

## DRILL RISER BUOYANCY MODULES

### FIELD OF INVENTION

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The invention relates broadly to the repair and reinforcement of drill riser buoyancy modules.

### BACKGROUND

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In offshore drilling operations, a drill riser provides a conduit for the drill string and drilling fluids from the ocean floor to the rig. The drill riser is made from carbon steel, with a number of ancillary lines attached to the central drill riser. The drill riser has significant weight in water and this weight has to be supported by the floating  
15 drilling vessel. In order to reduce the weight that the drilling vessel has to support, the drill riser string's weight in water is reduced by adding discrete buoyancy units called Drill Riser Buoyancy Modules (DRBMs) that are fitted along the length of the riser. This enables drilling at greater depth than would otherwise be possible.

20 DRBMs are generally semi-cylindrical, usually 4 to 5 meters long, comprising hollow spherical filler material and foam dispersed in an epoxy resin binder. The entire mixture is integrally molded within a durable outer skin. This outer skin is made from glass reinforced vinylester/epoxy resins or commonly termed as 'fiberglass'. Typically, two DRBMs, one on either side/s of the riser pipe, make up the riser pipe  
25 buoyancy assembly.

Out at sea, plastic or reinforced plastic materials are unable to withstand repeated impact against hard, unyielding surfaces such as steel decks or rotating machinery. Generally most damages to a DRBM would occur from rough handling by workers  
30 who are more accustomed to dealing with heavy steel assemblies and who do not make allowance for the different nature of handling of such modules. The hasty and harsh conditions, which are often a part of rig fit-out, also contribute to a DRBM's damage.

35 Damages to a DRBM are usually classified into:

- 1) Leading Edge Cracks and Damages

- 2) Surface Degradation
- 3) Transverse Cracks
- 4) Longitudinal Cracks

5     Surface Degradation and Leading Edge Cracks & Damages

Damage to leading edges from repeated impact against hard surfaces and surface degradation from weathering are the most common forms of damage. Although these damages may initially have very little effect on the performance of the DRBM even when held for long periods at their maximum service depth, the overall integrity  
10   of the DRBM may be compromised when exposed to repeated impacts.

Transverse & Longitudinal Cracks

Generally, DRBMs with transverse cracks are first subjected to a 'drop test' to determine a 'complete' fracture. A 'complete' fracture is where the DRBMs are  
15   severed into two or more separate pieces. If a DRBM sustains a 'complete' fracture, it will be deemed as unserviceable or beyond repair.

Longitudinal cracks on a DRBM are treated as unserviceable or beyond repair regardless of whether they are identified as having a 'complete' fracture.  
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Furthermore, besides damages, certain structural flaws may arise during the manufacturing of a DRBM. These flaws may weaken the structural integrity of the DRBM and may cause premature failure. In addition, there may be areas that are inherently weak due to their profile. These structurally weak areas need to be  
25   reinforced to prolong their service life.

A need therefore exists to provide a method for repairing or reinforcing DRBMs that seeks to address at least one of the above problems.

30   **SUMMARY**

According to a first aspect of the present invention, there is provided a method of repairing a cracked drill riser buoyancy module, comprising the steps of aligning a plurality of cracked pieces of the cracked module, cutting out one or more  
35   cavities in the aligned cracked pieces for positioning one or more reinforcement members across one or more crack-lines, inserting the reinforcement members and a filler material into the cavities and building a laminate across the filled cavities.

The module may be severed into separate cracked pieces prior to the alignment step.

In alternate embodiments, the cavities are preferentially cut out up to half-way of a thickness of the module.

In other embodiments, the reinforcement members can be made of fiberglass reinforced plastic.

The filler material preferentially comprises one or more of a group consisting of resin, Aerosil, talcum powder, and Microballoons.

In other embodiments, the laminate comprises one or more of a group consisting of a chopped strandmat layer, a woven roving layer and a surface veil layer.

According to another embodiment of the present invention, there is an apparatus that is repaired by implementing any one of the aforementioned methods.

In other embodiments, the laminate is built as follows: a first chopped strandmat layer; a first woven roving layer above the first chopped strandmat layer; a second chopped strandmat layer over the first woven roving layer; a second woven roving layer above the second chopped strandmat layer; a third chopped strandmat layer over the second woven roving layer; a third woven roving layer above the third chopped strandmat layer; a fourth chopped strandmat layer over the third woven roving layer; a fourth woven roving layer above the fourth chopped strandmat layer; a fifth chopped strandmat layer over the fourth woven roving layer; and a surface veil layer above the fifth chopped strandmat layer.

According to a second aspect of the present invention, there is provided a method of reinforcing an area on a drill riser buoyancy module, comprising the steps of cutting out one or more cavities in the module for positioning one or more reinforcement members, inserting the reinforcement members and a filler material into the cavities and building a laminate across the filled cavities.

Further, the area may be inherently structurally weak.

In alternate embodiments, the reinforcement members can be made of fiberglass reinforced plastic.

In other embodiments, the cavities are cut out up to half-way of a thickness of the module.

The filler material comprises one or more of a group consisting of resin, Aerosil, talcum powder, and Microballoons.

In further embodiments, the laminate comprises one or more of a group consisting of a chopped strandmat, a woven roving layer and a surface veil layer.

According to another embodiment of the present invention, there is an apparatus that is reinforced according to any one of the aforementioned reinforcing methods.

In other embodiments, the laminate is built as follows: a first chopped strandmat layer; a first woven roving layer above the first chopped strandmat layer; a second chopped strandmat layer over the first woven roving layer; a second woven roving layer above the second chopped strandmat layer; a third chopped strandmat layer over the second woven roving layer; a third woven roving layer above the third chopped strandmat layer; a fourth chopped strandmat layer over the third woven roving layer; a fourth woven roving layer above the fourth chopped strandmat layer; a fifth chopped strandmat layer over the fourth woven roving layer; and a surface veil layer above the fifth chopped strandmat layer.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

Example embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

Fig. 1a is a perspective view of a DRBM with a damaged surface that has been repaired.

Fig. 1b is a cross-sectional view along the section A-A of Fig 1a.

Fig. 1c shows an embodiment of a laminate of fiberglass reinforced plastic (FRP) in a DRBM with a damaged surface.

Fig. 2a is a perspective view of a DRBM having leading edge cracks that have been repaired.

Fig. 2b is a cross-sectional view along the section B-B of Fig 2a.

Fig. 2c shows an embodiment of a laminate of FRP.

Fig. 3a is a perspective view of a DRBM having a transverse crack that has been repaired.

Fig. 3b is a cross-sectional view along the section C-C of Fig 3a.

Fig. 3c is an enlarged view of area 350 of Fig 3b.

Fig. 4a is a perspective view of a DRBM having a longitudinal crack that has been repaired.

Fig. 4b is an enlarged view of section 450 of Fig. 4a.

Fig. 5 is a cross-sectional view of a reinforced DRBM.

Figure 6 is a flow chart illustrating one embodiment of a method of repairing a damaged surface of a DRBM.

Fig. 7 is a flow chart illustrating one embodiment of a method of repairing leading edge cracks on a DRBM.

Fig. 8 is a flow chart illustrating one embodiment of a method of repairing transverse cracks on a DRBM.

Fig. 9 is a flow chart illustrating one embodiment of a method of repairing longitudinal cracks on a DRBM.

Fig. 10 is a flow chart illustrating one embodiment of a method of reinforcing a DRBM.

5 Fig. 11 is a flow chart illustrating one embodiment of a method of coat painting a DRBM.

Fig. 12 is a flow chart illustrating another embodiment of a method of repairing cracks on a DRBM.

10 Fig. 13 is a flow chart illustrating another embodiment of a method of reinforcing a DRBM.

### DETAILED DESCRIPTION

15 Fig. 1a is a perspective view of a DRBM 101, designated generally as reference numeral 100, with a damaged surface cavity 102 that has been repaired and an undamaged original surface 104. It is understood that any number of damaged surface cavities may be present on any part of the DRBM's 101 surface.

20 Fig 1b shows a cross-sectional view along the section A-A of Fig 1a, in which the damaged surface cavity 102 is repaired by advantageously filling the cavity up with a layer of filler material, preferentially lightweight putty 108 and thereafter a laminate of fiberglass reinforced plastic (FRP) 106 is disposed above the putty layer 108. The lightweight putty 108 may, for example, comprise of one or more of resin, aerosol, talcum powder and Microballoons. The laminate of FRP 106 may, for example,  
25 comprise of a plurality of chopped strandmat (CSM) layers, woven roving layers (WR) and surface veil layers.

Fig 1c shows an embodiment of the laminate 106, designated generally as reference numeral 150, which may comprise one layer of CSM 111a followed by one layer of  
30 WR 110 disposed above it, further followed by another layer of CSM 111b that is disposed above said 2 layers 108a and 110, followed by a surface veil layer 112 disposed above the layer 111b. The CSM and WR layers are each approximately 0.8mm thick, while the surface veil layer is approximately 0.5mm thick. The total thickness of the laminate 106 is thus approximately 2.9mm.

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Fig. 2a is a perspective view of a DRBM 201, designated generally as reference numeral 200, with one of its leading edges 202a having two cracked surfaces 204a,

204b that have been repaired. It is understood that any number of cracked surfaces with differing sizes may form on any leading edge 202a/202b of the DRBM 201.

Fig 2b shows a cross-sectional view along the section B-B of Fig 2a, in which the cracked surfaces 204a, 204b are repaired by advantageously filling them up with a layer of filler material, preferentially lightweight putty 208 and thereafter a laminate of FRP 206 is disposed above the putty layer 208. The lightweight putty 208 may, for example, comprise of one or more of resin, aerosol, talcum powder and Microballoons. The laminate of FRP 206 comprises, for example, a plurality of CSM layers, WR layers and surface veil layers.

Fig 2c shows an embodiment of the laminate of FRP 206, designated generally as reference numeral 250, which may comprise a plurality of alternately disposed CSM layers 210a/210b/210c/210d/210e and WR layers 212a/212b/212c/212d, that are all eventually disposed below a surface veil layer 214. The CSM and WR layers are each approximately 0.8mm thick, while the surface veil layer is approximately 0.5mm thick. The total thickness of the laminate 206 is thus approximately 7.7mm.

Fig. 3a is a perspective view of a DRBM 301, designated generally as reference numeral 300, having a transverse crack 302 that has been repaired. The DRBM 301 may be severed into a plurality of separate pieces. In order to repair the damage caused by the crack 302 and to additionally reinforce the DRBM 301, it is preferred that a plurality of reinforcement members, advantageously FRP reinforcement pultrusion rods 304a – 304e are inserted into the DRBM 301 across the crack 302. The reinforcement rods may be of any suitable dimension.

Fig 3b shows a cross-sectional view along the section C-C of Fig 3a, in which the plurality of FRP reinforcement pultrusion rods 304a – 304e are inserted into the DRBM 301 to reinforce the same.

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Fig 3c shows an enlarged view of section 350 of Fig 3b, in which the remaining gaps in and/or around the crack are filled with a filler material, preferentially lightweight putty 308, in which the putty 308 is disposed below a laminate of FRP 310. The lightweight putty 308 may preferentially comprise of one or more of resin, Aerosil, talcum powder and Microballoons. The laminate of FRP 310 comprises, for example, a plurality of CSM layers, WR layers and surface veil layers.

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The laminate of FRP 310 is similar to Fig 2c, designated generally as reference numeral 250, which may comprise a plurality of alternately disposed CSM 210a/210b/210c/210d/210e and WR 212a/212b/212c/212d layers, that are all eventually disposed below a surface veil layer 214. The CSM and WR layers are each approximately 0.8mm thick, while the surface veil layer is approximately 0.5mm thick. The total thickness of the laminate 310 is thus approximately 7.7mm.

Fig. 4a is a perspective view of a DRBM 401, designated generally as reference numeral 400, having a longitudinal crack 402 that has been repaired. The DRBM 401 may be severed into a plurality of separate pieces. Fig. 4b shows an enlarged view of section 450 of Fig. 4a. In order to repair the damage caused by the longitudinal crack 402 and to reinforce the DRBM's 401 structure, the repaired DRBM 401 comprises of a plurality of reinforcement members, advantageously FRP reinforcing plates 404a – 404f, surrounded by a filler material, preferentially lightweight putty 406 and a laminate of FRP 408 that is built up over the respective reinforced areas, e.g. 409. The reinforcement plates 404a-f may be of any suitable dimension. The lightweight putty 406 may preferentially comprise of one or more of resin, Aerosil, talcum powder and Microballoons. The laminate of FRP 408 comprises, for example, a plurality CSM layers, WR layers and surface veil layers. It is noted that in the enlarged view of section 450, only a portion of the laminate of FRP 408 is shown for better clarity.

The laminate of FRP 408 is similar to Fig 2c, designated generally as reference numeral 250, which may comprise a plurality of alternately disposed CSM 210a/210b/210c/210d/210e and WR 212a/212b/212c/212d layers, that are all eventually disposed below a surface veil layer 214. The CSM and WR layers are each approximately 0.8mm thick, while the surface veil layer is approximately 0.5mm thick. The total thickness of the laminate 408 is thus approximately 7.7mm.

In addition to the reinforced areas e.g. 409, sufficient repair areas, e.g. 411, on the cracked surfaces of the DRBM 401 along the crack line 402 is grounded off to a taper. Thereafter, the areas, e.g. 411, are cleaned and a laminate of FRP e.g. 413 is built up. Next, the DRBM 401, after curing, can be flipped over to its other side and sufficient repair areas on the inside and around the crack line 402 can be grounded off, followed by built up of laminates of FRP.

Fig. 5 is a cross-sectional view of a DRBM 502, designated generally as reference numeral 500, having a plurality of areas 504a – 504b that have been reinforced.

These areas are inherently structurally weak due to their circular profile and are prone to premature failure. Other structurally weak areas of the DRBM may be present and are not mentioned here. Additionally, structurally weak areas may also arise due to manufacturing flaws. Moreover, reinforced areas need not be structurally weak nor suffer from manufacturing flaws – reinforcement can be carried out wherever strengthening is desired. Reinforcement members 506a – 506b are placed in the vicinity of the reinforced areas 504a – 504b and the remaining space around the reinforcement members is filled with a material comprising a filler material, preferentially lightweight putty 508a – 508b, and a laminate of FRP 510a – 510b. The lightweight putty 508a – 508b may preferentially comprise of one or more of resin, Aerosil, talcum powder and Microballoons. The laminate of FRP 510a – 510b may, for example, comprise a plurality of CSM layers, WR layers and surface veil layers.

The laminate of FRP 510a – 510b is similar to Fig 2c, and designated generally as reference numeral 250, which may comprise a plurality of alternately disposed CSM 210a/210b/210c/210d/210e and WR 212a/212b/212c/212d layers, that are all eventually disposed below a surface veil layer 214. The CSM and WR layers are each approximately 0.8mm thick, while the surface veil layer is approximately 0.5mm thick. The total thickness of the laminate 510a – 510b is thus approximately 7.7mm.

Figure 6 is a flow chart illustrating one embodiment of a method, designated generally as reference numeral 600, of repairing a damaged surface of a DRBM. The method begins with grinding off areas of the damaged surface of the DRBM 602. Thereafter, the surface that has been grounded is cleaned with compressed air and brushes 604. Next, acetone or any other suitable solvent is used to chemically clean the surface 606. Then, the surface, which is now uneven, is reshaped with a filler material, preferentially lightweight putty 608. The putty may, for example, comprise of one or more of resin, Aerosil, talcum powder and Microballoons. The surface, which has now been reshaped, is sanded and smoothened 610. Next, any dust on the DRBM is cleaned with compressed air and brushes 612. Thereafter, the reshaped surface is cleaned with acetone or any other suitable solvent 614. A laminate is built across the reshaped surface as follows: a CSM layer is disposed below a WR layer; the WR layer is then disposed below another subsequent CSM layer and a surface veil layer is disposed above all three layers 616. Next, the laminate is smoothly terminated at its edges complete with the surface veil layer so that any abrupt change on the DRBM's surface is avoided 618. Finally, the DRBM is fully cured for at

least 12 hours and coat painting is carried out if no more repair work on the DRBM is required 620.

Figure 7 is a flow chart illustrating one embodiment of a method, designated generally as reference numeral 700, of repairing leading edge cracks on a DRBM. The method advantageously begins with grinding off any areas with missing foam and also areas around the leading edge cracks 702. Thereafter, the areas that have been grounded are cleaned with compressed air and brushes 704. Next, acetone or any other suitable solvent is used to chemically clean the areas 706. Then, the areas with missing foam and the areas around the leading edge cracks are filled with a filler material, preferably putty 708. The putty is preferentially lightweight and may, for example, comprise one or more of resin, Aerosil, talcum powder and Microballoons. Then, the areas, which are uneven, are reshaped with said putty 710. The areas, which have now been reshaped, are sanded and smoothened 712. Next, any dust on the DRBM is cleaned with compressed air and brushes 714. Thereafter, the reshaped areas are cleaned with acetone or any other suitable solvent 716. A laminate is built across the reshaped areas as follows: a CSM layer is disposed below a WR layer; and this alternate layering of one CSM disposed below one WR layer is further continued thrice. Thereafter, a final CSM layer is disposed above the alternating CSM and WR layers. Finally, a surface veil layer is disposed above all nine layers 718. Next, the laminate is smoothly terminated at its edges so that any abrupt change of the DRBM's leading edge surface is avoided 720. Finally, the DRBM is fully cured for at least 12 hours and coat painting is carried out if no more repair work on the DRBM is required 722.

Figure 8 is a flow chart illustrating one embodiment of a method, designated generally as reference numeral 800, of repairing transverse cracks on a DRBM. The transverse cracks may each comprise a cracked surface. The transverse cracks may also sever the DRBM into a plurality of separate pieces. The method advantageously begins with aligning the plurality of cracked DRBM pieces together to abut their corresponding cracked surfaces 802. Next, all locations where a plurality of reinforcement members, preferably FRP pultrusion reinforcement bars, are to be placed on both pieces of the DRBM are marked out 804. Thereafter, a cutting disc may be used to cut out cavities for positioning the reinforcement bars 806 across one or more crack lines. The cavities are preferentially cut out up to half-way of the thickness of the DRBM. Next, a filler material, preferentially lightweight putty, may first be inserted into said cavities, followed by placing the reinforcement bars into the

same, and any remaining space in the cavities may be finally filled with said putty 808. The putty is preferentially lightweight and may, for example, comprise of one or more of resin, Aerosil, talcum powder and Microballoons. Next, a sufficient repair area on the cracked surfaces of the DRBM along a transverse crack line is grounded off to a taper 810. Thereafter, the area that has been grounded is cleaned with compressed air and brushes 812. Next, acetone or any other suitable solvent is used to chemically clean the area 814. The laminate is built across a transverse joint as follows: a CSM layer is disposed below a WR layer; this alternate layering of one CSM disposed below one WR layer is further continued thrice. Thereafter, a final CSM layer is disposed above the alternating CSM and WR layers. Finally, a surface veil layer is disposed above all nine layers 816. Next, the laminate is smoothly terminated at its edges so that any abrupt change of the DRBM's transverse joint surface is avoided 818. Next, the DRBM is fully cured for at least 12 hours and the DRBM is flipped over to its other side and steps 810 to 818 are repeated 820. Finally, the DRBM is fully cured again for at least 12 hours and coat painting is carried out if no more repair work on the DRBM is required 822.

Figure 9 is a flow chart illustrating one embodiment of a method, designated generally as reference numeral 900, of repairing longitudinal cracks on a DRBM. The longitudinal cracks may each comprise a cracked surface. The longitudinal cracks may sever the DRBM into a plurality of separate pieces. The method advantageously begins with aligning the plurality of cracked DRBM pieces together to abut the corresponding cracked surfaces 902. Next, all locations where a plurality of reinforcement members, preferably FRP reinforcement plates, are to be placed on both pieces of the DRBM are marked out 904. Thereafter, a cutting disc is used to cut out cavities for positioning the reinforcement plates 906. The cavities are preferentially cut out up to half-way of the thickness of the DRBM. Next, a filler material, preferentially lightweight putty may first be inserted into said cavities, followed by placing the reinforcement plates into the same, and any remaining space in the cavities is finally filled with said putty 908. The putty is preferentially lightweight and may, for example, comprise one or more of resin, Aerosil, talcum powder and-cell and Microballoons. Next, a sufficient repair area on the surface of the DRBM along a longitudinal crack line is grounded off to a taper 910. Thereafter, the area that has been grounded is cleaned with compressed air and brushes 912. Next, acetone or any other suitable solvent is used to chemically clean the area 914. The laminate is built across a longitudinal joint as follows: a CSM layer is disposed below a WR layer; this alternate layering of one CSM disposed below one WR layer is

further continued thrice. Thereafter, a final CSM layer is disposed above the alternating CSM and WR layers. Finally, a surface veil layer is disposed above all nine layers 916. Next, the laminate is smoothly terminated at its edges so that any abrupt change of the DRBM's longitudinal joint surface is avoided 918. Next, the DRBM is fully cured for at least 12 hours and the DRBM is flipped over to its other side and steps 910 to 918 are repeated 920. Finally, the DRBM is fully cured again for at least 12 hours and coat painting is carried out if no more repair work on the DRBM is required 922.

Figure 10 is a flow chart illustrating one embodiment of a method, designated generally as reference numeral 1000, of reinforcing structurally weak areas on a DRBM. If the structurally weak area on the DRBM is not reinforced, the DRBM's structural integrity may be compromised and this may lead to a shortened service life.

The method preferentially begins with marking out the locations where a plurality of reinforcement members, preferably FRP bars and/or reinforcement plates, are to be placed at the areas to be reinforced on the DRBM 1002. Reinforced areas need not be structurally weak nor suffer from manufacturing flaws – reinforcement can be carried out wherever strengthening is desired. Thereafter, a cutting disc is used to cut out cavities for positioning the reinforcement members 1004. The cavities are preferentially cut out up to half-way of the thickness of the DRBM. Next, a filler material, preferentially lightweight putty, may first be inserted into said cavities, followed by placing the reinforcement members into said cavities, and any remaining space in the cavities is finally filled with said putty 1006. The putty is preferentially lightweight and may, for example, comprise one or more of resin, Aerosil, talcum powder and Microballoons. Next, sufficient repair area in the vicinity of the reinforced area is grounded off to a taper 1008. Thereafter, the repair area that has been grounded is cleaned with compressed air and brushes 1010. Next, acetone or any other suitable solvent is used to chemically clean the repair area 1012. Thereafter, a laminate is built across the repair area as follows: a CSM layer is disposed below a WR layer; this alternate layering of one CSM disposed below one WR layer is further continued thrice. Thereafter, a final CSM layer is disposed above the alternating CSM and WR layers. Finally, a surface veil layer is disposed above all nine layers 1014. Next, the laminate is smoothly terminated at its edges so that there is any abrupt change of the DRBM's surface is avoided 1016. Next, the DRBM is fully cured for at least 12 hours and the DRBM is flipped over to its other side and steps 1008 to

1016 are repeated 1018. Finally, the DRBM is fully cured again for at least 12 hours and coat painting is carried out if no more repair work on the DRBM is required 1020.

Figure 11 is a flow chart illustrating one embodiment of a method, designated generally as reference numeral 1100, of coat painting a DRBM as disclosed in steps 620, 722, 822, 922 and 1020 above. The method preferentially begins with sanding any areas where repairs and/or reinforcements have been carried out 1102. Thereafter, the areas are cleaned with compressed air and brushes 1104. Next, the areas are preferentially cleaned with acetone or any other suitable solvent 1106. A first run of coating paint may then be applied on the DRBM's entire surface 1108. Subsequently, a second run of the paint is advantageously applied immediately after the first run 1100. Finally, the paint is left for approximately four hours for it to cure 1112.

Figure 12 is a flow chart 1200 illustrating a method of repairing a cracked drill riser buoyancy module according to another embodiment. At step 1202, a plurality of cracked pieces of the cracked module are aligned. At step 1204, one or more cavities are cut out in the aligned cracked pieces for positioning one or more reinforcement members across one or more crack-lines. At step 1206, the reinforcement members and a filler material are inserted into said cavities. At step 1208, a laminate is built across the filled cavities.

Figure 13 is a flow chart 1300 illustrating method of reinforcing an area on a drill riser buoyancy module. At step 1302, one or more cavities are cut out in the module for positioning one or more reinforcement members. At step 1304, the reinforcement members and a filler material are inserted into said cavities. At step 1306, a laminate is built across the filled cavities.

It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the embodiments without departing from a spirit or scope of the invention as broadly described. The embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

**CLAIMS**

1. A method of repairing a cracked drill riser buoyancy module, comprising the steps of:
- 5 aligning a plurality of cracked pieces of the cracked module;  
cutting out one or more cavities in the aligned cracked pieces for positioning one or more reinforcement members across one or more crack-lines;  
inserting the reinforcement members and a filler material into said cavities;  
and
- 10 building a laminate across the filled cavities.
2. The method according to claim 1, wherein the module is severed into separate cracked pieces prior to the alignment step.
- 15 3. The method according to claim 1, wherein the reinforcement members are made of fiberglass reinforced plastic.
4. The method according to claim 1, wherein the cavities are cut out up to half-way of a thickness of the module.
- 20 5. The method according to claim 1, wherein the filler material comprises one or more of a group consisting of resin, Aerosil, talcum powder, and Microballoons.
- 25 6. The method according to claim 1, wherein the laminate comprises one or more of a group consisting of a chopped strandmat layer, a woven roving layer and a surface veil layer.
7. The method according to claim 1, wherein the laminate is built as follows:
- 30 a first chopped strandmat layer;  
a first woven roving layer above the first chopped strandmat layer;  
a second chopped strandmat layer over the first woven roving layer;  
a second woven roving layer above the second chopped strandmat layer;  
a third chopped strandmat layer over the second woven roving layer;  
a third woven roving layer above the third chopped strandmat layer;  
35 a fourth chopped strandmat layer over the third woven roving layer;  
a fourth woven roving layer above the fourth chopped strandmat layer;  
a fifth chopped strandmat layer over the fourth woven roving layer; and

a surface veil layer above the fifth chopped strandmat layer.

- 5 8. A method of reinforcing an area on a drill riser buoyancy module, comprising the steps of:
- cutting out one or more cavities in the module for positioning one or more reinforcement members;
- inserting the reinforcement members and a filler material into said cavities;
- and
- 10 building a laminate across the filled cavities.
9. The method according to claim 8, wherein the area is inherently structurally weak.
10. The method according to claim 8, wherein the reinforcement members are made of fiberglass reinforced plastic.
- 15 11. The method according to claim 8, wherein the cavities are cut out up to half-way of a thickness of the module.
- 20 12. The method according to claim 8, wherein the filler material comprises one or more of a group consisting of resin, Aerosil, talcum powder, and Microballoons.
13. The method according to claim 8, wherein the laminate comprises one or more of a group consisting of a chopped strandmat, a woven roving layer and a surface veil layer.
- 25 14. The method according to claim 8, wherein the laminate is built as follows:
- a first chopped strandmat layer;
- a first woven roving layer above the first chopped strandmat layer;
- 30 a second chopped strandmat layer over the first woven roving layer;
- a second woven roving layer above the second chopped strandmat layer;
- a third chopped strandmat layer over the second woven roving layer;
- a third woven roving layer above the third chopped strandmat layer;
- a fourth chopped strandmat layer over the third woven roving layer;
- 35 a fourth woven roving layer above the fourth chopped strandmat layer;
- a fifth chopped strandmat layer over the fourth woven roving layer; and
- a surface veil layer above the fifth chopped strandmat layer.

**DRILL RISER BUOYANCY MODULES****ABSTRACT**

5           A method of repairing a cracked drill riser buoyancy module and a method of  
reinforcing an area on a drill riser buoyancy module. The method of repairing a  
cracked drill riser buoyancy module comprises the steps of aligning a plurality of  
cracked pieces of the cracked module, cutting out one or more cavities in the aligned  
cracked pieces for positioning one or more reinforcement members across one or  
10 more crack-lines, inserting the reinforcement members and a filler material into the  
cavities and building a laminate across the filled cavities.

Figure 12