APPLICATION FOR PATENT

Zonal Isolation Of Telescoping Perforation Apparatus With Memory Based Material

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FIELD OF THE INVENTION

[0001] This invention is in the field of methods and apparatus for isolating one formation zone of an oil or gas well bore from another zone.

BACKGROUND OF THE INVENTION

[0002] It is common to drill an oil or gas well bore into and through several different formation zones, where the zones are layered vertically. In such cases, it is typical to isolate each zone from the zones above and below it by installing a packer in the well bore between zones, surrounding a tubular element, such as production piping, which is used to access the various zones. Known systems for achieving this isolation commonly use inflatable or mechanically expandable packers. The inflated packers can be filled with various fluids or even cement. These types of packers can be expensive, and setting them in place can be complicated, since electrical or mechanical systems are usually required for the setting operation. These packers are also less effective in open hole applications than in cased hole applications, because they sometimes do not truly conform to the irregular walls of the open hole, resulting in a limited pressure seal capacity. The problems of expense and complexity are even greater in an application where numerous zones are being accessed by a multi-purpose tool having numerous perforation sections for production of fluid from the well or injection of fluid into the well. This is because numerous packers are required to isolate between zones, and because operation of the numerous perforation sections adds to the overall complexity of operating such a tool.

BRIEF SUMMARY OF THE INVENTION

[0003] The present invention is a method and apparatus for isolating between zones with a packer. In the preferred embodiment the packer constructed of memory based material, such as a memory based foam, where the multiple zones are accessed by means of radially telescoping perforation elements. The memory based material is formed onto a base element, such as a mandrel or another tubular element, to form a packer with an outer diameter slightly larger than the downhole diameter in which the packer will be used. The packer is positioned between two sections of radially telescoping perforation elements, in a downhole tool. Two or more packers can be arranged between three or more sections of radially telescoping perforation elements. The memory based material is compressed, such as by elevating a memory based foam to a temperature at which it begins to soften, sometimes called the transition temperature, and the outside diameter of the memory based material is reduced to a smaller diameter, such as by being compressed. Once compressed, the memory based material is then stabilized at that smaller diameter, such as by cooling a memory based foam below the transition temperature, causing it to harden at this desired, smaller, run-in diameter. Then, the tool is run into the hole on a tubular work string, placing each packer at a depth where zonal isolation is required, and placing each section of radially telescoping perforation elements at a depth where zonal access is required. Once each packer is at its respective required zonal isolation depth, the memory based material is then expanded, such as by raising a memory based foam above the transition temperature, causing it to tend to return to its original, larger, outer diameter. Since the original diameter is larger than the hole diameter, the packer conforms to the bore hole and exerts an effective pressure seal on the bore hole wall, between zones. As an alternative, the mandrel or other base element can be hollow, and it can be expanded either before, during, or after the temperature-induced expansion of the foam expansion element. This expansion can be achieved by a mechanical, hydraulic, or hydro-mechanical device. Expansion of the mandrel can enhance the overall expansion achieved with a given amount of memory based material expansion, and it can increase the resultant pressure exerted by the memory based expansion element on the borehole wall, thereby creating a more effective

seal. Different packers can be adapted to expand at different temperatures, or through other means adapted to expand at different selected times, as desired by the operator. If desired, cementing of the annulus can also be performed, in the normal fashion. Other alternatives to shape memory packers are envisioned for sealing producing zones such as mechanically or hydraulically set packers, inflatable packers, barriers made of a hardenable material and other designs used downhole to isolate one portion of the wellbore from another.

[0004] The novel features of this invention, as well as the invention itself, will be best understood from the attached drawings, taken along with the following description, in which similar reference characters refer to similar parts, and in which:

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0005] Figure 1 is a perspective view of the preferred memory based packer invention, in its originally formed size and shape and is intended to schematically illustrate the use of alternative barriers in the present invention;

[0006] Figure 2 is a perspective view of the apparatus shown in Figure 1, reduced to its interim size and shape;

[0007] Figure 3 is a perspective view of the apparatus shown in Figure 1, expanded to seal against the borehole wall;

[0008] Figures 4 and 5 are partial section views of the memory based packer of the present invention, implementing a hydro-mechanical device to expand the mandrel;

[0009] Figures 6 and 7 are partial section views of the memory based packer of the present invention, implementing a mechanical device to expand the mandrel;

[0010] Figure 8 is a partial section view of the memory based packer of the present invention, implementing a hydraulic device to expand the mandrel;

[0011] Figures 9 and 10 show a first embodiment of the invention incorporating a memory based packer with a telescoping perforation tool having a solid walled shifting sleeve, some sand control elements, and some fracturing elements;

[0012] Figures 11 and 12 show a second embodiment of the invention incorporating a memory based packer with a telescoping perforation tool having a shifting sleeve incorporating a sand control medium, where none of the telescoping elements have a sand control medium;

[0013] Figures 13 and 14 show a third embodiment of the invention incorporating a memory based packer with a telescoping perforation tool having a shifting sleeve with ports, some sand control elements, and some fracturing elements; and

[0014] Figures 15 and 16 show a fourth embodiment of the invention incorporating a memory based packer with a telescoping perforation tool having a shifting sleeve with some sand control ports, and some fracturing ports.

DETAILED DESCRIPTION OF THE INVENTION

[0015] As shown in Figure 1, the preferred packer for use in the present invention is a memory based packer 10 having a base element, such as a tubular element or a mandrel 20, on which is formed a memory based expansion element 30, such as an element constructed of memory based foam. The mandrel 20 can be any desired length or shape, to suit the desired application, and it can be hollow if required. It can also have any desired connection features, such as threaded ends. The mandrel 20 can be a portion of the tubular body of the overall tool, or it can be a separate tubular element. The expansion element 30 is shown with a cylindrical shape, but this can be varied, such as by means of concave ends or striated areas (not shown), to facilitate deployment, or to enhance the sealing characteristics of the packer. The expansion element 30 is composed of a memory based material, for example, an elastic memory foam such as Tembo™ foam, an open cell syntactic foam manufactured by Composite Technology Development, Inc. This type of foam has the property of being convertible from one size and shape to another size and/or shape, by changing the temperature of the foam. This type of foam

can be formed into an article with an original size and shape as desired, such as a cylinder with a desired outer diameter. The foam article thusly formed is then heated to raise its temperature to its transition temperature. As it achieves the transition temperature, the foam softens, allowing the foam article to be reshaped to a desired interim size and shape, such as by being compressed to form a smaller diameter cylinder. The temperature of the foam article is then lowered below the transition temperature, to cause the foam article to retain its interim size and shape. When subsequently raised again to its transition temperature, the foam article will return to its original size and shape.

[0016] In the present invention, the cylindrical memory based expansion element 30 can be originally formed onto the mandrel 20 by wrapping a blanket of the memory based material onto the mandrel 20, with the desired original outer diameter OD_1. Alternatively, the process for forming the expansion element 30 on the mandrel 20 can be any other process which results in the expansion element 30 having the desired original diameter, such as by molding the memory based material directly onto the mandrel 20. The desired original outer diameter OD_1 is larger than the bore hole diameter BHD (shown for reference in Figure 1) in which the packer 10 will be deployed. For instance, an expansion element 30 having an original outer diameter OD_1 of 10 inches might be formed for use in an 8.5 inch diameter borehole.

[0017] Then, the memory based packer is reduced in diameter, for example by raising the temperature of the expansion element 30 above the transition temperature of the memory based foam material, which causes the foam to soften. At this point, the expansion element 30 is compressed to a smaller interim outer diameter OD_2. For instance, the expansion element 30 might be compressed to an interim outer diameter OD_2 of 7.5 inches for use in an 8.5 inch diameter borehole. This facilitates running the packer 10 into the borehole. This type of foam may be convertible in this way to an interim size and shape approximately one third the volume of the original size and shape. After compression, the expansion element 30 is lowered below its transition temperature, causing it to retain its smaller interim outer diameter OD_2. This cooling step can be achieved by exposure to the ambient environment, or by exposure to forced cooling.

[0018] After this diameter reduction, the memory based packer 10 is lowered into the borehole to the desired depth at which zonal isolation is to occur, as shown in Figure 2. Once the packer 10 is located at the desired depth for isolating the borehole, the expansion element 30 is again expanded, such as by being raised to the transition temperature of the foam. As shown in Figure 3, this causes the expansion element 30 to expand to a final outer diameter OD_3. Because of the properties of the elastic memory foam, the expansion element 30 attempts to return to the original outer diameter OD_1. However, since the original outer diameter OD_1 was selected to be larger than the borehole diameter BHD, the expansion element 30 can only expand until the final outer diameter OD_3 matches the borehole diameter BHD. This can cause the expansion element 30 to exert a pressure of between 300 and 500 psi on the borehole wall.

[0019] The memory based packer can be adapted to selectively expand at different times; for example, where memory based foam is used, the foam material composition can be formulated to achieve the desired transition temperature. This quality allows the foam to be formulated in anticipation of the desired transition temperature to be used for a given application. For instance, in use with the present invention, the foam material composition can be formulated to have a transition temperature just slightly below the anticipated downhole temperature at the depth at which the packer 10 will be used. This causes the expansion element 30 to expand at the temperature found at the desired depth, and to remain tightly sealed against the bore hole wall. Downhole temperature can be used to expand the expansion element 30; alternatively, other means can be used, such as a separate heat source. Such a heat source could be a wireline deployed electric heater, or a battery fed heater. For example, such a heat source could be mounted to the mandrel 20, incorporated into the mandrel 20, or otherwise mounted in contact with the foam expansion element 30. The heater could be controlled from the surface of the well site, or it could be controlled by a timing device or a pressure sensor. Still further, an exothermic reaction could be created by chemicals pumped downhole from the surface, or heat could be generated by any other suitable means. Also, on a tool where several packers 10 are employed, each packer can be formulated to expand at a different temperature, giving the operator individual control of the expansion of each packer.

[0020] As an alternative, if it is desired to enhance the overall amount of packer expansion achievable, in addition to the expansion achievable with a given volume of memory based material, the mandrel 20 itself can be a hollow base element which can be expanded radially. This additional expansion can be achieved by the use of a mechanical, hydraulic, or hydro-mechanical device. For example, as shown in Figure 4, a hydro-mechanical expander 40 can be run into the tubing on a work string, either before, during, or after the memory based expansion of the material. The hydro-mechanical expander 40 can consist essentially of an anchoring device 42, a hydraulic ram 44, and a conical pig 46. Once the conical pig 46 reaches the mandrel 20, the anchoring device 42 is activated to anchor itself to the tubing. Activation of the anchoring device 42 can be mechanical, electrical, or hydraulic, as is well known in the art. Once the expander 40 is thusly anchored in place, the hydraulic ram 44 can be pressurized to force the conical pig 46 into and through the mandrel 20 of the packer 10, as shown in Figure 5. Since the outer diameter of the conical pig 46 is selected to be slightly larger than the inner diameter of the mandrel 20, as the conical pig 46 advances through the mandrel 20, it radially expands the mandrel 20.

[0021] As mentioned above, this expansion of the mandrel 20 can be implemented before, during, or after the memory based expansion of the expansion element 30. It can be seen that radial expansion of the mandrel 20 in this way can enhance the overall expansion possible with the packer 10. Therefore, for a given amount of memory based material in the expansion element 30, the final diameter to which the packer 10 can be expanded can be increased, or the pressure exerted by the expanded packer 10 can be increased, or both. For example, a relatively smaller overall diameter packer 10 can be run into the hole, thereby making the running easier, with mandrel expansion being employed to achieve the necessary overall expansion. Or, a relatively larger overall diameter packer 10 can be run into the hole, with mandrel expansion being employed to achieve a higher pressure seal against the borehole wall.

[0022] As a further alternative to use of the hydro-mechanical expander 40, the mandrel 20 can be expanded by mechanically forcing a conical pig 50 through the

mandrel 20 with a work string, as shown in Figures 6 and 7. Forcing of the pig 50 through the mandrel 20 can be either by pushing with the work string, as shown in Figure 6, or by pulling with the work string, as shown in Figure 7. Still further, the mandrel 20 can be expanded by hydraulically forcing a conical pig 60 through the mandrel 20 with mud pump pressure, as shown in Figure 8.

[0023] While memory based packers are preferred, other barriers used downhole to isolate one portion of the wellbore from another can be used as alternatives. These barriers can be mechanically or hydraulically set packers, inflatables, or materials that can be deposited in an annular space and become firm barriers such as, for example, cement.

[0024] The present invention provides one or more memory based packers 10 between two or more sections of radially telescoping perforating elements, for selectively perforating a well bore liner, fracturing a formation, and producing or injecting fluids, sand-free. Examples of such tools are shown in Figures 9 through 16. In each of these, the memory based packers 10 are mounted on a tubular tool body having a plurality of radially outwardly telescoping tubular elements. The radially telescoping tubular elements are grouped in two or more groups, separated vertically, to align with the various zones of the formation in which the tool will be used. Packers can be provided between the groups of telescoping tubular elements. A mechanical means can be provided for selectively controlling the hydrostatic fracturing of the formation through one or more of the telescoping elements and for selectively controlling the sand-free injection or production of fluids through one or more of the telescoping elements. Selective expansion of the memory based packers 10 is as described above.

[0025] The apparatus can have a built-in sand control medium in one or more of the telescoping elements, to allow for injection or production, and a check valve in one or more of the telescoping elements, to allow for one way flow to hydrostatically fracture the formation without allowing sand intrusion after fracturing. Vertical isolation of the zones is achieved by placement of one or more memory based packers 10.

[0026] Other types of telescoping perforation sections used in the apparatus of the present invention, along with the memory based packer, can have a sleeve which shifts between a fracturing position and an injection/production position, to convert the tool between these two types of operation. The sleeve can shift longitudinally or it can rotate.

[0027] In a first shifting-sleeve type, the sleeve can be a solid walled sleeve, as shown in Figures 9 and 10, which shifts to selectively open and close the different telescoping elements, with some telescoping elements having a built-in sand control medium (which may be referred to in this case as "sand control elements") and other telescoping elements having no built-in sand control medium (which may be referred to in this case as "fracturing elements"). In this embodiment of the apparatus 100, the shifting sleeve 16 is a solid walled sleeve as before, but it can be positioned and adapted to shift in front of, as in Figure 9, or away from, as in Figure 10, one or more rows of fracturing elements 12. It can be seen that the fracturing elements 12 have an open central bore for the passage of proppant laden fracturing fluid. The sand control elements 14 can have any type of built-in sand control medium therein, with examples of metallic beads and screen material being shown in the Figures. Whether or not the shifting sleeve 16 covers the sand control elements 14 when it uncovers the fracturing elements 12 is immaterial to the efficacy of the tool 100. Isolation between the zones is provided by the expanded memory based packer 10.

[0028] In a second shifting-sleeve type of the apparatus 100, as shown in Figures 11 and 12, the sleeve itself can be a sand control medium, such as a screen, which shifts to selectively convert the telescoping elements between the fracturing mode and the injection/production mode. In this embodiment, none of the telescoping elements would have a built-in sand control medium. This longitudinally sliding shifting sleeve 16 is constructed principally of a sand control medium such as a screen. Figure 11 shows the sleeve 16 positioned in front of the telescoping elements 12, for injection or production of fluid. Figure 12 shows the sleeve 16 positioned away from the telescoping elements 12, for pumping of proppant laden fluid into the formation. In this embodiment, none of the

telescoping elements has a built-in sand control medium. Isolation between the zones is provided by the expanded memory based packer 10.

[0029] In a third shifting-sleeve type, as shown in Figures 13 and 14, the sleeve can have ports which are shifted to selectively open and close the different telescoping elements, with some telescoping elements having a built-in sand control medium (which may be referred to in this case as "sand control elements") and other telescoping elements having no built-in sand control medium (which may be referred to in this case as "fracturing elements"). In this embodiment of the apparatus 100, the sleeve shifts to selectively place the ports over either the "sand control elements" or the "fracturing elements". This shifting sleeve 16 is a longitudinally shifting solid walled sleeve having a plurality of ports 24. The sleeve 16 shifts longitudinally to position the ports 24 either in front of or away from the fracturing elements 12. Figure 13 shows the ports 24 of the sleeve 16 positioned away from the fracturing elements 12, for injection or production of fluid through the sand control elements 14. Figure 14 shows the ports 24 of the sleeve 16 positioned in front of the fracturing elements 12, for pumping of proppant laden fluid into the formation. In this embodiment, the fracturing elements 12 have an open central bore for the passage of proppant laden fracturing fluid. The sand control elements 14 can have any type of built-in sand control medium therein. Here again, whether or not the shifting sleeve 16 covers the sand control elements 14 when it uncovers the fracturing elements 12 is immaterial to the efficacy of the tool 10. Isolation between the zones is provided by the expanded memory based packer 10.

[0030] In a fourth shifting-sleeve type, as shown in Figures 15 and 16, the sleeve can have ports, some of which contain a sand control medium (which may be referred to in this case as "sand control ports") and some of which do not (which may be referred to in this case as "fracturing ports"). In this embodiment of the apparatus 100, none of the telescoping elements would have a built-in sand control medium, and the sleeve shifts to selectively place either the "sand control ports" or the "fracturing ports" over the telescoping elements. This shifting sleeve 16 is a rotationally shifting solid walled sleeve having a plurality of ports 24, 26. A first plurality of the ports 26 (the sand control ports)

have a sand control medium incorporated therein, while a second plurality of ports 24 (the fracturing ports) have no sand control medium therein. The sleeve 16 shifts rotationally to position either the fracturing ports 24 or the sand control ports 26 in front of the telescoping elements 12. Figure 15 shows the fracturing ports 24 of the sleeve 16 positioned in front of the elements 12, for pumping of proppant laden fluid into the formation. Figure 16 shows the sand control ports 26 of the sleeve 16 positioned in front of the telescoping elements 12, for injection or production of fluid through the elements 12. In this embodiment, all of the telescoping elements 12 have an open central bore; none of the telescoping elements has a built-in sand control medium. Isolation between the zones is provided by the expanded memory based packer 10.

[0031] It should be understood that a rotationally shifting type of sleeve, as shown in Figures 15 and 16, could be used with only open ports, as shown in Figures 13 and 14, with both fracturing elements 12 and sand control elements 14, without departing from the present invention. It should be further understood that a longitudinally shifting type of sleeve, as shown in Figures 13 and 14, could be used with both open ports and sand control ports, as shown in Figures 15 and 16, with only open telescoping elements 12, without departing from the present invention.

[0032] While the particular invention as herein shown and disclosed in detail is fully capable of obtaining the objects and providing the advantages hereinbefore stated, it is to be understood that this disclosure is merely illustrative of the presently preferred embodiments of the invention and that no limitations are intended other than as described in the appended claims.

We claim:

1. A method for isolating formation zones of a well, said method comprising:

forming an expansion element of memory based material on a base element, said expansion element having an original outer diameter larger than a selected borehole diameter;

providing at least one radially telescoping perforation element on said base element;

reducing the diameter of said memory based material to an interim outer diameter smaller than said selected borehole diameter;

stabilizing said memory based material at said interim outer diameter;

running said base element into a borehole to align said radially telescoping perforation element with a selected formation zone; and

allowing said memory based material to radially expand to seal between said base element and said borehole, to thereby isolate said selected formation zone.

2. The method recited in claim 1, further comprising:

forming said memory based material on a hollow mandrel;

attaching said hollow mandrel to said base element; and

radially expanding said hollow mandrel.

3. The method recited in claim 2, wherein said radial expansion of said hollow mandrel is employed prior to said radial expansion of said memory based material.

4. The method recited in claim 2, wherein said radial expansion of said hollow mandrel is employed during said radial expansion of said memory based material.

5. The method recited in claim 2, wherein said radial expansion of said hollow mandrel is employed after said radial expansion of said memory based material.

6. The method recited in claim 2, further comprising:

anchoring a hydro-mechanical expander within said base element; and

activating said hydro-mechanical expander to force a conical pig through said hollow mandrel, to achieve said radial expansion of said hollow mandrel.

7. The method recited in claim 2, further comprising:

lowering a conical pig through said base element on a work string; and

forcing said conical pig through said hollow mandrel with said work string, to achieve said radial expansion of said hollow mandrel.

8. The method recited in claim 7, wherein said conical pig is pushed through said hollow mandrel.

9. The method recited in claim 7, wherein said conical pig is pulled through said hollow mandrel.

10. The method recited in claim 2, further comprising:

pumping a conical pig through said base element with fluid pressure; and

forcing said conical pig through said hollow mandrel with said fluid pressure, to achieve said radial expansion of said hollow mandrel.

11. A tool for accessing isolated formation zones of a well, said tool comprising:

a tubular body; and

a substantially cylindrical expansion element formed on said tubular body, said expansion element being formed of memory based material, said expansion element having first and second stable states;

at least one radially telescoping perforation element on said tubular body adjacent to said expansion element, said at least one perforation element being adapted to access at least one selected formation zone;

wherein said memory based material in said first stable state has a first outer diameter larger than the diameter of the borehole of said well;

wherein said memory based material is selectively convertible to said second stable state at a second outer diameter smaller than said borehole diameter; and

wherein said memory based material is selectively convertible back to said first stable state at said first outer diameter.

12. The tool recited in claim 11, further comprising:

a plurality of said radially telescoping perforation elements grouped in a plurality of groups, said groups being longitudinally separated along said tubular body; and

a plurality of said expansion elements, said expansion elements being arranged between said groups of perforation elements.

13. The tool recited in claim 12, wherein said plurality of expansion elements are adapted to individually convert back to said first stable state at said first outer diameter.

14. The tool recited in claim 11, wherein said memory based material comprises a memory based elastic foam.

15. The tool recited in claim 11, wherein said at least one radially telescoping perforation element includes a sand control medium.

16. The tool recited in claim 11, further comprising:

a first plurality of said radially telescoping perforation elements adapted to inject fluid into a formation zone; and

a second plurality of said radially telescoping perforation elements adapted to produce fluid from a formation zone;

wherein said first plurality of perforation elements and said second plurality of perforation elements are separated from each other by said at least one expansion element.

17. A downhole completion method, comprising:

delivering a tubular housing to a predetermined location downhole;

providing valving on said tubular to selectively allow flow through a wall that defines said housing to go through in a filtered or unfiltered condition;

isolating said valving in at least one producing zone in the wellbore;

expanding said tubular when located downhole;

treating said producing zone using the unfiltered position of said valving;

producing said producing zone with said valving in the filtered position.

18. The method of claim 17, comprising:

expanding said tubular only adjacent to where said isolating has occurred.

19. The method of claim 17, comprising:

associating telescoping members with said valving.

20. The method of claim 17, comprising:

using a memory based material for said isolating.

21. The method of claim **20**, comprising:

performing said expanding before, during or after shape change of said memory material.

22. The method of claim **17**, comprising:

using at least one sliding sleeve for said valving.

23. The method of claim **22**, comprising:

associating a screen material with said sliding sleeve.

24. The method of claim **19**, comprising:

associating a screen material with said telescoping members.

25. The method of claim **22**, comprising:

operating said sliding sleeve by longitudinal shifting or by rotation.