Title: SEAL ARRANGEMENT AND METHOD OF SEALING

FIG. 1

Abstract: A seal arrangement includes a body having at least two walls defining a cavity, the walls are engagable with at least one structure through expansion of the body, and graphite is sealingly engaged with the body and the structure and resiliently compressively maintained within the cavity by the at least one structure.
SEAL ARRANGEMENT AND METHOD OF SEALING

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Application No. 14/090307, filed on November 26, 2013, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Elastomers are commonly used to seal members to one another because of their ability to seal to surfaces that are rough or include imperfections. Applications for such seals include tubular systems employed in earth formation boreholes such as in the hydrocarbon recovery and carbon dioxide sequestration industries. Such seals however can degrade at high temperatures and high pressures and in corrosive environments. Operators, therefore, are always receptive to new sealing arrangements and methods that overcome these shortcomings.

BRIEF DESCRIPTION

[0003] Disclosed herein is a seal arrangement. The seal arrangement includes a body having at least two walls defining a cavity, the walls are engagable with at least one structure through expansion of the body, and graphite is sealingly engaged with the body and the structure and resiliently compressively maintained within the cavity by the at least one structure.

[0004] Further disclosed herein is a method of sealing. The method includes, positioning graphite within a cavity defined by walls of a body, expanding the body, engaging at least one structure with the walls, expanding the graphite, compressing the graphite against the at least one structure and sealing the graphite to the at least one structure and the body.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

[0006] FIG. 1 depicts a partial cross sectional view of a seal arrangement disclosed herein in a sealing position;

[0007] FIG. 2 depicts a partial cross sectional view of an embodiment of the seal arrangement of FIG. 1 in a non-sealing position;
FIG. 3 depicts a partial cross sectional view of an alternate embodiment of the
seal arrangement of FIG. 1 in a non-sealing position;

FIG. 4 depicts a partial cross sectional view of an alternate seal arrangement
disclosed herein;

FIG. 5 depicts a partial cross sectional view of another alternate seal
arrangement disclosed herein in a non-sealing position; and

FIG. 6 depicts a partial cross sectional view of the seal arrangement of FIG. 5
in a sealing position;

FIG. 7 depicts a partial cross sectional view of an alternate embodiment of a
seal arrangement disclosed herein with a portion thereof shown at a greater magnification;

FIG. 8 depicts a perspective view of an alternate embodiment of a seal
arrangement disclosed with the body and outer structure removed; and

FIG. 9 depicts a perspective view of the embodiment of FIG. 8 at a different
position.

DETAILED DESCRIPTION

A detailed description of one or more embodiments of the disclosed apparatus
and method are presented herein by way of exemplification and not limitation with reference
to the Figures.

Referring to Figure 1, an embodiment of a seal arrangement disclosed herein
is illustrated generally at 10. The seal arrangement 10 includes expandable graphite 14
positioned within a cavity 18 in a body 22, and the graphite 14 sealably engages with a
structure 26 proximate an opening 30 in the body 22. The graphite 14 is volumetrically
expandable in response to specific changes in environment such as changes in temperature,
for example. Volumetric expansion of the graphite 14 causes it to be forcedly engaged with
walls 34 of the body 22 as well as to forcedly engage with a surface 38 of the structure 26.
The graphite 14 is deformable such that it conforms to troughs 42, peaks 46 and other
imperfections in the surface 38 creating a seal between the graphite 14 and the structure 26 in
the process. The graphite 14 also seals to the walls 34 of the body 22 thereby resulting in the
body 22 being sealably engaged to the structure 26. The graphite 14 is configured to
plastically deform at loads below where it elastically deforms. And it is the plastic
deformation that allows the graphite 14 to contour to the surface 38 and form a seal
therewith.
[0017] The graphite 14 in its expanded state is compressible and therefore has resiliency. This resiliency allows it to maintain loading against the body 22 and the structure 26 and maintain sealing thereto even during changes in the volume of the cavity 18. An optional second compressible member 50 can be positioned within the cavity 18 that also is resilient and therefore provides additional compressive forces to the graphite 14. Although other embodiments are contemplated, the resilient member 50 in this embodiment is a tubular shaped hoop with a compressible fluid 54 sealed therewithin. As forces on the resilient member 50 flatten the cross sectional shape that is initially round, the decrease in volume of the compressible fluid 54 causes pressure therein to resiliently increase.

[0018] Referring to Figure 2, an embodiment of the seal arrangement 10 is illustrated at a position prior to the graphite 14 being sealingly engaged with the structure 26. In this embodiment, the structure 26 is a tubular with only a small portion of a quarter cross section being shown. The surface 38 of the structure 26 in this case is the inner radial surface of the tubular 26. A second tubular 58 is positioned radially within the structure 26 and substantially concentric with the structure 26. An outer radial surface 62 of the second tubular 58 has a ramped portion 66, which is frustoconical such that radial dimensions of the outer ramped portion 66 increase toward the right side of the Figure. The body 22, when moved rightward in the Figure, has an inner radial face 70 that engages with the surface 62 and radially expands as the rightward movement continues. Walls 74 of the body 22, which are substantially perpendicular to the face 70 in this embodiment, also grow radially as the body 22 is moved relative to the ramped portion 66. After sufficient radial growth the walls 74 engage with the surface 38 of the structure 26, thereby enclosing the cavity 18 and encasing the graphite 14 therewithin while allowing fluids or gases to escape. Volumetric expansion of the graphite 14 causes it to fill the cavity 18 and generate compressive forces against the surface 38. These compressive forces are sufficient to sealingly engage the graphite 14 with the surface 38 even when the surface 38 includes the troughs 42 and peaks 46 discussed above in reference to Figure 1.

[0019] It should be noted that the volume of the cavity 18 increases as the radial dimensions of the body 22 increase prior to engagement of the walls 74 with the structure 26. The expansion of the graphite 14 is selected to be greater than the volumetric increase of the cavity 18 and as such the graphite 14 is able to fill the increased sized cavity 18. In fact, the graphite 14 can expand between about 50% and 200% in volume.

[0020] Referring to Figure 3, an alternate embodiment of the seal arrangement 10 is illustrated at a position prior to the graphite 14 being sealingly engaged with the structure 26.
This embodiment is similar to that of Figure 2 with the primary difference being that the graphite 14 in this embodiment is expanded prior to the body 22 being moved up the ramped portion 66 into engagement with surface 38. In this embodiment some of the graphite 14 may be "wiped" out of the cavity 18 as the graphite 14 contacts the surface 38 prior to the walls 74 contacting the surface 38. This condition does not alter the function of the embodiment since enough of the graphite 14 will be radially compressed into the cavity 18 via contact with the surface 38 prior to engagement of the body 22 with the structure 26 to generate the resilient forces in the graphite 14 sufficient to cause the graphite 14 to seal to both the surface 38 and the body 22. Other embodiments (not shown) can incorporate elements of both Figure 2 and Figure 3 in that the graphite 14 can expand both before the walls 74 engage the surface 38 and after.

[0021] Referring to Figure 4, an alternate embodiment of a seal arrangement disclosed herein is illustrated at 110. The seal arrangement 110 differs from the seal arrangement 10 in that a body 122 that defines cavity 118 containing the graphite 14 has two openings 130. One of the openings 130 faces radially outwardly in a fashion similar to that of the earlier describe embodiments, and one of the openings 130 faces radially inwardly. Resilient forces, due to the volumetric compression of the graphite 14 within the cavity 118, cause the graphite 14 to sealingly engage with the surface 38 and the outer radial surface 62 of the second tubular 58 in addition to walls 174 of a body 122. Note in this embodiment the compressive forces are generated by the graphite 14 alone since a version of the second resilient member 50 is not employed. Additionally, structural members 132 (one being shown in phantom) of the body 122 extend through the graphite 14 while holding the walls 174 a fixed distance apart without detrimentally affecting the functioning of the seal arrangement 110.

[0022] Referring to Figures 5 and 6, an alternate embodiment of a seal arrangement disclosed herein is illustrated at 210. The seal arrangement 210 includes two structures 226, 258 that are sealable to one another by a body 222 and the expandable graphite 14. The body 222 defines a cavity 218 that houses the graphite 14. The body 222 includes an opening 230 that is closed by engagement of walls 274 of the body 222 with a surface 238 that in this embodiment is an inner radial surface of a tubular that is the first structure 226. At least one of two frustoconically oriented legs 224 of the body 222 slidingly engage with an outer radial surface 262 of the second structure 258. Longitudinally moving ends 228 of the legs 224 toward one another causes the walls 274 to move radially outwardly until they engagably contact the surface 238, thereby enclosing the graphite 14 within the cavity 218. The
graphite 14 as shown in Figure 5 (in the non-sealing position), is already volumetrically expanded such that a portion of it extends through the opening 230 and outside of the cavity 218. Simultaneously moving both of the legs 224 can cause the graphite 14 to move radially only into contact with the surface 238 thereby avoiding any scrapping of the graphite 14 with the surface 238 that would occur if there were relative longitudinal movement therebetween during the enclosing of the cavity 218. The foregoing allows the graphite 14 to become directly radially compressed into the cavity 218 as the walls 274 become engaged with the surface 238 as illustrated in Figure 6.

[0023] It should be noted that although the graphite 14 was expanded prior to enclosing it within the cavity 218, as evidenced by Figure 5, the graphite 14 could be expanded after the cavity 218 has been enclosed by the surface 238 as was done in the embodiment illustrated in Figure 2.

[0024] Referring to Figure 7, an alternate embodiment of a seal arrangement disclosed herein is illustrated at 310 in cross section with a small portion shown magnified. The primary difference between the seal arrangement 310 and those of the embodiments discussed above is that the graphite 14 in this embodiment is in the form of a plurality of slabs 316. The slabs 316 are oriented in the cavity 18, 118, 218 of the body 22, 122, 222 such that faces 320 on opposing sides of the slabs 316, across the smallest dimension of the slabs 316, abut the faces 320 on slabs 316 perimetrically adjacent thereto. Thus the slabs 316 are stacked in this manner such that they substantially fill the full 360 degrees of the cavity 18, 118, 218.

[0025] Referring to Figures 8 and 9, another alternate embodiment of a seal arrangement disclosed herein is illustrated at 410. The arrangement 410 is similar to the arrangement 310 with the primary difference being the shapes of slabs 416 of the graphite 14. In this embodiment opposing faces 420 do not face directly 180 degrees from one another as they did in the arrangement 310 but instead are form an angle such that a cross section taken longitudinally through one of the slabs 420 substantially forms a trapezoid. Additionally, every other one of the slabs 420 distributed along the cavity 18, 118, 218 is flipped 180 degrees relative to both its neighbors. This orientation allows the faces 420 to remain abutted to one another as the slabs are moved radially outward such as along ramped portion 466 of tubular 458, for example. Allowing the faces 420 to remain abutted while they are moved radially outwardly may allow sealing to occur between the adjacent slabs 416 with less deformation of the slabs 416.
[0026] In some embodiments disclosed herein the graphite 14 employed is expandable graphite. One example of expandable graphite usable as the graphite 14 is disclosed in copending U.S. Patent Application No. 14/072016 filed November 5, 2013 assigned to the same assignee as this application, the entire contents of which are incorporated herein by reference.

[0027] While the invention has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the claims. Also, in the drawings and the description, there have been disclosed exemplary embodiments of the invention and, although specific terms may have been employed, they are unless otherwise stated used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention therefore not being so limited. Moreover, the use of the terms first, second, etc. do not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another. Furthermore, the use of the terms a, an, etc. do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item.
CLAIMS

What is claimed is:

1. A seal arrangement comprising:
   a body having at least two walls defining a cavity, the walls being engagable with at least one structure through expansion of the body; and
   graphite being sealingly engaged with the body and the structure and resiliently compressively maintained within the cavity by the at least one structure.

2. The seal arrangement of claim 1, wherein expansion of the graphite generates loading of the graphite against the structure.

3. The seal arrangement of claim 1, wherein a compressed resilient member other than the graphite maintains compressive loads on the graphite.

4. The seal arrangement of claim 1, wherein the graphite deforms into sealing engagement with the structure.

5. The seal arrangement of claim 4, wherein the graphite deforms plastically.

6. The seal arrangement of claim 5, wherein plastic deformation occurs in the graphite at loads less than elastic deformation.

7. The seal arrangement of claim 1, wherein engagement between the body and the structure prevent the graphite from escaping from the cavity.

8. The seal arrangement of claim 7, wherein engagement between the body and the structure is through radial expansion of the body.

9. The seal arrangement of claim 7, wherein a volume of the cavity increases as the body engages with the structure.

10. The seal arrangement of claim 1, wherein volumetric expansion of the graphite is in a range of about 50% to 200%.

11. The seal arrangement of claim 1, wherein the graphite expands with changes in temperature.

12. The seal arrangement of claim 1, wherein the at least one structure is two structures.

13. The seal arrangement of claim 12, wherein the graphite sealably engages with the two structures.

14. The seal arrangement of claim 1, wherein the graphite is expandable graphite.

15. The seal arrangement of claim 1, wherein the graphite is in the form of a plurality of slabs.
16. The seal arrangement of claim 15, wherein the plurality of slabs are stacked perimetrically adjacent to one another.

17. The seal arrangement of claim 15, wherein the plurality of slabs have an initial shape that is substantially trapezoidal in cross section.

18. A method of sealing, comprising:
   positioning graphite within a cavity defined by walls of a body;
   expanding the body;
   engaging at least one structure with the walls;
   expanding the graphite;
   compressing the graphite against the at least one structure; and
   sealing the graphite to the at least one structure and the body.

19. The method of sealing of claim 18, further comprising maintaining the graphite within the cavity.

20. The method of sealing of claim 18, further comprising resiliently compressing the graphite within the cavity.

21. The method of sealing of claim 18, further comprising resiliently compressing a resilient member other than the graphite within the cavity.

22. The method of sealing of claim 18, further comprising altering temperature of the graphite to cause it to expand.

23. The method of sealing of claim 18, further comprising increasing volume of the cavity.

24. The method of sealing of claim 18, further comprising maintaining the body longitudinally fixed in relation to the at least one structure while expanding the body.
FIG. 7
# A. CLASSIFICATION OF SUBJECT MATTER

F16J 15/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16J 15/00; F16L 17/06; H01M 8/02; E04C 2/52; F01D 11/02; F16J 15/16; F04D 29/08; E04B 1/94; F16L 53/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic database consulted during the international search (name of database and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: graphite seal, expandable, gasket, plastically, deformation and slab

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:
  * "A" document defining the general state of the art which is not considered to be of particular relevance
  * "E" earlier application or patent but published on or after the international filing date
  * "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  * "O" document referring to an oral disclosure, use, exhibition or other means
  * "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 28 January 2015 (28.01.2015)

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Name and mailing address of the ISA/KR

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