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(54) Title: METHOD AND SYSTEM FOR SEALING A VOID IN AN UNDERGROUND WELLBORE

(57) Abstract: Voids (14) in a underground wellbore (1) are sealed by: - inserting a corrosion prone object (10A-C, 12) in the void (14); - injecting an oxidizing agent into the void (14); and - allowing the oxidizing agent to induce corrosion of the corrosion prone object and to thereby generate corrosion products (13A-E) that are physically larger than the corrosion prone object (10A-C, 12) and that seal the void (14).



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METHOD AND SYSTEM FOR SEALING A VOID IN AN UNDERGROUND
WELLBORE

BACKGROUND OF THE INVENTION

The invention relates to a method and system for sealing a void in an underground wellbore.

5 Underground wellbores provide a harsh environment in which varying high temperatures and pressures and geological movement of the surrounding earth formation may deform downhole tubulars, conduits and/or other well equipment, which may generate voids adjacent to such well equipment that may generate fluid leakage paths for high
10 temperature and high pressure well fluids, such as crude oil and/or natural gas.

It is known to install steel and/or elastomeric seals in downhole voids to inhibit leakage of well fluids to surface.

15 A difficulty is that downhole voids may not have a well defined, for example annular, shape in which case the installed steel and/or elastomeric seals may still provide a fluid leakage path for well fluids.

It is known from US patents 7,059,415 ; 7527,099;
20 7,578,347 and 7,699,115 and European patents EP1759086 and EP1792049 to solve this problem by inserting swellable seals which are able to seal irregularly shaped voids in a wellbore.

25 A disadvantage of the known swellable elastomeric seals is that the long-term performance of these seals is not known and a disadvantage of the other steel and elastomeric seals is that they have no capability to self heal if voids have an irregular shape and/or are initiated at unexpected locations.

There is a need for providing a method and system for sealing downhole voids in wellbores which provide a cost effective, reliable and durable seal with a long time performance and which have a capability to self heal even if the voids have an irregular shape and/or are initiated at unexpected locations.

SUMMARY OF THE INVENTION

In accordance with the invention there is provided a method of sealing a void in an underground wellbore, the method comprising:

- inserting a corrosion prone object in the void;
- injecting an oxidizing agent into the void; and
- allowing the oxidizing agent to induce corrosion of the corrosion prone object and to thereby generate corrosion products that are physically larger than the corrosion prone object and that seal the void.

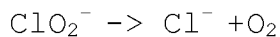
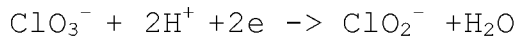
The void may have an annular shape and may be located adjacent to a ferrometallic well conduit, such as a well casing, well liner, or an electrical or hydraulic conduit provided with a ferrometallic lining, and the corrosion prone object may comprise an aluminum ring arranged in the void adjacent the conduit.

Optionally, a series of aluminum rings is arranged at selected longitudinal intervals along the length of an annular void at the outer and/or inner surface of the ferrometallic well conduit.

The oxidizing agent may comprise an electrolyte, such as a brine, and oxygen and/or an oxygen generating agent, such as a chemical oxygen generating agent selected from the group consisting of H_2O_2 , NaClO_3 , KClO_4 , NaNO_3 and combinations thereof and or a microbial oxygen generating agent.

Optionally, the microbial oxygen generating agent

comprises thermophilic chlorate reducing micro-organisms,
such as thermophilic chlorate reducing organisms
comprising bacteria of the genus Archaeoglobus,
Geobacillus and/or Thermus, which use hydrogen (H) and
5 electrons(e) provided by brine and/or other fluids in the
void followed by dismutation of chlorite (ClO_2^-) by the
micro-organisms on the basis of the reactions:



10 Optionally, the thermophilic chlorate reducing micro-
organisms multiply at an ambient temperature of at least
80° C and comprise bacteria of the genus Archaeoglobus
fulgidis.

15 In accordance with the invention there is furthermore
provided a system for sealing a void in an underground
wellbore, the system comprising:

- a corrosion prone object arranged in the void;
- means for injecting an oxidizing agent into the void to
allow the oxidizing agent to induce corrosion of the
20 corrosion prone object and to thereby form the corrosion
products that are physically larger than the corrosion
prone object and that seal the void.

25 These and other features, embodiments and advantages
of the method and system according to the invention are
described in the accompanying claims, abstract and the
following detailed description of non-limiting
embodiments depicted in the accompanying drawings, in
which description reference numerals are used which refer
to corresponding reference numerals that are depicted in
30 the drawings.

Similar reference numerals in different figures
denote the same or similar objects.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows an underground wellbore in which voids around a well liner are sealed by corroding aluminum rings in accordance with the present invention;

Figure 2 shows in more detail two potential leak paths in the wellbore of Figure 1;

Figure 3 shows how the potential leak paths shown in Figure 2 are sealed by two of the aluminum rings shown in Figure 1;

Figure 4 shows three potential leak paths in a downhole power and or transmission cable assembly; and

Figure 5 shows how the three potential leak paths shown in Figure 4 are sealed by corroded corrosion prone objects according to the invention.

DETAILED DESCRIPTION OF THE DEPICTED EMBODIMENTS

Figure 1 shows a wellbore 1 traversing an underground formation 2. The wellbore 2 comprises a casing 3 around which cement may be pumped to provide a seal between the casing 3 and the irregular inner wall 4 of the wellbore 1, or alternatively the casing 3 may be radially expanded against the inner wall 4 of the wellbore 1.

A tubing string 5 is suspended from a wellhead 6 into the wellbore 1 and a packer is arranged between the tubing string 5 and the lower end of the casing 3 near the casing shoe 7. The tubing string 5 comprises three series of perforated sections 5A-5D through which hydrocarbon fluids, such as crude oil and/or natural gas flow into the interior of the tubing string 5 as illustrated by arrows 8A-8C.

The earth formatting 2 surrounding the wellbore 1 comprises several crude oil and/or natural gas containing layers 1A-1C, which are separated by sealing layers 11A-11D, which may be formed by shale, salt or clay layers.

The pressures in the different crude oil and/or natural gas containing layers 1A-1C may be different from each other and to prevent back flux of crude oil and/or gas from a high pressure layer 1A-1C into a low pressure layer 1A-1C two Inflow Control Valves ICV1 and 2 are installed in the tubing string 5 between the perforated sections 5A-5C.

In order to inhibit back flux of crude oil and/or natural gas from a high pressure layer 1A-1C into a low pressure layer 1A-1C through the annular space 14 that forms a void between the tubing string 5 and the irregular inner wall 4 of the wellbore 1 four aluminum rings 10A-D are mounted on the outer surface of the tubing string 5 between and each of the perforated sections 5A-C and below the lowermost section 5C and above the uppermost section 5A.

Furthermore an aluminum ring 12 is mounted on the outer surface of the casing 3, just above the casing shoe 7.

After well completion during which the casing 3 and tubing string 5 are lowered into the wellbore 1 a brine is injected into the wellbore, which brine comprises at least some residual oxygen and/or an oxidizing agent, which brine will cause corrosion of the aluminum rings 10A-D and 12, such that aluminum oxide corrosion products 13A-E are formed on the outer surfaces of the aluminum rings 10A-D and 12, which aluminum oxide products have a larger volume than the aluminum rings 10A-D and 12, such that the corrosion products 13A-E seal off any residual annular spaces around the aluminum rings 10A-D and 12 that remain during well completion or after start up of production of hydrocarbon fluids through the wellbore 1.

Figure 2 shows arrows 20 and 21 which illustrate potential leak paths around the casing 3 and tubing string 5 shown in Figure 1.

Figure 3 shows how the aluminum corrosion products 13A and 13E formed on the outer surfaces of the aluminum rings 10 and 12 seal off the potential leak paths illustrated by arrows 20 and 21 shown in Figure 2.

Figure 4 shows a cable assembly 40 of power and or signal transmission cables 41, which may comprise hydraulic conduits, electrical cables and/or optical fibers, which are embedded in a gel 42 which is surrounded by an inner protective tube 43 made of 304SS steel, which tube 43 is surrounded by a plastic filler 44 that is encapsulated in an outer protective tube 45 which may be made of an Inconel 825 alloy.

The cable assembly 40 may be embedded in the annular cement layer surrounding the casing 3 and/or tubing string 5 and may pass through openings in the sealing ring 9 near the casing shoe and or in the wellhead 6 shown in Fig 1-3.

Figure 5 shows a cable assembly 50 which is protected against leakage by incorporating corroding bodies in accordance with the invention. The cable assembly 50 shown in Figure 5 comprises four power and or signal transmission cables 51, which may comprise hydraulic conduits, electrical cables and/or optical fibers, which are embedded in a gel 52 which is surrounded by an inner protective tube 53 made of 304SS steel, which tube 53 is surrounded by a plastic filler 54 that is encapsulated in an outer protective tube 55 which may be made of an Inconel 825 alloy.

The cable assembly 50 may be embedded in the annular cement layer surrounding the casing 3 and/or tubing

string 5 and may pass through openings in the sealing ring 9 near the casing shoe and or in the wellhead 6 shown in Fig 1-3.

5 The gel filled interior 52 of the inner protective tubing 53 in which the cables 51 are embedded does not provide a potential fluid leakage path, but to inhibit fluid leakage through the plastic filler in the annular space 54 between the inner and outer protective tubings 53 and 55 a series of strings 56, 57 comprising
10 aluminum/stainless steel brade are arranged in the plastic filler in said annular space 54, in which strings the aluminum is induced to corrode by injecting brine or another oxidizer comprising oxygen and/or an oxidizing agent into the wellbore 1, which brine or another
15 oxidizer will diffuse through internal micro annuli in the filler into the annular space 54 and cause the aluminum to corrode and generate aluminum oxide corrosion products which will expand and close the internal micro annuli formed.

20 In order to inhibit fluid leakage through an external annular space between the outer protective tubing 55 and the inner surface of the cement lining and/or sealing rings 9 at the casing shoe 7 or in the wellhead 6 the outer surface of the outer protective tubing 55 is
25 provided with an aluminum coating 58, which will corrode if brine or another oxidizer is injected into the wellbore 1 and form aluminum oxide corrosion products which will seal said external annular space.

30 It will be understood that instead of aluminum other corrosion prone materials may be used, such as iron, bronze, zinc, copper, tin, magnesium, gallium, bismut and/or corrosion prone alloys, which generate corrosion products that are physically larger than the uncorroded

corrosion prone material and that instead of injecting brine comprising oxygen and/or an oxidizing agent other oxidizing agents may be injected into the wellbore 1 to induce corrosion of the corrosion prone material.

C L A I M S

1. A method of sealing a void in an underground wellbore, the method comprising:

- inserting a corrosion prone object in the void;
- injecting an oxidizing agent into the void; and
- 5 - allowing the oxidizing agent to induce corrosion of the corrosion prone object and to thereby generate corrosion products that are physically larger than the corrosion prone object and that seal the void.

2. The method of claim 1, wherein the void has an annular shape and the corrosion prone object comprises a ring which is inserted into the void.

3. The method of claim 2, wherein the annular shaped void is located adjacent to a ferrometallic well conduit and the corrosion prone object comprises an aluminum ring arranged in the void adjacent the conduit.

4. The method of claim 3, wherein a series of aluminum rings is arranged at selected longitudinal intervals along the length of an annular void at the outer and/or inner surface of the ferrometallic well conduit.

5. The method of claim 4, wherein the ferrometallic well conduit is a well casing, well liner, or an electrical or hydraulic conduit provided with a ferrometallic lining.

6. The method of claim 5, wherein the ferrometallic well conduit is a well casing or well liner made of a low alloy steel, such as L80 or P110 steel.

7. The method of any one of claims 1-6, wherein the oxidizing agent comprises an electrolyte and oxygen and/or an oxygen generating agent.

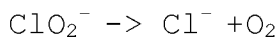
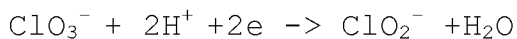
8. The method of claim 7, wherein the electrolyte comprises a brine.

9. The method of claim 7 or 8, wherein the oxidizing agent comprises a chemical oxygen generating agent selected from the group consisting of H_2O_2 , NaClO_3 , KClO_4 , NaNO_3 and combinations thereof.

5 10. The method of claim 9, wherein the oxidizing agent comprises a microbial oxygen generating agent.

11. The method of claim 10, wherein the microbial oxygen generating agent comprises thermophilic chlorate reducing micro-organisms.

10 12. The method of claim 11, wherein the thermophilic chlorate reducing organisms comprise bacteria of the genus *Archaeoglobus*, *Geobacillus* and/or *Thermus*, which use hydrogen (H) and electrons(e) provided by brine and/or other fluids in the void followed by dismutation of chlorite (ClO_2^-) by the micro-organisms on the basis of the reactions:



15 13. The method of claim 12, wherein the thermophilic chlorate reducing micro-organisms multiply at an ambient temperature of at least 80°C and comprise bacteria of the genus *Archaeoglobus fulgidis*.

14. A system for sealing a void in an underground wellbore, the system comprising:

- 25
- a corrosion prone object arranged in the void;
 - means for injecting an oxidizing agent into the void to allow the oxidizing agent to induce corrosion of the corrosion prone object and to thereby form the corrosion products that are physically larger than the corrosion prone object and that seal the void.
- 30

15. The system of claim 14, wherein the annular shaped void is located at the outer surface of a ferrometallic well conduit, the corrosion prone object comprises an

aluminum ring arranged around the conduit and the means for injecting an oxidizing agent comprises means for injecting an electrolyte and oxygen and/or an oxygen generating composition into the void.

Fig.1

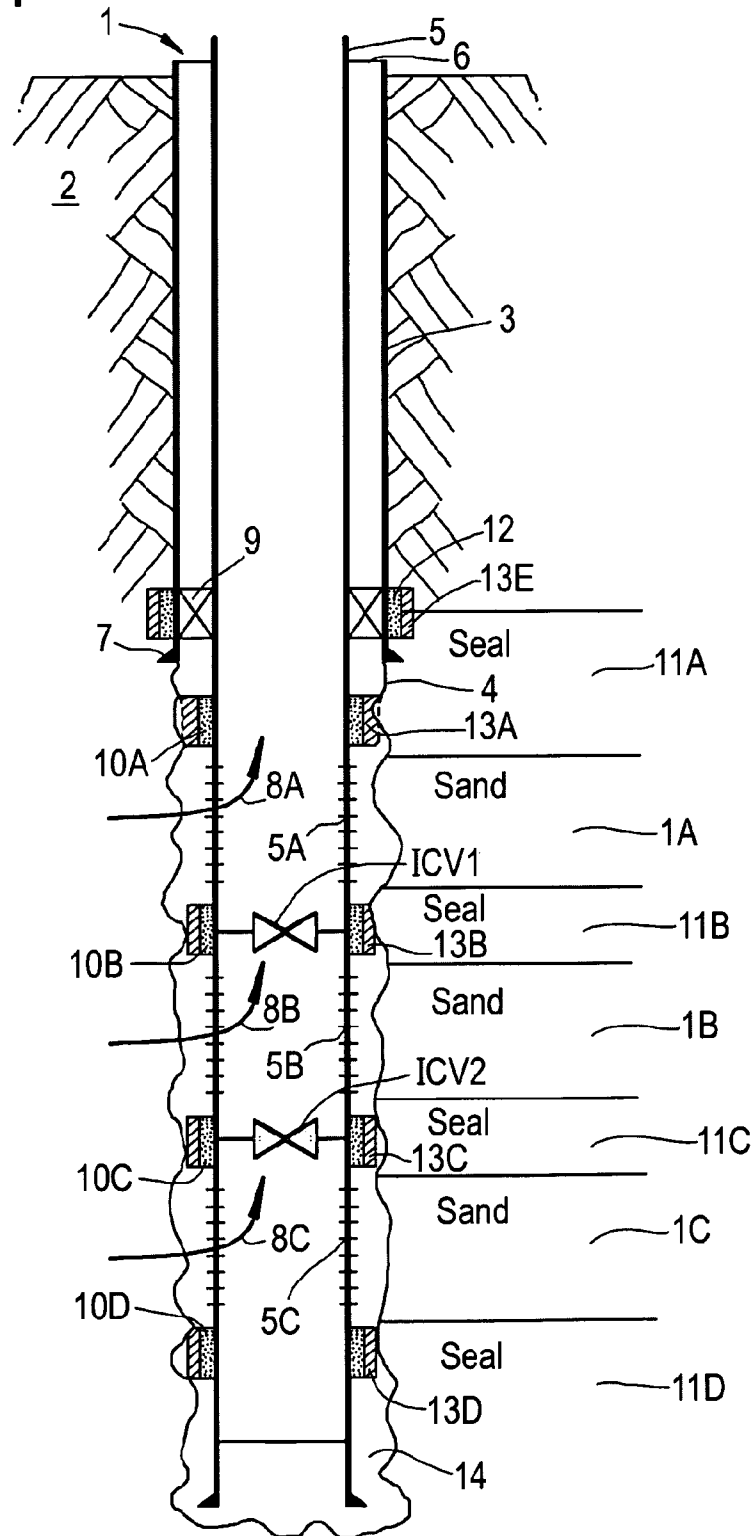


Fig.2

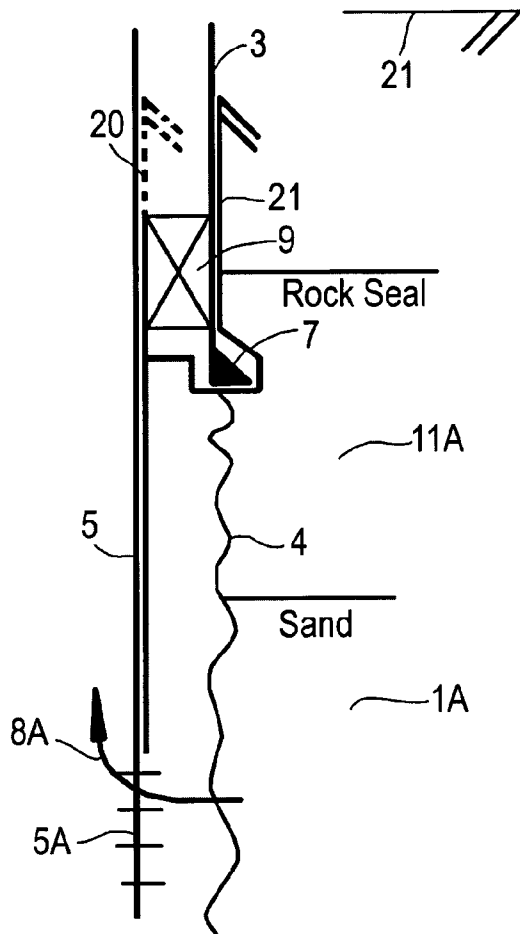


Fig.3

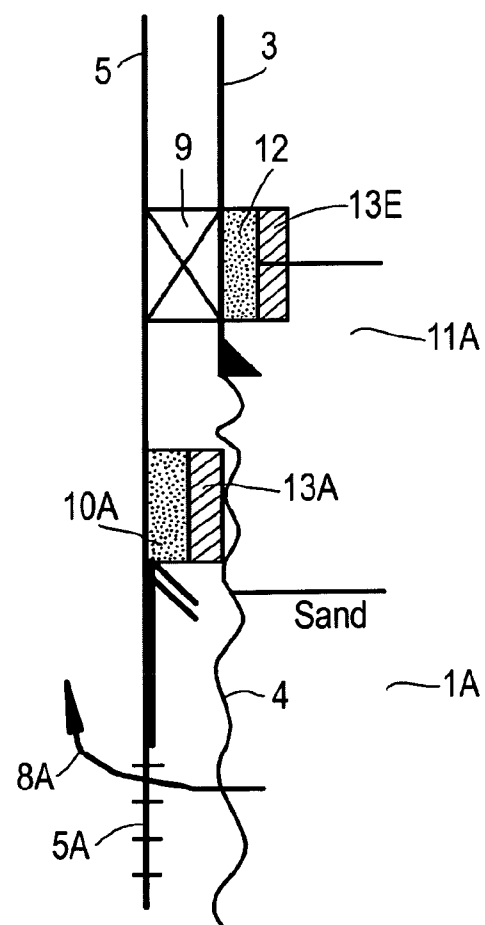


Fig.4

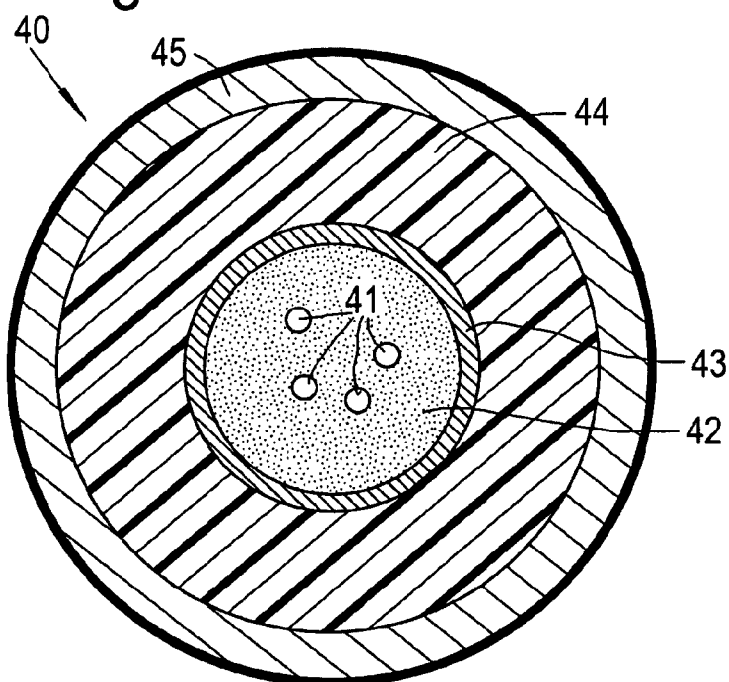
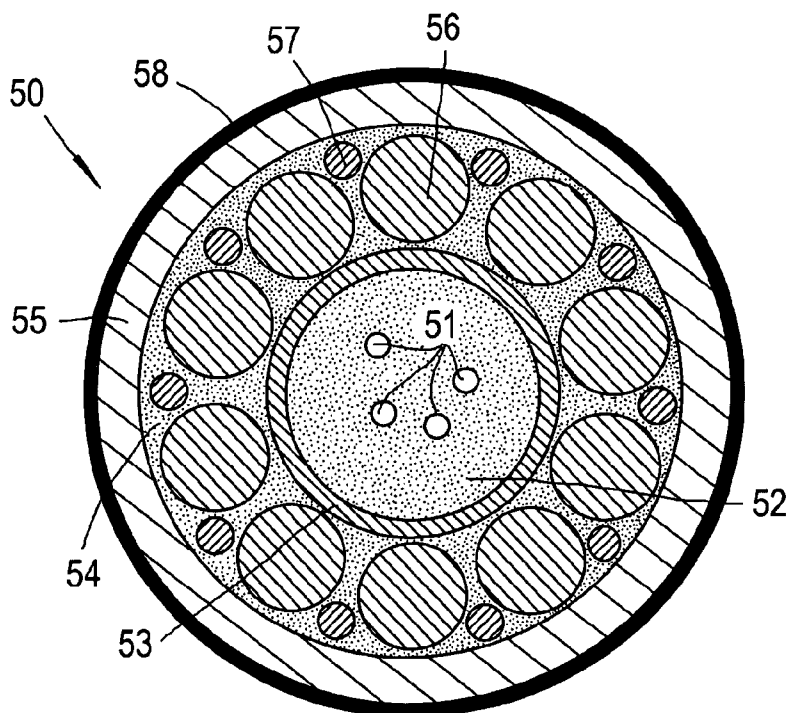
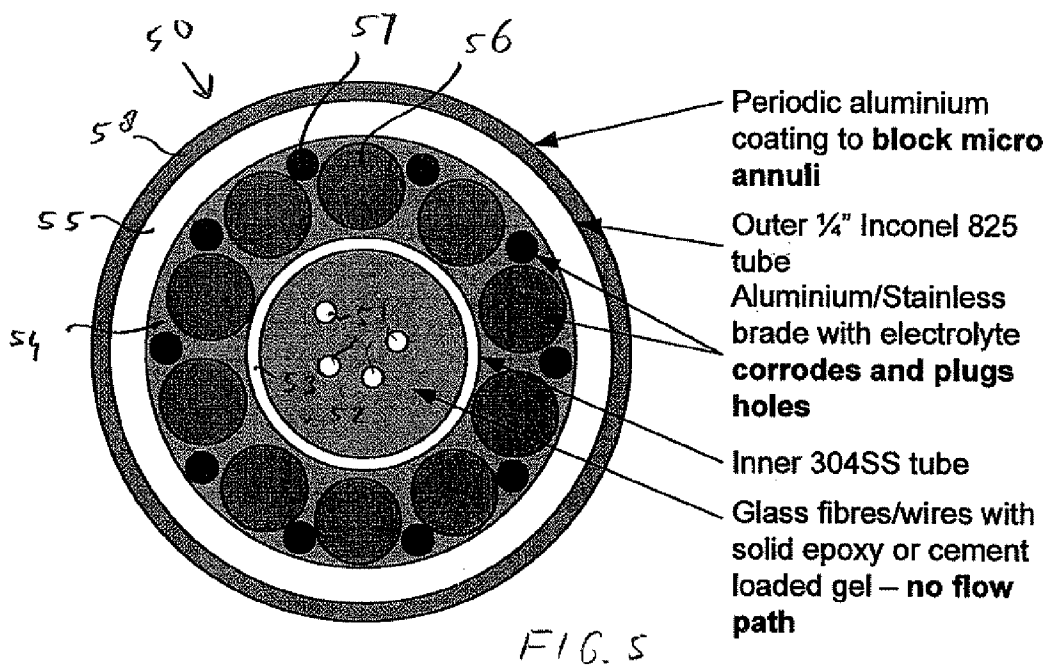
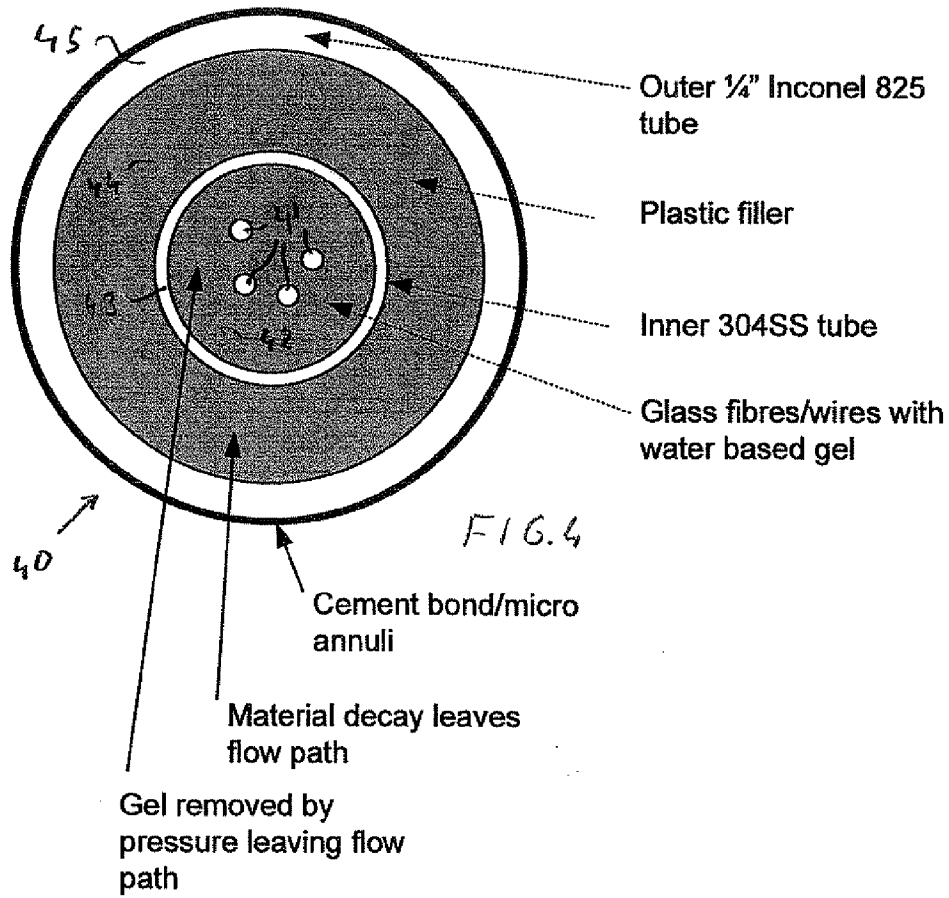


Fig.5



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INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER
INV. C09K8/516
ADD.

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)
C09K

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2005/225083 A1 (COLE ANTHONY T [NL]) 13 October 2005 (2005-10-13) the whole document -----	1-15
A	US 3 511 313 A (EILERS LOUIS H ET AL) 12 May 1970 (1970-05-12) claims 4,5 -----	1-15
A	US 7 059 415 B2 (BOSMA MARTIN GERARD RENE [NL] ET AL) 13 June 2006 (2006-06-13) claim 1 -----	1-15

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Further documents are listed in the continuation of Box C.

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See patent family annex.

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"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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2011/074256

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005225083 A1	13-10-2005	AU 2003210156 A1 CA 2477308 A1 CN 1639497 A EP 1481183 A1 US 2005225083 A1 WO 03074917 A1	16-09-2003 12-09-2003 13-07-2005 01-12-2004 13-10-2005 12-09-2003
US 3511313 A	12-05-1970	NL 6610232 A US 3511313 A	13-03-1967 12-05-1970
US 7059415 B2	13-06-2006	AT 321188 T BR 0211253 A CA 2453660 A1 CN 1533465 A DE 60210113 T2 EP 1407113 A1 US 2004261990 A1 WO 03008756 A1	15-04-2006 27-07-2004 30-01-2003 29-09-2004 02-11-2006 14-04-2004 30-12-2004 30-01-2003