A downhole seal (10) comprises a swelling portion (16). The swelling portion (16) comprises a central region (18) comprising a first swelling material and a first end region (20) comprising a second swelling material. The first and second swelling materials have different swelling properties and define portions of the outer surface of the swelling portion. In use, the first and second swelling materials may be specifically selected to achieve a predetermined or preferential swelling characteristic of the sealing portion and thus of the downhole seal, and in particular a preferential swelling characteristic of an end region of the swelling portion and downhole seal.
FIELD OF THE INVENTION

The present invention relates to a downhole seal, and in particular to a downhole seal incorporating a swellable material.

BACKGROUND TO THE INVENTION

It is known in the art to establish seals in downhole locations using materials which swell upon contact with a particular activator, such as water or hydrocarbons. Typically, an annular band of swellable material is mounted and bonded to the exterior surface of a base tubular member or pipe and run into a wellbore to the required depth.

The present inventors have discovered that the end or edge regions of swelling seals of the type described herein initially swell faster than the central region, which may be unfavourable in certain circumstances. For example, if the seal is exposed to an activator during run-in then the faster swelling end regions, and particularly the leading end region, may cause the seal to hang-up in the well. Additionally, if the end regions are caused to engage a bore wall or restriction prior to the central region then it is possible that resident bore fluid may become trapped between the end and central regions and the bore wall. This trapped fluid may compromise the seal and it is possible that, in the case of an open bore, the trapped fluid will be forced into the formation which may also become compromised.

As noted above, it is likely that a swelling seal will be exposed to an activator while being run into the wellbore which may result in a seal being established at an undesired location within the wellbore, or at least the outer diameter of the band increasing which can cause significant problems. A proposed solution to this problem is presented in US 7,143,832 which describes a well packer which incorporates a swelling band with a swelling rubber core surrounded by a swelling rubber cover or mantle, wherein the cover is selected to swell at a slower rate than the core. However, the arrangement described in US 7,143,832 will still suffer from the problem of end regions of the seal swelling at a faster rate than the central region.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention there is provided a downhole seal comprising a swelling portion, said swelling portion comprising:

a central region comprising a first swelling material; and
a first end region comprising a second swelling material, wherein the first and second swelling materials have different swelling properties and define portions of the outer surface of the swelling portion.

In use, the first and second swellable materials may be specifically selected to achieve a predetermined or preferential swelling characteristic of the sealing portion and thus of the downhole seal, and in particular a preferential swelling characteristic of an end region of the swelling portion and downhole seal. This therefore permits the problems associated with the end regions of conventional swelling seals to be addressed.

The second material may be adapted to swell at a slower rate than the first material. This arrangement may be used to permit the end region of the swelling portion to swell at a slower rate than the central region, or alternatively to permit the central and end regions to swell at the same effective rate. The latter arrangement may be achieved by virtue of the phenomenon identified by the inventors that end regions of a swelling seal inherently swell faster than, for example, central regions. Thus, although the properties of the second material may be conducive to a slower swelling rate than the first material, the end location of the second material may establish an overall effective swelling rate which is similar to that of the central region. As noted above, the present invention thus allows predetermined or preferential swelling properties of the sealing portion and thus of the downhole seal to be achieved.

In an alternative arrangement, the second material may be adapted to swell at a faster rate than the first material. This arrangement may be advantageous in downhole operations where a faster swell rate of the end region is desirable.

The downhole seal may comprise a seal body, wherein the swelling portion defines at least a portion of the seal body. The swelling portion may define the entire seal body. In alternative embodiments the seal body may comprise one or more additional elements, such as additional swelling or non-swelling elements. The additional element may be located adjacent an outer surface, inner surface or internally of the swelling portion, or any combination thereof. The seal body may comprise an outer portion adapted to at least partially surround or encapsulate the swelling portion. The outer portion may function to restrict or delay exposure of the swelling portion to a swelling activator, thus delaying swelling of said swelling portion.

In one embodiment, the swelling portion may be adapted to be mounted on a member, for example on the outer or inner surface of a member. The member may form part of the downhole seal of the present invention. The member may comprise
a tubular member, such as a casing tubular, liner tubular, production tubular, drilling tubular, collar, sleeve, connector or the like.

The downhole seal may comprise a unitary swelling portion. The swelling portion may form or define a single annular band. The swelling portion may be adapted to swell radially outwardly, radially inwardly, axially or any combination thereof.

One or both of the first and second materials may comprise an elastomer.

The first and second materials may be adapted to be activated by a chemical activator, thermodynamic activator, fluid dynamic activator or the like, or any suitable combination thereof. For example, the first and second swellable materials may be adapted to be activated by a fluid, such as water, hydrocarbons, cement, drilling mud or the like, or any suitable combination thereof. Alternatively, or additionally, the swellable materials may be adapted to be activated by temperature, pressure, sound, radiation or the like.

The central and first end regions may be integrally formed. Alternatively, the central and first end regions may be separately formed and subsequently assembled to define the seal body.

The first end region may be located axially adjacent the central region, and preferably adjacent an end of the central region. That is, at least a portion of the first end region may be located adjacent one axial end of the central region.

Alternatively, or additionally, the first end region may be located circumferentially adjacent a portion of the central region, and preferably adjacent an end of the central region. That is, at least a portion of the first end region may be located adjacent an outer surface of a portion of the central region. In this arrangement the central region may define a recess, wherein the first end region is located or disposed within said recess. The recess may comprise a circumferential recess and may be located in the outer or inner surfaces of the central region. A plurality of recesses may be provided.

The first end region may be located directly adjacent the central region. In an alternative embodiment, the swelling portion may comprise a further region interposed between the central and first end regions. The further region may comprise any suitable material, such as a swelling material, non-swelling material or the like.

It should be understood that although the first and second materials have been defined as having different swelling properties, the materials may in fact be the same, albeit prepared or otherwise treated in a particular manner to establish the
different swelling properties. Alternatively, or additionally, different materials may be utilised.

The swelling portion may be arranged such that an interface is established between the first and second materials. The interface may be defined by an abrupt change in material or by a discontinuity or the like. Alternatively, the interface may be defined by a gradual change in material. For example, the swelling portion may comprise a plurality of materials which change over a gradual interface between the first and second material of the central and first end regions.

The central and first end regions of the swelling portion may be defined by one or more materials held in a matrix formed by a further material, and the size, concentration or relative proportions of the different materials may be varied to define the different regions of the swelling portion.

The central and first end regions may be entirely formed, respectively, by the first and second materials. Alternatively, one or both of the central and first end regions may comprise one or more additional materials. The additional material may or may not be swellable.

The swellable materials may be adapted to swell by the same activator, or alternatively by a different activator. For example, in some embodiments one of the regions of the seal body may be formed of a material which is activated by a fluid which is normally resident in one part of a wellbore, and another region may be formed of a material which is activated by a different fluid normally resident in another part of the same wellbore. In this arrangement the particular composition of fluids within the wellbore may be determined, such as by logging techniques, and the required properties of the materials forming the seal body then selected to be run into the wellbore as part of the downhole seal.

The swellable materials may be adapted to swell by changing wellbore fluids. For example, during a first period of well production the wellbore fluid may be predominantly hydrocarbons, and during subsequent periods may be predominantly water. The swellable materials may be adapted to swell by a changing property of a wellbore fluid, such as a chemical, thermodynamic, fluid dynamic property or the like. For example, swelling may be achieved where the salinity, temperature, flow rate or the like of a wellbore fluid varies with time.

In embodiments of the invention the downhole seal may be adapted for use as a packer.

The swelling portion may comprise a second end region located axially opposed to the first end region. In this arrangement, at least a portion of the central region may be interposed between the first and second end regions. The second
end region may be formed from the second swellable material, or from an alternative swelling or non-swelling material.

The second end region may be similar to the first end region in many or all respects, and as such for brevity all optional features identified above in relation to the first end region may be assumed to apply to the second end region.

The first and second end regions may be interconnected. For example, the first and second end regions may be interconnected via a web extending through the central region or alternatively along an internal surface of the central region. The web may be at least partially formed of the same material as the first and second end regions, or alternatively may be formed of a different material. In one arrangement the first and second end regions may be provided as a unitary component defining a central annular recess, wherein the central region of the swelling portion is located within said annular recess.

According to a second aspect of the present invention there is provided a method of controlling the swelling characteristics of a downhole seal, said method comprising the steps of:

selecting a first swelling material and forming a central region of a swelling portion; and

selecting a second swelling material and forming a first end region of the swelling portion, wherein the first and second swelling materials have different swelling properties and define portions of the outer surface of the swelling portion.

According to a third aspect of the present invention there is provided a downhole seal comprising:

a tubular support member; and

a swelling portion comprising:

a central region comprising a first swelling material; and

a first end region comprising a second swelling material,

wherein the first and second swelling materials have different swelling properties and define portions of the outer surface of the swelling portion.

According to a fourth aspect of the present invention, there is provided a method of establishing a seal within a wellbore, said method comprising the steps of:

providing a downhole seal according to the first or third aspects;

running the seal body into a wellbore; and

permitting the first and second materials to swell to achieve a preferential effective swelling characteristic of the downhole seal.
BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic representation of a downhole seal in accordance with an embodiment of the present invention;

Figure 2 is a longitudinal cross-sectional view of the downhole seal of Figure 1;

Figures 3A and 3B are cross-sectional views of the downhole seal of Figure 1 in different states of sealing within a wellbore; and

Figures 4 to 7 are longitudinal cross-sectional views of downhole seals in accordance with alternative embodiments of the present invention;

DETAILED DESCRIPTION OF THE DRAWINGS

Reference is first made to Figure 1 of the drawings in which there is shown a downhole seal, generally identified by reference numeral 10, in accordance with one embodiment of the present invention. The downhole seal 10 comprises a seal body 12 in the form of an annular band mounted on the outer surface of a wellbore tubular body 14, such as a production tubular. As will be described in further detail below, the seal body 12 incorporates a swelling portion 16 formed of a swellable material, such as a swelling elastomer, which is adapted to swell when exposed to an activator, such as water, hydrocarbons or the like, either present within the wellbore or specifically injected into the wellbore. In use, the downhole seal 10 may be run into a wellbore, such as an open wellbore, cased wellbore or the like on a tubing string, and when exposed to a relevant activator the swelling portion 16 of the seal body 12 will swell to establish an annular seal at a downhole location. As will be discussed in detail below, the downhole seal 10 in the embodiment shown is specifically adapted to minimise the problems associated with conventional swelling seals in which end regions tend to swell at a faster rate than the central region.

A longitudinal cross-sectional view of the downhole seal 10 is shown in Figure 2, reference to which is now made. The swelling portion 16, which in the embodiment shown defines the entire seal body 12, comprises a central region 18 and first and second axially opposing end regions 20, 22. The first and second end regions 20, 22 are axially disposed relative to the central region 18 and are located adjacent axially opposing end faces 24, 26 of the central region 18. It should be noted, however, that the end faces 24, 26 of the central region are diagrammatically represented as very well defined interfaces between the central and first and second end regions. 18, 20, 22. While in some embodiments this may be the case it should
be understood that in other embodiments the manufacturing or forming process, for example, may result in a more gradual interface between the different regions.

The central and end regions 18, 20, 22 define portions of the outer surface of the swelling portion 16.

The central region 18 is formed of a first swellable material and the end regions 20, 22 are formed of a second swellable material. The first and second materials have different swelling properties and in the embodiment shown the first material forming the central region 18 is adapted to swell at a faster rate than the second material of the end regions 20, 22. Accordingly, in use, in one arrangement the swelling portion 16 of the seal body 12 will have an effective swelling profile or characteristic in which the central region 18 will swell at a faster rate than the end regions 20, 22, thus advantageously assisting to address problems in the art associated with end regions swelling too fast.

The downhole seal 10 is shown in Figures 3A and 3B in sequential stages of sealing within a wellbore 28. In Figure 3A, the downhole seal 10 is shown being run into the wellbore 28 in the direction of arrow A towards the required wellbore destination. The seal 10 may be run in on a tubing string (not shown), such as a production tubing string, coiled tubing or the like. Upon contact with an activator 30, which may be water or hydrocarbons, for example, located within the well bore 28 the regions 18, 20, 22 of the sealing portion 16 will begin to swell. As noted above, in the embodiment shown the material of the end regions 20, 22 is selected to have a slower swelling rate than the material of the central region 18 and as such a swelling profile is established in which the central region 18 swells faster than the end regions 20, 22. This profile, which is represented in Figure 3A, therefore permits easier run-in of the seal 10 and eliminates the problems associated with conventional seals in which end regions tend to swell faster.

In Figure 3B both the central and end regions 18, 20, 22 are shown fully swollen to seal the annulus 32 formed between the wellbore 28 and the outer surface of the tubular body 14.

Reference is now made to Figure 4 in which there is shown a longitudinal cross-sectional view of a downhole seal, generally identified by reference numeral 110, in accordance with an alternative embodiment of the present invention. The downhole seal 110 is similar to the downhole seal 10 described above in many respects, and as such like features are identified by like reference numerals, incremented by 100.

Thus, the downhole seal 110 comprises a seal body 112 mounted on the outer surface of a tubular body 114. The seal body 112 also comprises a swelling
portion 116 formed of a central region 118 and first and second axially opposed end regions 120, 122, wherein the central and end regions 118, 120, 122 define the outer surface of the swelling portion 116. The central region 118 is formed of a first swellable material and the end regions 120, 122 are formed of a second swellable material, wherein the second material is adapted to swell at a slower rate then the first material. This arrangement therefore provides the swelling portion 116 with a preferential swelling profile or characteristic, similar to that described above with reference to downhole seal 10.

The seal body 112 further comprises an outer cover or casing of material 117 which encapsulates the swelling portion 116. In the embodiment shown the casing 117 is formed of a non-swelling material and functions to delay exposure of the swelling portion 116 to a swelling activator, such as a wellbore fluid. This arrangement therefore may assist to address the problems associated with premature swelling of swellable seals, particularly while being run into a wellbore.

A further alternative embodiment of a downhole seal according to the present invention is shown in Figure 5, reference to which is now made. The downhole seal, generally identified by reference numeral 210, is similar to seal 10 first shown in Figure 1 and as such like features share like reference numerals, incremented by 200.

The downhole seal 210 therefore comprises a seal body 212 mounted on a tubular member 214, wherein the seal body 212 is entirely formed of a swelling portion 216. Similar to the embodiments described above, the swelling portion 216 comprises a central region 218 formed of a first swellable material, and first and second end regions 220, 222 formed of a second swellable material, wherein the second material is adapted to swell at a slower rate then the first material.

The swelling portion 216 further comprises a web 221 extending between the first and second end regions 220, 222 and an inner surface of the central region 218. Specifically, the first and second end regions 220, 222 and the web 221 collectively define an annular recess 223 within which the central region 218 is located.

The web 221 in the embodiment shown is formed of the same material as the end regions 220, 222. In use, the web 221 may alter the effective swelling profile or characteristic of the entire swelling portion 216. For example, once the central and end regions 218, 220, 222 form a seal against a bore wall, the web 221 may assist to, for example, increase or maintain the sealing pressure by continuing to swell at a slower, and delayed, rate than the central region 218.

In the further embodiment shown in Figure 6, a downhole seal, generally identified by reference numeral 310, comprises a seal body 312 mounted around the
outer surface of a tubular body 314. The seal body 312 is formed entirely from a swelling portion 316, wherein the swelling portion 316 includes a central region 318 which incorporates outer annular recesses 340, 342 at either end thereof. The swelling portion 316 further comprises annular end regions 320, 322 located within respective recesses 340, 342 of the central region 318. The central region 318 is formed of a first swellable material and the annular end regions 320, 322 are formed of a second swellable material, wherein the first and second materials have different swelling properties. In the embodiment shown in Figure 6 the second material is adapted to swell at a slower rate than the first material. Accordingly, in use, when the seal body 312 is exposed to a swelling activator the swelling portion 316 will begin to swell, with the end regions 320, 322 swelling at a slower rate than the central region 318. The recessed areas 340, 342 of the central region 318 will initially be at least partially isolated from exposure to a swelling activator. However, when the activator has permeated through the end regions 320, 322 and exposed to the recessed areas 340, 342, then these areas will be caused to swell at the faster rate. This embodiment therefore again assists to minimise problems in the art associated with end regions of swellable seals swelling too fast, while providing an effective swelling characteristic which allows end regions to initially swell slowly and then increase in swell rate with time.

Further embodiments of the invention include downhole seals in which more than two materials of different swelling properties are utilised to form a seal body. For example, in the embodiment shown in Figure 7 a downhole seal 410 includes a seal body 412 mounted on a base tubular body 414, wherein the seal body 412 comprises a swelling portion 416 having a central region 418 and first and second end regions 420, 422, wherein each region 418, 420, 422 is formed of a respective swellable material with different swelling properties. The particular swelling properties of each material may be selected in accordance with the desired effective swelling characteristic of the swelling portion 416.

The present invention, as described in the exemplary embodiments above, provides particular advantages in that a particular swelling characteristic of a swellable downhole seal may be established by the selection and combination of materials of different swelling properties.

It should be understood that the embodiments described above are merely exemplary and that various modifications may be made thereto without departing from the scope of the present invention. For example, the arrangement of regions of different swelling properties forming the seal body may be selected in accordance with the particular effective swelling characteristic required. In this respect, the
downhole seal first shown in Figure 1 is formed such that the end regions 20, 22
swell at a slower rate than the central region 18. However, in other embodiments of
the invention a swelling portion may be formed such that the end regions swell at the
same rate at the central region, providing uniform expansion. Additionally, in certain
embodiments having end regions to swell at a faster rate than a central region may
be desired. In this respect it is a particular advantage of the present invention that
any required swelling profile or characteristic can be achieved by appropriate
selection of swelling material.

In the arrangement shown in Figure 4 the outer cover 117 is formed of a non-
swelling material. However, in other embodiments a cover may be provided which is
formed of a swelling material, and the properties of this swelling material may be
specifically selected to alter the swelling characteristics of the entire seal body. Further, in other embodiments the outer cover may only partially encapsulate the
swelling portion.

Also, in the arrangement shown in Figure 5, the web comprises the same
swellable material as the end regions. However this is not essential and the web
may comprise any suitable swellable material, and in some cases may comprise a
non-swelling material. The web may be utilised as structural support for the seal
body. Additionally, the web may extend through the central region, rather than along
the inner surface of the central region.

In all embodiments described the central region interposes two end regions of
swellable material. However, only one end region may be provided, such as a
leading end region relative to the intended direction of travel of the seal through a
wellbore. Furthermore, in each case described the end regions are located directly
adjacent the central region. However, in alternative embodiments further regions
may be interposed between the end regions and the central region.

Additionally, it should be noted that although materials of different swelling
properties are utilised, the materials may in fact be the same, albeit prepared or
otherwise treated in a particular manner to establish the different swelling properties.
Alternatively, or additionally, different materials may be utilised. Also, the swellable
materials may be adapted to swell by the same activator, or alternatively by a
different activator. For example, in some embodiments one of the regions of the seal
body may be formed of a material which is activated by a fluid which is normally
resident in one part of a wellbore, and another region may be formed of a material
which is activated by a different fluid normally resident in another part of, or at
another time in, the same wellbore. In this arrangement the particular composition of
fluids within the wellbore may be determined, such as by logging techniques, and the
required properties of the materials forming the seal body then selected to be run into
the wellbore as part of the downhole seal.

Furthermore, the seal body may also comprise a non-swelling material, or alternatively, or additionally, one of the swellable materials of the embodiments described above may be substituted for a non-swellable material.

Additionally, although some preferred seal body effective sealing characteristics have been described above, the materials of the seal body may be selected and arranged to provide any required seal characteristic.
CLAIMS:

1. A downhole seal comprising a swelling portion, said swelling portion comprising:
   a central region comprising a first swelling material; and
   a first end region comprising a second swelling material,
   wherein the first and second swelling materials have different swelling properties and define portions of the outer surface of the swelling portion.

2. The downhole seal according to claim 1, wherein the second material is adapted to swell at a slower rate than the first material.

3. The downhole seal according to claim 1 or 2, wherein the downhole seal comprises a seal body, and wherein the swelling portion defines at least a portion of the seal body.

4. The downhole seal according to claim 3, wherein the swelling portion defines the entire seal body.

5. The downhole seal according to claim 3, wherein the seal body comprise one or more additional elements.

6. The downhole seal according to any preceding claim, comprising a unitary swelling portion.

7. The downhole seal according to any preceding claim, wherein one or both of the first and second materials comprise an elastomer.

8. The downhole seal according to any preceding claim, wherein the first and second materials are adapted to be activated to swell by at least one of a chemical activator, thermodynamic activator and fluid dynamic activator.

9. The downhole seal according to any preceding claim, wherein the first end region is located axially adjacent the central region.

10. The downhole seal according to any preceding claim, wherein the first end region is located circumferentially adjacent a portion of the central region.
11. The downhole seal according to any preceding claim, wherein the central region defines a recess, and the first end region is disposed within said recess.

12. The downhole seal according to any preceding claim, wherein the first end region is located directly adjacent the central region.

13. The downhole seal according to any one of claims 1 to 11, wherein the swelling portion comprises a further region interposed between the central and first end regions.

14. The downhole seal according to any preceding claim, wherein the swelling portion is arranged such that an interface is established between the first and second materials.

15. The downhole seal according to claim 14, wherein the interface is defined by an abrupt change in material.

16. The downhole seal according to claim 14, wherein the interface is defined by a gradual change in material.

17. The downhole seal according to any preceding claim, wherein at least one of the first and second swellable materials is adapted to swell by changing wellbore fluids.

18. The downhole seal according to any preceding claim, wherein at least one of the first and second swellable material is adapted to swell by a changing property of a wellbore fluid.

19. The downhole seal according to any preceding claim, wherein the swelling portion comprises a second end region located axially opposed to the first end region, such that at least a portion of the central region is interposed between the first and second end regions.

20. The downhole seal according to claim 19, wherein the first and second end regions are interconnected.
21. A method of controlling the swelling characteristics of a downhole seal, said method comprising the steps of:
   selecting a first swelling material and forming a central region of a swelling portion; and
   selecting a second swelling material and forming a first end region of the swelling portion, wherein the first and second swelling materials have different swelling properties and define portions of the outer surface of the swelling portion.

22. A downhole seal comprising:
   a tubular support member; and
   a swelling portion comprising:
      a central region comprising a first swelling material; and
      a first end region comprising a second swelling material,
   wherein the first and second swelling materials have different swelling properties and define portions of the outer surface of the swelling portion.

23. A method of establishing a seal within a wellbore, said method comprising the steps of:
   providing a downhole seal according to the first or third aspects;
   running the downhole seal into a wellbore; and
   permitting the first and second materials to swell to achieve a preferential effective swelling characteristic of the downhole seal.
INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2009/000330

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B33/12

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

B. DOCUMENTS SEARCHED

Minimum documentation searched (classification system toDowed by classification symbols)
E21B

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

Electronic database consulted during the international search (name of database and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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26 May 2009

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