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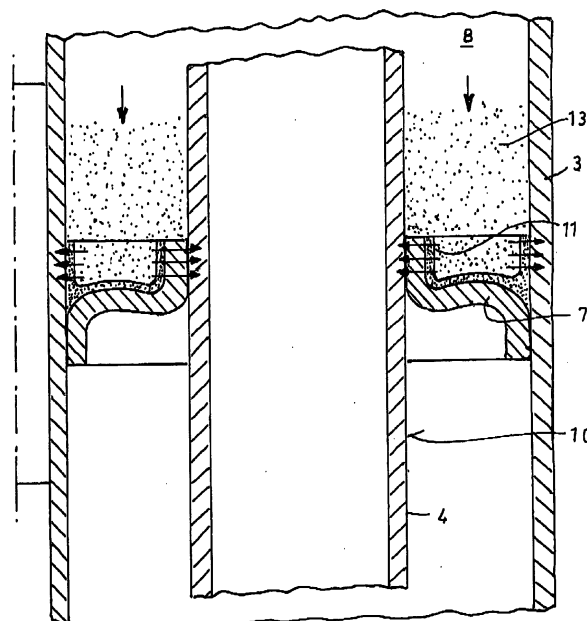
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(54) **Grout seal and method to grout an annular space between two foundation members of an offshore structure**

(57) The invention refers to a grout seal for sealing the annular space (8) between two concentrically placed foundation members of an offshore structure. The grout seal includes at least one resilient primary sealing member attached to the inner wall of an outer foundation member, said primary sealing member extending peripherally within the annular space (8) between the foundation members and resting against an outer wall of the inner

foundation member in order to seal a grout (13) against the ingress of water and to secure said grout (13) against egress into water. The grout seal includes at least one elastically compressible secondary sealing member (11) directly exposed to said grout (13) and being arranged in a fashion that allows said secondary sealing member (11) to be at least partially radially compressed by the pressure exerted by the grout mass.

Fig.3



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Description

[0001] The invention refers to a grout for sealing the annular space between two concentrically placed foundation members of an offshore structure including at least one sealing member extending within the annular space between the foundation members in order to seal a grout against the ingress of water and to secure said grout against egress into water.

[0002] The invention furthermore refers to a method to grout an annular space between two foundation members of an offshore structure.

[0003] A grout seal and a method for grouting are for instance disclosed in GB 2 433 540 A. According to the grouting method disclosed in this reference, there is provided in addition to a primary seal to support the grout column a secondary contingency brush seal to support the grout if the primary seal fails. This method is particularly intended for grouting the annuli between an offshore platform leg or pile sleeve and a foundation pile driven there through.

[0004] A method for grouting annuli in offshore platforms is also disclosed in European patent application 0 204 041. This reference moreover discloses a grouting arrangement for an offshore platform having an annular support member, having in turn a pile driven there through forming an annular space there between. This arrangement comprising a seal assembly including a lower pile seal assembly attached to the annular support member and an upper pile seal assembly attached to said annular support member. The grout system for grouting said annular space includes a control valve for controlling the flow of grouting material into said annular space, a surface grout line leading to the control valve, and a first line leading from the control valve to said annular space. The annular space is located between the lower and upper pile seal assembly, a lower pile seal assembly provides a small annular space in which a material can be pumped to seal the space and which has great enough load-bearing strength to support in conjunction with a pile seal member a grout column in an annular space above the aforementioned space.

[0005] Tubular grouted connections as aforementioned are commonly used in offshore constructions, including offshore wind turbine generator support structures. The connection may be between a transition piece and pile on a monopile-type foundation or between a pile and pile sleeve of a jacket or a tripod-type foundation. As this is for instance also disclosed in EP 0 204 041 A, rubber wiper seals are normally used as a temporarily seal at the bottom of tubular grouted connections to contain the grout prior to its curing. After curing, the grout is normally self-supporting. Common grouted connections normally rely on a pressure being exerted on the top of the seal by the uncured grout to maintain a seal between for instance the pile sleeve and the pile against ingress of salt water as long as the grout is not yet cured.

[0006] Sometimes, as this is the case with the grouting

method disclosed in EP 0 204 041 A, additional sealing measures have been proposed in order to provide proper sealing against the ingress of water and in order to secure said grout against egress into water.

[0007] When the grouted connection is subject to bending, relative displacement of the outer wall relative to the inner wall will occur. With the current design, this means that a gap will open between the seal and the inner wall and the seal will be lost. The loss of seal has the consequence that water can enter the grouted connection which as a detrimental impact on the fatigue performance of the grout. In the event of local grout crushing or cracking at the highly stressed end of the grouted connection, the seal is not able to prevent loss of crushed/cracked grout material. The likelihood of grout material being lost is increased, since the seal does not prevent the ingress and egress of water.

[0008] As this can be for instance taken from the aforementioned patent publication, the known grouted connections suffer also from the disadvantage that a loss of grout during establishment of the grouted connection might occur.

[0009] It is thus an object of the present invention to provide a grouted seal which does not suffer from the above-mentioned disadvantages. It is moreover an object of the present invention to provide a method to grout an annular space between two foundation members avoiding the above-mentioned disadvantages. This and other objects are solved by the invention as defined by the independent claims. Advantageous embodiments may be derived from the dependent claims.

[0010] The invention provides a grout seal for sealing the annular space between two concentrically placed foundation members of an offshore structure including at least one sealing member extending within the annular space between the foundation members in order to seal a grout against the ingress of water and to secure said grout against egress into water. This grout seal is characterized by at least one elastically compressible member extending within said annular space and permanently providing an active pressure acting radially against horizontal or radial displacement of the foundation members relative to each other.

[0011] Said elastically compressible member will expand and contract with the horizontal displacement of the foundation members relative to each other. This results in a reduction of stresses in the grout at the end of the connection.

[0012] In one advantageous embodiment of the grout seal according to the present invention, said elastically compressible member is in the form of a packer. Packers as such are well-known in the art for well completions. Such packers are devices used to isolate the annulus or ancre or secure the bottom of a production tubing string of oil field or gas field.

[0013] Such a packer may for instance provide a primary sealing for said grout.

[0014] Such packer alternatively may provide a sec-

ondary sealing for said grout and may for instance be provided below or above an ordinary wiper seal.

[0015] In a particularly preferred embodiment of the grout seal according to the invention, said packer may comprise an elastically deformable member which is set hydraulically or by a pressurized gas, the grout may or may not rest on said packer. An additional seal in form of a wiper seal may be included above said packer.

[0016] The grout seal according to another preferred embodiment of the invention comprises at least one resilient primary sealing member attached to the inner wall of an outer foundation member or to the outer wall of an inner foundation member and resting against the outer wall of the inner foundation member or resting against the inner wall of the outer foundation member in order to seal said grout against the ingress of water and/or to secure said grout against egress into water, this grout seal being characterized by at least one elastically compressible secondary sealing member directly exposed to the said grout and being arranged in a fashion that allows said secondary sealing member to be at least partially readily compressed by the pressure exerted by the grout mass.

[0017] Said sealing member will be radially compressed by the mass of the "wet" grout column exerting pressure on the sealing member. Once the grout is fully cured, due to the elastic deformation of the secondary sealing member, said sealing member will expand and contract with the horizontal displacement of the outer wall relative to the inner wall. This results in a reduction of stresses in the grout at the end of the connection. Moreover, a sealing engagement of the sealing member with the surrounding material is always provided due to the resilience of the material and due to the compression force stored in the material of the sealing member.

[0018] It is particularly advantageous that the secondary sealing member provides an active pressure acting radially against horizontal or radial displacement of the foundation member relative to each other.

[0019] In one particularly preferred embodiment of the invention, the secondary sealing member is directly attached to the primary sealing member. The secondary sealing member for instance can be glued or sprayed onto the rubber wiper seal providing the primary seal and/or onto the steel walls of the foundation members. The secondary sealing member can be provided in the form of a foamed material, which for instance has been expanded by a chemical reaction. The secondary sealing member may for instance be provided as a foamed polyurethane sealing.

[0020] The primary sealing member may be in the form of a diaphragm-type wiper seal, the lower, downwardly facing surface of which peripherally rests against the outer wall of the inner foundation member.

[0021] The secondary sealing member may be at least partially attached to the upper surface of the primary sealing member. As aforementioned, the secondary sealing member can be provided as an elastically deformable

and compressible layer directly attached to the surface of the primary sealing member. Attached in the sense of the present invention means "glued", "sprayed", or "welded" onto the primary sealing member.

[0022] Alternatively or additionally, a secondary sealing member may be at least partially attached to the inner wall of the outer foundation member or the outer wall of the inner foundation member.

[0023] It is readily apparent for a person skilled in the art that many variations of the secondary seal member are within the scope of the present invention as long as the secondary sealing member exerts expansion forces acting readily between the foundation members.

[0024] In a particularly preferred embodiment of the grout seal according to the present invention, the secondary sealing member is a compressible membrane which has preferably being glued, welded or sprayed onto the primary seal and/or the inner wall of the outer foundation member and/or the outer wall of the inner foundation member.

[0025] Alternatively, the secondary sealing member may comprise at least one elastomeric pad which has been placed so between the inner wall of the outer foundation member and the outer wall of the inner foundation member that it may be at least partially radially compressed by the pressure exerted by the grout mass.

[0026] According to yet another aspect of the present invention, there is provided a grout seal for sealing the annular space between two concentrically placed foundation members of an offshore structure including at least one resilient sealing member attached to the inner wall of an outer foundation member, said sealing member extending peripherally within the annular space between the foundation members in order to seal a grout against the ingress of water and to secure said grout against egress into water, this grout seal being characterized in that the sealing member at least where exposed to said grout has elastically compressible/deformable properties to such an extent that it may be compressed by the grout and provides an active pressure after the grout has been cured.

[0027] The sealing member may be positioned and dimensioned such that it provides an active pressure acting radially against horizontal or radial displacement of the foundation members relative to each other.

[0028] According to yet another aspect of the present invention, there is provided a method to grout an annular space between two foundation members of an offshore structure.

[0029] The object of the invention is also achieved by a method to grout an annular space between two foundation members of an offshore structure, the method including providing at least one elastically deformable member extending in the annular space such that the elastically member provides an active pressure acting radially against horizontal and/or radial displacements of the foundation members relative to each other.

[0030] The method according to the invention prefer-

ably includes providing at least one elastically compressible sealing member, exposing said sealing member to a grout to be filled into said annular space such that it is at least partially compressed by the mass of said grout while not yet cured to such an extent that the sealing member provides an active pressure acting radially against horizontal or radial displacement of the foundation members relative to each other.

[0031] One preferred variant of the method according to the invention is characterized by providing at least a primary and a secondary sealing member, whereas the secondary sealing member is elastically compressible.

[0032] It is particularly advantageous when the secondary sealing is placed above the primary sealing member so that the secondary sealing member at least carries a part of the weight force exerted by the column of the wet grout resting on the sealing member.

[0033] The invention in the following will be described by way of example with reference to the accompanying drawings in which:

Figure 1 shows in a rather simplified manner an offshore platform with a jacket foundation comprising pile sleeves enclosing foundation piles,

Figure 2 shows an enlarged detail of the grouted connection of the pile sleeves and piles shown in Figure 1, as a sectional view prior to grouting,

Figure 3 shows an enlarged longitudinal sectional view corresponding to the view in Figure 2 with the injected grout mass,

Figure 4 shows another embodiment of the grouted connection according to the present invention, and

Figure 5 shows yet another embodiment of the grouted connection according to the present invention.

[0034] Figure 1 shows a part of an offshore platform, namely a jacket foundation 1 the legs 2 of which are provided with pile sleeves 3, which are penetrated by piles 4 fixed to the sea floor 5. In this specific embodiment as described hereinafter, the piles 4 have been rammed into the sea floor prior to attachment of the jacket foundation 1. It is to be understood that of course the grout seal according to the present invention is suitable and applicable for any type of offshore foundations, namely also for monopile foundations. By way of example the specific embodiment refers, however, to a jacket foundation.

[0035] The piles of the jacket foundation according to the specific embodiment have been driven through a template in order to determine the exact position of the piles 4. This method is commonly known is prepiling as op-

posed to so-called postpiling, where the jacket foundation 1 is first placed on the sea floor 5 and the piles 4 are rammed through the pile sleeves 3 afterwards.

[0036] With the instant embodiment, the jacket foundation 1 has been placed on the sea floor 5 after ramming of the piles 4 in predetermined positions. The jacket foundation 1 has been placed onto the piles 4 such that the piles 4 extend through the pile sleeves 3. This connection has been grouted afterwards as this will be described in more detail in the following.

[0037] As this can be taken from Figure 2, the pile sleeve 3 defines an outer foundation member, whereas the pile 4 defines an inner foundation member. Attached to the inner wall 6 of the outer foundation member, i.e. the pile sleeve 3, is a diaphragm-type wiper seal 7. The inner foundation member is defined by the pile 4, the pile sleeve 3 and the pile 4 being concentrically placed with respect to one another defining an annular space 8 there between. The wiper seal 7 at its inwardly directed rim 9 rests against an outer wall 10 of the pile 4.

[0038] A person skilled in the art will appreciate that the grouted connection/grout seal according to the instant application must not necessarily be a connection between pile sleeves and piles, but rather may be any connection between foundation members more or less concentrically arranged within each other and defining an annular space there between.

[0039] Also it is not necessarily required that the outer foundation member and the inner foundation member have circular cross sections, although in the instant application for the sake of simplification the term "concentrically" is being used.

[0040] Figure 2 shows the connection still to be grouted where the piles 4 already penetrate the pile sleeves 3. The diaphragm-type wiper seal 7 which for instance may be made from a resilient rubber-type material has been pierced and/or deflected by the pile 4 while the pile sleeve 3 has been put on the pile 4.

[0041] Although a conventional wiper seal has a certain resilience, this material is not compressible.

[0042] As this can be taken from Figures 2 and 3, attached to the upwardly facing surface of the wiper seal 7 is a secondary sealing member 11 which is for instance made from a compressible foamed material. The secondary sealing member 11 fully covers the upper surface of the wiper seal as well as part of the inner wall 6 of pile sleeve 3 so that the secondary sealing member together with the wiper seal form a kind of pocket 12 for receiving a grout 13. The grout may be in form an alkali silicate material which cures upon contact with a curing agent. The grout 13 may be injected into the annular space 8 via a grouting line, which for the sake of simplification is not shown in the drawings. The grouting line will lead into the annular space 8 somewhere above the wiper seal 7.

[0043] Figure 3 shows the grouted connection according to the invention with the grout 13 filled in. The column of the grout mass 13 resting on the wiper seal will consequently compress the secondary sealing member as

this is suggested in Figure 3. After the grout 13 has been cured, the mass of the grout 13 will not fully rest on the wiper seal 7 anymore. Moreover, the grout 13 will shrink to a certain extent upon hardening. Due to the compressibility of the secondary sealing member 11, the sealing member provides an active pressure and seal during horizontal displacements of the pile sleeves 6 relative to the piles 4, as this is suggested by the arrows in Figure 3. This pressure is constantly urging the wiper seal into engagement of the outer wall 10 of the pile 4. Although this seems to be clear from the above-given description/explanations, it is to be mentioned that the wiper seal 7 completely peripherally surrounds the pile 4 and completely fills the annular space 8 between the pile sleeves 3 and piles 4.

[0044] An alternative embodiment of the present invention is shown in Figure 4 which shows the ungrouted connection. Same parts are provided with the same reference numerals.

[0045] As this may be taken from Figure 4, the secondary sealing member is only in the form of a compressible sealing pad 14 attached to the upper surface of the wiper seal 7 and covering only the peripheral rim of the wiper seal 7 in the area where the wiper seal 7 is deflected by the pile 4 and extends vertically.

[0046] In an alternative embodiment to that, the secondary sealing member 11 may for instance only be provided on the inner wall 6 of the pile sleeve 3 in that area where the wiper seal 7 and the pile sleeve 3 form a pocket 12 for receiving the grout 13.

[0047] Yet another embodiment of the grout seal according to the present invention may be taken from Figure 5 of the appended drawings. Same parts are denoted by the same reference numerals.

[0048] In this third embodiment according to the invention, a primary sealing member is provided by a grout packer 15 which is designed as an elastically deformable hollow torus member attached to the inner wall 6 of the pile sleeves 3 which in this embodiment form the outer foundation member. The grout packer 15 is filled with a liquid or a gas or a curable elastically deformable material and maintains an active pressure and seal during horizontal displacement of the inner wall 6 of the pile sleeves 3 relative to the outer wall 10 of the pile 4. In the embodiment as shown in Figure 5, the grout 13 rests on the grout packer 15, however, there may be provided an additional wiper seal above or below the grout packer 15.

[0049] In the embodiment shown in Figure 5, the grout packer 15 is attached to the inner wall 6 of the pile sleeve 3, however, the grout packer 15 may also be attached to the outer wall 10 of the pile 4.

Reference numerals

[0050]

1 jacket foundation

2 legs
3 pile sleeves
4 piles
5 sea floor
6 inner wall
7 wiper seal
8 annular space
9 rim of wiper seal
10 outer wall of pile
11 secondary sealing member
12 pocket
13 grout
14 sealing pad
15 grout packer

30 Claims

1. Grout seal for sealing the annular space (8) between two concentrically placed foundation members of an offshore structure including at least one sealing member extending within the annular space (8) between the foundation members in order to seal a grout (13) against the ingress of water and/or to secure said grout (13) against egress into water, **characterized by** at least one elastically compressible member extending within said annular space (8) and permanently providing an active pressure acting radially against horizontal or radial displacement of the foundation members relative to each other.
2. Grout seal according to claim 1, **characterized in that** said elastically compressible member is in the form of a packer (15).
3. Grout seal according to claim 2, **characterized in that** said packer (15) provides a primary sealing for said grout (13).
4. Grout seal according to claim 2, **characterized in that** said packer (15) provides a secondary seal for said grout (13).
5. Grout seal according to anyone of the preceding claims, **characterized in that** said packer (15) com-

prises an elastically deformable member which is preferably set hydraulically or by a pressurized gas.

6. Grout seal according to anyone of the preceding claims comprising at least one resilient primary sealing member attached to the inner wall (6) of an outer foundation member or to the outer wall of an inner foundation member and resting against the outer wall (10) of the inner foundation member or resting against the inner wall of the outer foundation member in order to seal said grout (13) against the ingress of water and/or to secure said grout against egress into water, and comprising at least one elastically compressible secondary sealing member (11) directly exposed to said grout (13) and being arranged in a fashion that allows said secondary sealing member (11) to be at least partially radially compressed by the pressure exerted by the grout mass.
7. Grout seal according to claim 6, **characterized in that** the secondary sealing member (11) provides an active pressure acting radially against horizontal or radial displacement of the foundation members relative to each other.
8. Grout seal according to claim 6 or 7, **characterized in that** the secondary sealing member (11) is directly attached to the primary sealing member.
9. Grout seal according to anyone of claims 6 to 8, **characterized in that** the primary sealing member is diaphragm-type wiper seal (7), the lower, downwardly facing surface of which peripherally rests against the outer wall (10) of the inner foundation member.
10. Grout seal according to anyone of claims 6 to 9, **characterized in that** the secondary sealing member (11) is at least partially attached to the upper surface of the primary sealing member.
11. Grout seal according to anyone of claims 6 to 10, **characterized in that** the secondary sealing member (11) is at least partially attached to the inner wall (6) of the outer foundation member.
12. Grout seal according to anyone of claims 6 to 9, **characterized in that** the secondary sealing member (11) is attached to the outer wall of the inner foundation member.
13. Grout seal according to anyone of claims 6 to 12, **characterized in that** the secondary sealing member (11) is a compressible membrane which preferably has been glued, welded or sprayed onto the primary sealing member and/or the inner wall of the outer foundation member and/or on the outer wall of the inner foundation member.

14. Grout seal according to anyone of claims 6 to 13, **characterized in that** the secondary sealing member (11) comprises at least one elastomeric pad (14).
15. Grout seal for sealing the annular space (8) between two concentrically placed foundation members of an offshore structure including at least one resilient sealing member attached to the inner wall of the outer foundation member, said sealing member extending peripherally within the annular space between the foundation members in order to seal a grout (13) against the ingress of water and secure said grout (13) against egress into water, **characterized in that** the sealing member at least where exposed to said grout (13) has elastically compressible properties to such an extent that it may be compressed by the grout (13) and provides an active pressure after the grout (13) has been cured.
16. Grout according to claim 15, **characterized in that** the sealing member is positioned and dimensioned such that it provides an active pressure acting radially against horizontal or radial displacements of the foundation members relative to each other.
17. Method to grout an annular space between two foundation members of an offshore structure, the method including providing at least one elastically compressible member extending within said annular space and providing an active pressure acting radially against horizontal or radial displacement of the foundation members relative to each other.
18. Method according to claim 17, the method including providing at least one elastically compressible sealing member to a grout to be filled within said annular space such that the sealing member is at least partially compressed by the mass of said grout while not yet cured to such an extent that the sealing member provides an active pressure acting radially against horizontal and/or radial displacement of the foundation members relative to each other.
19. Method according to anyone of claims 17 or 18, **characterized by** providing at least a primary and a secondary sealing member, whereas the secondary sealing member is elastically compressible.
20. Method according to anyone of claims 17 or 19, **characterized in that** the secondary sealing member is placed above the primary sealing member.

Fig.1

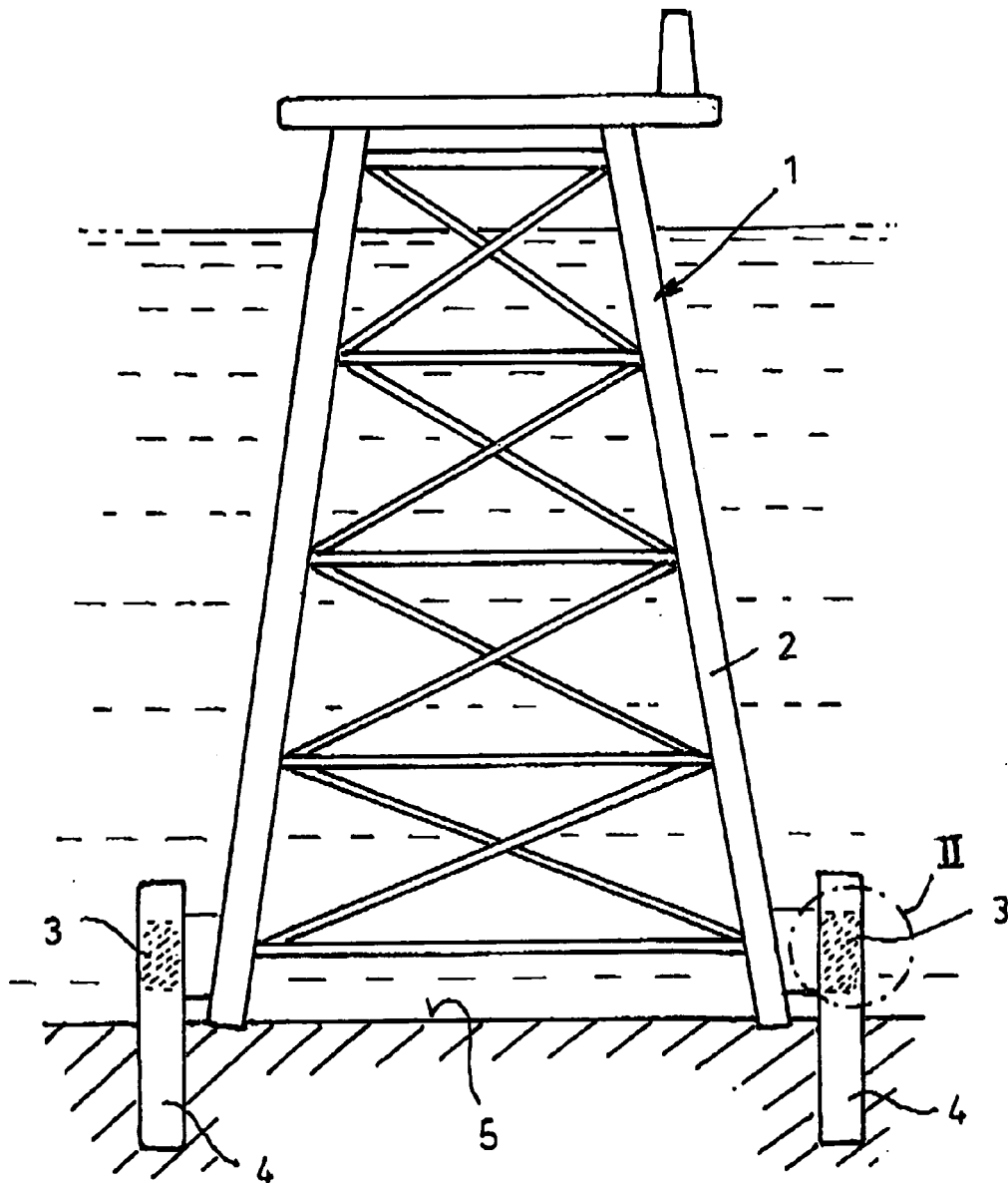


Fig.2

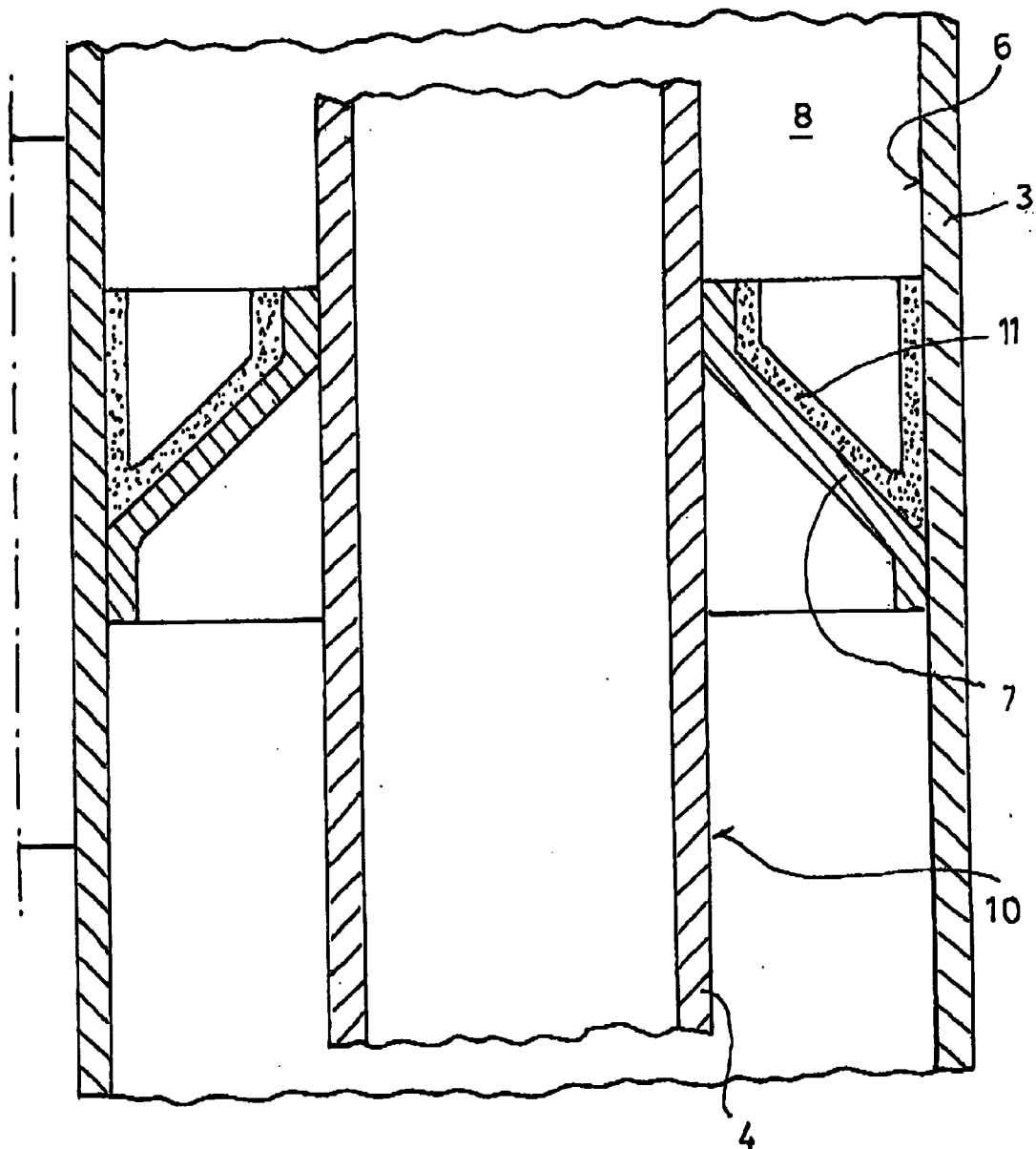


Fig. 3

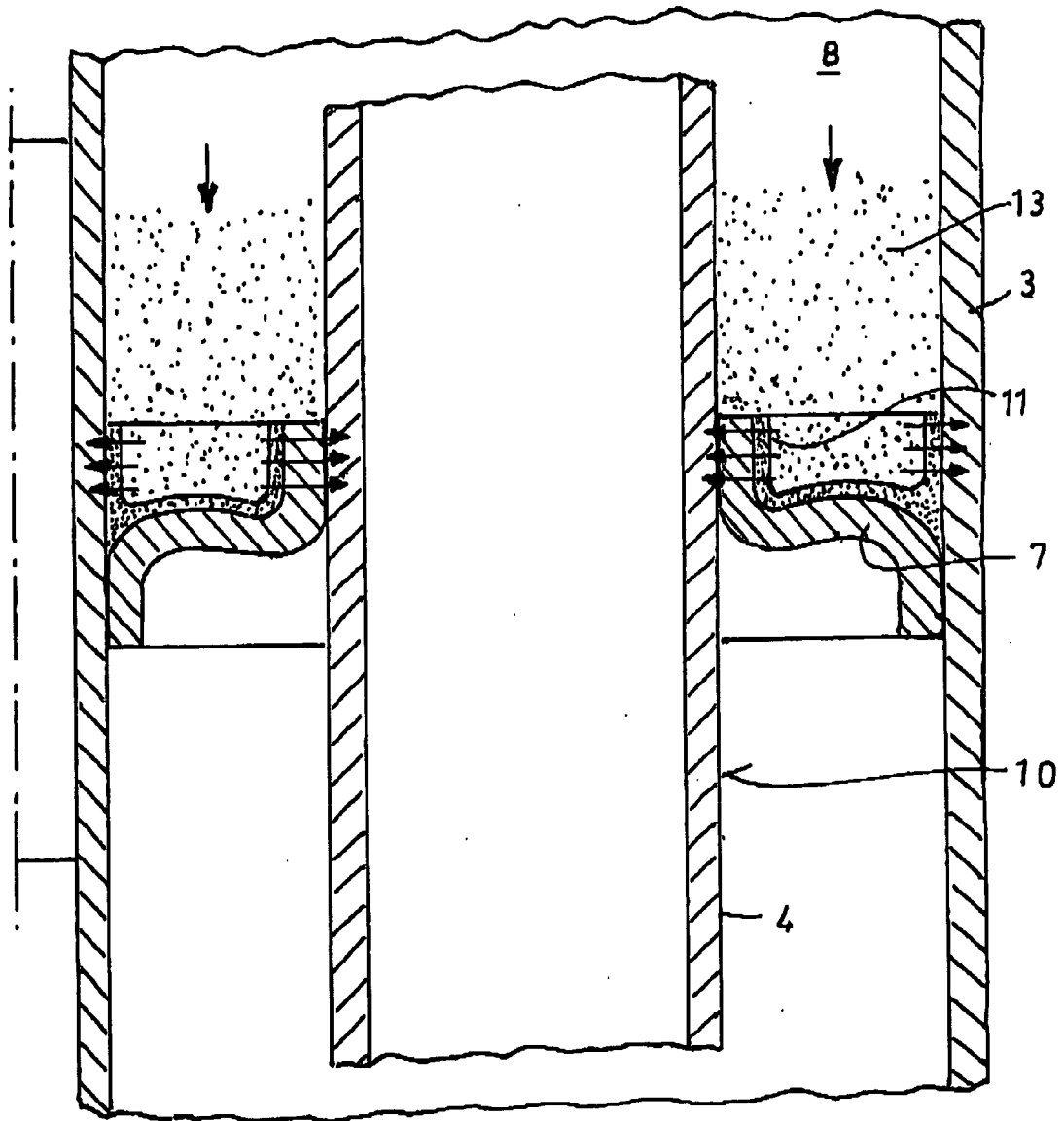


Fig.4

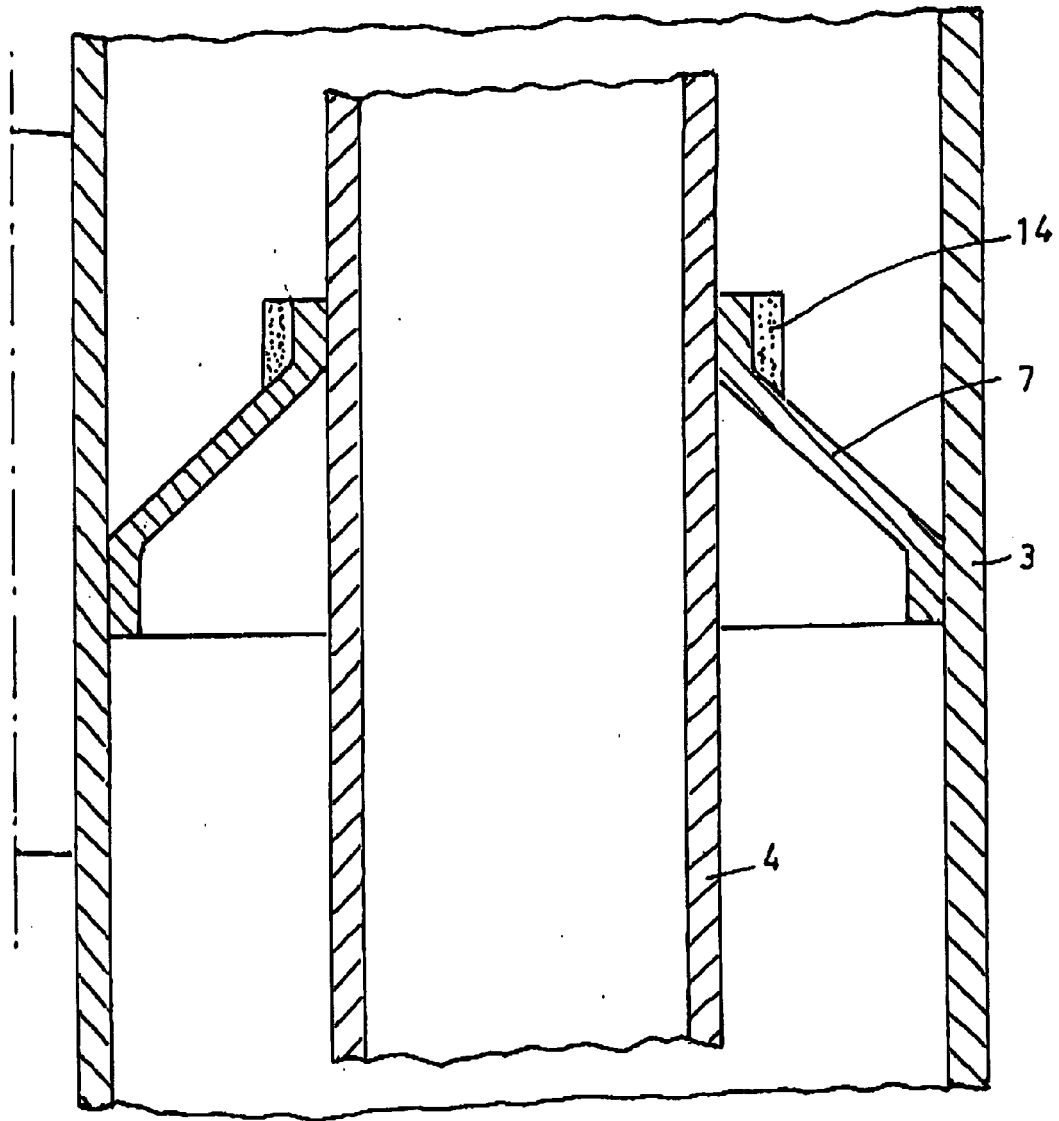
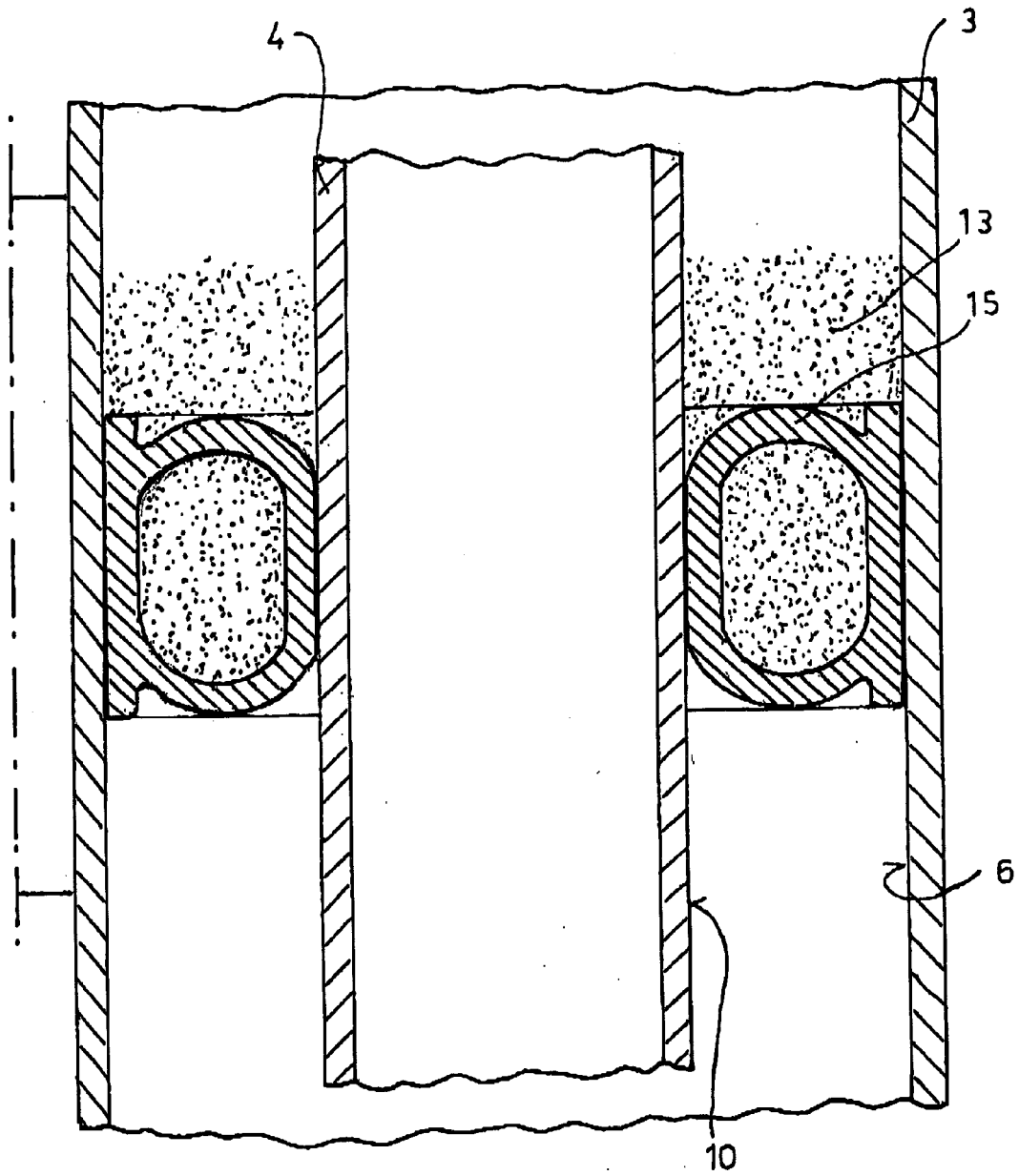


Fig.5





EUROPEAN SEARCH REPORT

Application Number
EP 12 00 4238

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X,D	GB 2 433 540 A (HARDY MARTIN [GB]; LTD SEAMARK SYSTEMS [GB]) 27 June 2007 (2007-06-27) * the whole document *	1-7,11, 12,17-20	INV. E02D27/42 E02D27/50
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			TECHNICAL FIELDS SEARCHED (IPC)
			E02D
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 18 December 2012	Examiner Friedrich, Albert
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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18-12-2012

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REFERENCES CITED IN THE DESCRIPTION

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- EP 0204041 A [0004] [0005] [0006]