Title: METHOD OF PROVIDING AN ANNULAR SEAL, AND WELLOBRE SYSTEM

Abstract: A method of providing an annular seal around a tubular in a wellbore penetrating a subsurface formation, the method comprising providing a tubular in the wellbore, wherein an annular space (18) is formed around the tubular; providing an annular gravel pack in the annular space; wherein the method further comprises arranging a band (9a, 9b, 9c, 9d) of gel-forming material around the tubular before providing the annular gravel pack, wherein the gel-forming material is swellable in a selected fluid, and wherein the annular seal is formed by contacting the band of gel-forming material with the selected fluid; and a wellbore system comprising a gravel-packed tubular in a wellbore, wherein the tubular is provided with a band of gel-forming material in a layer around the tubular, the band being surrounded by gravel (15), and wherein the gel-forming material is swellable in a selected fluid.
METHOD OF PROVIDING AN ANNULAR SEAL, AND WELLBORE SYSTEM

The present invention relates to a method of providing an annular seal and to a wellbore system.

In the production of fluids from a subsurface formation such as a reservoir of hydrocarbon fluid via a wellbore formed in the earth formation it can be desired to prevent transfer of a selected fluid between the subsurface formation and the surface facility. For example, a hydrocarbon fluid reservoir often overlays a water-containing layer of the earth formation. After continued production of hydrocarbon oil and/or gas from the reservoir, the water level below the reservoir may rise to the level of an intake zone of the wellbore. Also, under certain conditions of hydrocarbon fluid production an effect named "water-coning" may occur whereby water is drawn from the water-containing layer to the wellbore intake zone. As a result an increased amount of water will be produced, at the cost of production of hydrocarbon fluid. Such undesired fluid production can significantly reduce the economics of a hydrocarbon fluid prospect.

Hydrocarbon production wells are often extending horizontally can have intake zones extending over hundreds of meters or even kilometres. Ingression of an unwanted fluid such as water in a relatively small part of the intake zone, e.g. though coning, can occur sometime after the start of the production. It would then be desirable to isolate the section of the intake zone, and perform a remedial action or close off that zone.

Another situation in which zonal isolation in a gravel-packed completion can be desired is a damaged gravel pack, leading to increased sand production.

In principle zonal isolation can be arranged by using expandable packers. However, packers cannot be
effectively used in case of a gravel-packed well-completion. Gravel packing is often used for the control and reduction of sand influx from the formation into the production conduit. Gravel packing as used herein refers to placing gravel and/or other particulate matter around production conduit as part of a well completion. For instance, in an open-hole completion, a gravel pack is typically positioned between the wall of the wellbore and a perforated base pipe. The gravel pack serves as a filter withholding sand, additionally the base pipe can have sand-filtering means such as a sand screen or perforations in the form of slots of suitable width to withhold sand. Alternatively, in a cased-hole completion, a gravel pack is positioned between a casing string having perforations and a perforated base pipe, with or without additional sand-filtering means.

A gravel pack however stands in the way of expanding, either mechanically or by swelling, of a conventional packer. At best, a compaction of gravel can be achieved, which may lead to a limited flow barrier increase or sealing effect. SPE paper No. 122765 by R. Jansen et al. reports on using a conventional swellable packer in the context of a gravel pack completion, but it is not disclosed that the packer provides a seal through the gravel pack.

International patent application publication No WO 2007/092082 discloses a wellbore method and apparatus for completion, production and injection, wherein a plurality of production intervals in the wellbore are segmented by packers. In the production tubing sections between the packers sand screens are arranged. The packers can include swellable elements. After the packers were expanded to provide an annular seal and isolation between production tubing sections, gravel packing is installed around the sand screens.
Swell packers comprising shunt tubes, such as disclosed in EP-2184436-A2, still enable fluid flow through the shunt tube. Packers including shunt tubes thus only create a restriction in flow and are unable to provide full zonal isolation of the annular space.

There is a need for a simpler and more cost effective method that can be applied for zonal isolation in gravel pack completions, in particular for providing an annular seal in such a wellbore.

To this end, the present invention provides a method of providing an annular seal around a tubular in a wellbore penetrating a subsurface formation, the wellbore having a wellbore wall and the method comprising:

- providing a tubular in the wellbore, wherein an annular space is formed between the tubular and the wellbore wall;
- providing an annular gravel pack in the annular space;

wherein the method further comprises:

- arranging a band of solid gel-forming material around the tubular before providing the annular gravel pack;
- contacting the band of solid gel-forming material with a selected fluid, wherein the solid gel-forming material becomes a swellable gel;
- swelling of the gel into the gravel to form the annular seal between the tubular and the wellbore wall.

The invention is based on the insight gained by applicant that a gel-forming material can swell to form a seal even when a gravel pack is present in the annulus, different from e.g. an inflatable packer or a swellable elastomer packer. A band of gel-forming material that is arranged as a layer around the tubular can thus swell to the opposite wall of the annular space, and will incorporate gravel particles in the swollen gel, which in fact reinforces the seal provided in this way.
Additionally this method creates true zonal isolation since there will be no leak path through the gravel after the mobile gel has penetrated the gravel.

In one embodiment the selected fluid contacting the at least one band of gel-forming material is or forms part of a formation fluid entering the wellbore from the subsurface formation.

In one embodiment the contacting takes place at the time of a breakthrough of an unwanted formation fluid into the wellbore. In an important application, the selected fluid is water or brine, so that the annual seal formed by activating the gel-forming process when and where water-coning occurs.

In one embodiment the band of gel-forming material forms a first band of a plurality of bands of gel-forming material which are arranged around the tubular in a longitudinally spaced manner, the plurality also including a second band of gel-forming material. Then, two annular seals are formed by contacting the first and the second band with the selected fluid, so as to provide a zonal isolated annular space, which is defined by the longitudinal spacing between the first and second band. Two annular seals isolate the zone between them. If more than two bands are arranged along the tubular, different zones can be isolated by pairs of annular seals. When the selected fluid activating the swelling is in the formation fluid, the position of influx determines automatically where the seals are formed.

In one embodiment, the method further comprises detecting which of the plurality of bands of gel-forming material has or have formed an annular seal. This can be of interest when the swelling and sealing takes place automatically by the influx of the selected fluid, where it can be desired to perform a specific action in the thus isolated zone.
In one embodiment the method further comprises performing a remedial action in the zonal isolated annular space.

The remedial action can e.g. be total shut off of a specific zone to prevent inflow of unwanted fluids. This can be achieved by the deployment of a cementious material, resin or gel from within the tubular via openings in the tubular into the annular space, and possibly also the surrounding formation. The tool used for this operation can be run using drillpipe, coiled tubing or wireline. For example, coiled tubing equipped with packer elements is run into the tubular and positioned at the zone of interest. Packers are set within the tubular above and below the zone of interest, corresponding to the annular zone that isolated by the method of the invention. The isolated zone can now be shut off by injecting a cementious material, resin or gel.

Another remedial action can be a selective chemical treatment of that zone or though that zone, e.g. with scale inhibitor, acid stimulation, or wax removal etc., to improve the inflow of hydrocarbons from that zone.

A further remedial action can be the repair of a completion element, e.g. a damaged gravel pack in the annular isolated zone, e.g. by chemical sand consolidation. Thereby sand or gravel production from that zone can be stopped.

In one embodiment the tubular is provided with one or more bands of gel-forming material on surface, before installing the tubular in the wellbore. This makes installation of the bands simple, and provides for example an easy and economic way of automatically sealing water-ingress zones during the production life of the wellbore.

In one embodiment the tubular has a wall and comprises at least one open section with fluid inlet
openings in the wall, and at least one closed section with impermeable wall towards the annular space. Then the band of gel-forming material is suitably arranged in the at least one closed section.

In one embodiment the gel-forming material comprises a gel-forming component selected from the group consisting of a layered silicate, an inorganic polymer, a superabsorbent polymer.

The invention moreover provides a wellbore system comprising a gravel-packed tubular in a wellbore, wherein the tubular is provided with a band of solid gel-forming material in a layer around the tubular, the band being surrounded by gravel, and wherein the gel-forming material is adapted to become a swellable gel when contacted with a selected fluid.

The invention will now be further described by way of example and with reference to the drawings, wherein Figure 1 schematically shows a downhole section of a wellbore into which a tubular with bands of gel-forming material is run;

Figure 2 schematically shows the downhole section of the wellbore of Figure 1, while gravel is pumped into the annulus around the tubular;

Figure 3 schematically shows the downhole section of the wellbore of Figures 1 and 2 after an annular seals in accordance with the invention were formed to provide a zonal isolation; and

Figure 4 schematically shows an embodiment of a band of gel-forming material.

Like reference numerals are used in the Figures to refer to the same or similar objects.

Reference is made to Figure 1, showing a horizontal downhole section of a wellbore 1 extending, normally from surface, into the earth and penetrating a subsurface earth formation 3.
A tubular is provided in the wellbore by running production tubular 5 into the wellbore 1, indicated by the arrow. The production tubular comprises open sections 8a, 8b, 8c with inlet openings for fluid communication with the annulus, alternating with closed sections 9a, 9b, 9c. A plurality of bands 12a, 12b, 12c of gel-forming material are disposed exteriorly around the tubular 5, in the closed sections 9a, 9b, 9c. Arranging the bands was done in this example on surface, before running the tubular into the wellbore.

The length of an open section can e.g. be in the range of 1-500m, such as 10-200 m. The length of a closed section can be in the range of 0.5-50 m, typically 1-5 meters. An open section can e.g. be provided with perforations, slots, and/or a sand screen. The wellbore 1 is shown as an open-hole wellbore, but it will be understood that it can also be cased and suitably provided with casing perforations to allow ingress of formation fluids to be produced to via the production tubing to surface.

Figure 2 shows the production tubular when it is fully run into the wellbore 1, and while gravel 15 is being pumped via the downstream end of the production tubular 5 into the annular space 18, as indicated by the arrows. Thus an annular gravel pack is provided in the annular space 18. The bands of gel-forming material 9a, 9b, 9c, 9d are surrounded by gravel 15. Figure 2 depicts a wellbore system according to the invention.

Figure 3 shows the wellbore system after some time of operation. Formation fluid is entering into the wellbore as indicated by the arrows. Formation fluid such as oil is in principle produced from formation 3, flowing through the gravel pack into the production tubing 5 via openings in the open sections, and from there to surface (not shown). During the lifetime of the well the constitution of formation fluid can vary along the length
of the wellbore 1, i.e. can be different in the various virtual sections 20a, 20b, 20c, 20d generally corresponding to the open sections 8a, 8b, 8c, 8d. In one type of applications it is desired to produce predominantly hydrocarbons, such as oil. Suitably then, the gel-forming material does not form a gel when coming in contact with the reservoir fluid that is desired to be produced, e.g. oil.

Figure 3 shows the situation that the formation fluid flowing into the well in the section 20c is or contains a breakthrough fluid, e.g. water, such as at least 10 wt% water, or at least 50 wt% of water. The gel-forming material of bands 12a, 12b, 12c, 12d is a material that forms gel when coming in contact with the breakthrough fluid. The breakthrough fluid is a selected fluid that can be regarded as an activating fluid for the gel-forming material. The gel-forming material of bands 12b and 12c comes in contact with the inflowing water, and the bands swell through the gravel, until they meet the inner wall of the wellbore 1 (which can be uncased as shown, or cased), so as to provide an annular seals 22b, 22c. The annular seals 22b, 22c form a zonal isolation of section 20c. The zonal isolation prevents flow of fluid via the annulus in and out of the isolated zone, section 20c in this example. The bands 12b and 12c can be regarded as first and second bands of the plurality of bands of gel-forming material.

It is then for example possible to close the perforations/inlets in the open section 12c from inside the tubular 5, so that the water is not produced to surface. It is now also possible to isolate an annular zone between two annular seals by straddling with packers that zone from inside the production tubing. Selective treatment of that zone to either stimulate or shut off production is now possible. It is also possible to
monitor and measure the production from that specific zone.

If the wellbore is non-horizontal such as a substantially vertical well, over the lifetime of the well the level of the oil/water contact may rise due to depletion of the oil reservoir, and thus give rise to ingress of water from the lowest sections, which can be shut off in this way.

Forming one annular seal can for example be sufficient if the most downhole part of the wellbore annulus is to be sealed off.

The gel-forming material can be gel-forming when the selected fluid is water. Alternatively, it can be gel-forming when contacting with oil, e.g. crude. It is also possible that the gel-forming material is gel-forming when being contacted with either one or both of water and oil. Herein water is meant to include brine.

Suitable gel-forming material, when the selected fluid is or comprises water, is or comprises an inorganic polymer, in particular a layered silicate. Suitable layered silicates are sold by Rockwood Additives Limited under the trademark Laponite. Suitable gel-forming Laponite grades are e.g. grades RD, XLG, D, DF, XL21, HW, or LV. Relevant CAS Nos. of suitable Laponite materials are 53320-86-8 and 64060-48-6. Relevant EINECS Nos. of suitable Laponite materials are 258-476-2 and 285-349-9. A band of gel-forming material containing Laponite can for example be made by putting Laponite powder in a mould and applying pressure until a solid Laponite band is formed. Other components such as e.g. a filler or additives can be added in the moulding process. The gel-forming band can be placed with this method straight on the base pipe as well. Alternatively two half moon bands can be prepared separately and subsequently they can be glued in place with epoxy resin. The Laponite containing band can also be provided on a carrier or support.
Another suitable gel-forming material, when the selected fluid is or comprises water, is or comprises a superabsorbent, such as a polyacrylate and/or polyacrylamide based superabsorbent. The polyacrylate and/or polyacrylamide can be cross-linked. Suitable superabsorbents are sold by BASF under the trademark Luquasorb. Another suitable superabsorbent is sold by Imbibitive Technologies America Inc. (IMBTECH AMERICA) under the trademark AquaBiber.

Bands of gel-forming material can be made from superabsorbents, e.g. Luquasorb or AquaBiber materials, by putting grinded superabsorbent in a mould and applying pressure thereby creating a solid band. Depending on the salinity of the surrounding formation or completion fluids between 1-50 w/w% of metal halides, based on the mass of superabsorbent, can be added. The metal halides are preferably NaCl or KCl. Other components such as e.g. a filler or additives can be added as well. The gel-forming band can be placed with this method straight on the base pipe as well. In another embodiment, two half moon shaped bands can be prepared separately and subsequently they can be glued in place with epoxy resin.

Suitable gel-forming material, when the selected fluid is or comprises oil, is e.g. an alkylstyrene copolymer, e.g. the material sold under the trademark Imbiber by Imbibitive Technologies America Inc. (IMBTECH AMERICA). The same band forming process as for superabsorbents Luquasorb can for example be used.

The gel-forming material is suitably not free-flowing, before it is contacted with the selected fluid. For example, the gel-forming material can be solid, highly viscous, or thixotropic. Thixotropic materials do not freely flow, but flow when pressure is applied, i.e. show a behaviour like toothpaste. The gel-forming material does not contain a substantial quantity of a
solvent, e.g. less than 20 wt%, or less than 5 wt%, in particular no solvent.

It can be desired to apply a gel-forming material that is forming a gel when being contacted with either one or both of hydrocarbons, e.g. oil, and water. That can for example be achieved by a mixture of Imbiber material with either Luquasorb or Aquabiber material, such as a mixture of a weight ratio between 20/80 and 80/20 can be used to have a gel-forming band that swells when being contacted with water and/or hydrocarbons.

The gel-forming material is suitably stable at downhole conditions between 50-150 °C for at least one week, preferably at least one month, more preferably at least one year. Stability means that the material remains intact, in its unswollen and/or swollen state, at downhole temperatures, in particular between 50-150 °C and under contact with downhole fluids, like crude, brine, and gases.

The width of the band can be suitably chosen, and will typically be in the range of 0.1-100 m, preferably 0.25-25 m.

The gel-forming material swells when being contacted with the selected fluid. Suitably, the maximum swelling ratio, measured as the maximum thickness of the band achieved after long swelling in an open space, divided by the unswollen thickness, is in the range of 1,1-50, preferably 2-10, for example 5. The thickness of the band is suitably adapted to the size of the annulus and the maximum swelling ratio. The thickness will typically be in the range of 0,5 mm to 30 mm, preferably 1-20 mm.

Suitably the thickness is chosen such that a swelling between 10 and 90% of the maximum swelling ratio is needed to achieve an annular seal, not taking the gravel into account. For example, with a tubular of 12,7 cm in an open hole of 20,3 cm, the annulus is 3,8 cm thick. Then, for example, a band with a maximum swelling ratio
of 5 and a thickness of 1.5 cm will provide a seal at a swelling ratio of 2.5 in thickness (not taking gravel into account), i.e. 50% of the maximum swelling ratio.

Swelling ratio is suitably chosen such that the annular seal is able to withstand a differential pressure of 1-50 bars per meter of band formed.

The bands of gel-forming material can in principle be arranged anywhere along the tubular. For bands shorter than a pipe element of the production tubular, the position along the pipe element can sometimes be selected. Figure 4 shows a particular example of a relatively short gel-forming band arranged around a production tubular 30. The production tubular 5 is formed of a plurality of pipe elements, of which two pipe elements 31,32 are shown that are connected by a pin-and-box connection 35. The pin-and-box connection forms 35 forms a shoulder 37. The band of gel-forming material 40 is arranged in the vicinity of the shoulder 37, around the tubular 31 providing the pin-part if the connection.

The band is shown here flush with the diameter of the box part. It will be understood that the band can be thinner, or somewhat thicker as needed for the seal. An advantage of this arrangement is that the band 40 is protected, at least partially, by the shoulder when running the tubular in the wellbore, and that no or only a minimum obstacle is formed by the band for running the tubular in. As additional protection, a protection layer or skirt of a perforated material, like e.g. a metal gaze 42 can be provided at the external surface facing the annulus, and possibly at the sides. Such a protection skirt would not hamper the swelling of the gel. The band can have a support layer at the tubular side 44, which can be suitably fastened to the tubular, e.g. glued.

Running the bands of gel-forming material wrapped around the tubular as part of the completion installation is simple and cost-effective, and the position of the
potential annular seals can be determined with high accuracy. Activating the swelling can occur quasi automatically "in situ" by the ingress of a formation fluid containing the selected activating fluid, e.g. water, thus no further equipment is required in this case. As an alternative it is also possible to start the gel-forming process by deliberately feeding the selected fluid to into the annulus, so as to cause the annular seal to be formed. This can for example be achieved from within the tubular via the openings in the open sections. It is also possible to arrange separate conduits and/or reservoirs for the selected fluid, which can be operated remotely controlled from surface so as to contact the bands of gel-forming material and cause their swelling, e.g. triggered by a pressure pulse, a dart or ball from surface.

The gel-forming material swells when it is contacted with a selected fluid that is attracted into the matrix of the material, and thus activates the swelling. Swelling in suitable materials as layered silicates, superabsorbents or Imbiber discussed hereinabove, is caused by physico-chemical processes that are reversible, so that bonds on molecular level, such as hydrogen bridges, are reversibly formed. The swelling or swollen gel still has some ability to flow/rearrange, and can sometimes be regarded as a highly viscous fluid. Some flowing/rearranging properties are needed to penetrate through a gravel pack, wherein on a microscopic level the material distributes through the pore space created by the gravel particles. The swelling or swollen gel can be a thixotropic material. For comparison, a swellable elastomer, such as being used for swellable packers, are chemically cross-linked structures, e.g. made from acrylonitrile butadiene rubber (NBR) or ethylene propylene dimonomer (EPDM). See e.g. the Handbook of Plastics, Elastomers & Composites, Harper, Charles A.
Chemically crosslinked materials cannot flow and cannot penetrate through the pore space created by the gravel pack.

A gel according to the invention may be defined as a material which is able to flow only after overcoming an initial yield stress. In a practical embodiment, the yield stress may exceed about 100 Pa, for instance more than 200 Pa. An upper limit of the yield stress may be about 5 kPa. The solid gel-forming material is for instance able to absorb water to transform into the swellable gel.

Example

A lab scale arrangement of tubular was built, with a 12.5 cm (o.d.) inner tube coaxially arranged in a 17.8 cm (i.d.) outer tube. The inner tube was provided with a 10 cm wide band of a gel-forming material made of Luquasorb 1010. The thickness of the gel-forming band was initially 5 millimetres. Water was pumped through the annulus. Pressure started to increase over time, after about 72 hours, indicating that the gel-forming system was swelling and penetrating through the gravel sand, so as to form an annular seal. The experiment was stopped when the seal was able to withstand a pressure of 1 MPa differential pressure over the seal.

The present invention is not limited to the above described embodiments thereof, wherein various amendments are conceivable within the scope of the appended claims. Features of respective embodiments may for instance be combined.
1. A method of providing an annular seal around a tubular in a wellbore penetrating a subsurface formation, the wellbore having a wellbore wall and the method comprising:
   - providing a tubular in the wellbore, wherein an annular space is formed between the tubular and the wellbore wall;
   - providing an annular gravel pack in the annular space;

   wherein the method further comprises:
   - arranging a band of solid gel-forming material around the tubular before providing the annular gravel pack;
   - contacting the band of solid gel-forming material with a selected fluid, wherein the solid gel-forming material becomes a swellable gel;
   - swelling of the gel into the gravel to form the annular seal between the tubular and the wellbore wall.

2. The method according to claim 1, wherein the selected fluid contacting the at least one band of gel-forming material is or forms part of a formation fluid entering the wellbore from the subsurface formation.

3. The method according to claim 1 or 2, wherein the contacting takes place at the time of a breakthrough of an unwanted formation fluid into the wellbore.

4. The method according to any one of claims 1-3, wherein the band of gel-forming material forms a first band of a plurality of bands of gel-forming material which are arranged around the tubular in a longitudinally spaced manner, the plurality also including a second band of gel-forming material, and wherein two annular seals are formed by contacting the first and the second band with
the selected fluid, so as to provide a zonal isolated annular space.

5. The method according claim 4, wherein the method further comprises detecting which of the plurality of bands of gel-forming material has or have formed an annular seal.

6. The method according to any one of claims 4 or 5, wherein the method further comprises performing a remedial action in the zonal isolated annular space.

7. The method according to any one of claims, wherein the remedial action comprises at least one operation selected from the group consisting of shutting of fluid flow in or into that zone, chemical treatment, a repair operation of a well completion element.

8. The method according to any one of claims 1-7, wherein the tubular is provided with one or more bands of gel-forming material on surface, before installing the tubular in the wellbore.

9. The method according to any one of claims 1-8, wherein the tubular has a wall and comprises at least one open section with fluid inlet openings in the wall, and at least one closed section with impermeable wall towards the annular space, and wherein the band of gel-forming material is arranged in the at least one closed section.

10. The method according to claim 9, wherein the swollen gel forming the annular seal includes gravel.

11. The method according to any one of claims 1-10, wherein the gel-forming material comprises a gel-forming component selected from the group consisting of a layered silicate, an inorganic polymer, a superabsorbent.

12. The method according to any one of claims 1-11, wherein the selected fluid causing the gel-forming material to swell when being contacted with the gel-forming material comprises water, hydrocarbon oil, or water and hydrocarbon oil.

13. A wellbore system comprising a gravel-packed tubular in a wellbore, wherein the tubular is provided with
a band of solid gel-forming material in a layer around
the tubular, the band being surrounded by gravel, and
wherein the solid gel-forming material is adapted to
become a swellable gel when contacted with a selected
fluid.

14. The wellbore system according to claim 13, wherein
the band of gel-forming material forms a first band of a
plurality of bands of gel-forming materials which are
arranged around the tubular in a longitudinally spaced
manner, the plurality also including a second band of
gel-forming material.

15. The wellbore system according to claim 13 or 14,
wherein the tubular has a wall and comprises at least one
open section with fluid inlet openings in the wall, and
at least one closed section with impermeable wall towards
the annular space, and wherein the band of gel-forming
material is arranged in the at least one closed section.
## INTERNATIONAL SEARCH REPORT

**INTERNATIONAL SEARCH REPORT**

<table>
<thead>
<tr>
<th>A. CLASSIFICATION OF SUBJECT MATTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>INV. E21B33/12 E21B43/04 ADD.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>B. FIELDS SEARCHED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum documentation searched (classification system followed by classification symbols)</td>
</tr>
<tr>
<td>E21B</td>
</tr>
</tbody>
</table>

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)

EPO-Internal

<table>
<thead>
<tr>
<th>C. DOCUMENTS CONSIDERED TO BE RELEVANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category*</td>
</tr>
<tr>
<td>X</td>
</tr>
</tbody>
</table>

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 document but published on or after the international filing date
  - "L" later document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another document, or to involve a question of originality of invention
  - "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
  - "Z" document member of the same patent family

Date of the actual completion of the international search: 30 January 2012
Date of mailing of the international search report: 16/02/2012

Name and mailing address of the ISA:
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer: Georgescu, Mi hnea

Form PCT/ISA/01 (second sheet) (April 2005)
### DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
</table>
This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.: because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

This international Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant’s protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant’s protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.
This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-15

--

1.1. claims: 1-12

Method of claim 1 in which a solid gel-forming material swells into a gravel.

1.2. claims: 13-15

Apparatus of claim 13 in which a solid gel-forming material is adapted to become a swellable gel when contacted with a selected fluid.

---
<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>EP 2184436</td>
<td>12-05-2010</td>
<td>BR PI0904664 A2</td>
<td>08-02-2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CA 2685235 A1</td>
<td>11-05-2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 2184436 A2</td>
<td>12-05-2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB 2466475 A</td>
<td>30-06-2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2010155064 A1</td>
<td>24-06-2010</td>
</tr>
<tr>
<td>US 6303711</td>
<td>16-10-2001</td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CA 2705768 A1</td>
<td>04-06-2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO 2009070393 A1</td>
<td>04-06-2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2008194717 A1</td>
<td>14-08-2008</td>
</tr>
<tr>
<td>US 2007044963</td>
<td>01-03-2007</td>
<td>GB 2429725 A</td>
<td>07-03-2007</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2007044963 A1</td>
<td>01-03-2007</td>
</tr>
<tr>
<td>US 2007227733</td>
<td>04-10-2007</td>
<td>NONE</td>
<td></td>
</tr>
</tbody>
</table>