 1, further comprising an alignment nut positioned along the bolt.

4. The buoyancy module of claim 1, wherein the at least one recess is a plurality of recesses and the at least one single bolt tensioner is a plurality of single bolt tensioners, wherein each of the plurality of single bolt tensioners is positioned such that the bolt of each of the plurality of single bolt tensioners lies within a bolt channel of the first module body and a bolt channel of the second module body.
5. The buoyancy module of claim 1, wherein an interior portion of each of the first and second module body are filled with a foam.
6. The buoyancy module of claim 5, wherein the foam is syntactic foam.
7. The buoyancy module of claim 1, wherein the pad containment channel is recessed within the longitudinal channel.
8. The buoyancy module of claim 1, wherein the pad containment channel is formed using a plurality of protrusions.
9. The buoyancy module of claim 1, wherein the first module body further comprises a mating surface having an alignment protrusion and the second module body further comprises a mating surface having an alignment recess, the alignment protrusion of the first module body configured to align with the alignment recess of the second module body when the first and second module body are mated.
10. The buoyancy module of claim 1, wherein the first and second module body each further comprise a contact surface, the contact surface of the first module body positioned and configured to align with the contact surface of the second module body when the first and second module bodies are mated.
11. The buoyancy module of claim 1, wherein the pad is comprised of a high friction material selected from the group of: EPDM rubber, neoprene rubber, natural rubber, and polyurethane.
12. A method of installing a buoyancy module on a cable, pipe, or umbilical, the method comprising: a. providing a buoyancy module comprising: i. a first and second module body, the first module body adapted to mate with the second module body, wherein each module body includes a plurality of recesses, each recess comprising an upper portion and a bolt channel; ii. the first and second module body each further comprising a contact face, the contact face of the first module body positioned and configured to align with the contact face of the second module body when the first and second module bodies are mated, wherein the first and second module body are each machined to remove material such that the contact face of the first module body and the contact face of the second module body are both comprised of a foam; iii. a longitudinal channel running the length of at least the first module body, the longitudinal channel having a pad containment channel located therein; iv. a pad positioned within the pad containment channel; and v. a first and second single bolt tensioner, each of the first and second single bolt tensioner comprising a bolt, a cylindrical washer, and a cylindrical nut; b. positioning the first and second module body about a cable, pipe, or umbilical such that the cable, pipe, or umbilical lies within the longitudinal channel of the first module body and contacts the pad; c. positioning the first and second single bolt tensioner such that each bolt is located within the bolt channel of the first and second module body and each cylindrical nut is positioned in a recess of one of the first and second module body and each cylindrical washer is positioned in a recess of the other of the first and second module body; and d. tensioning the first and second single bolt tensioner to mate the first and second module body.