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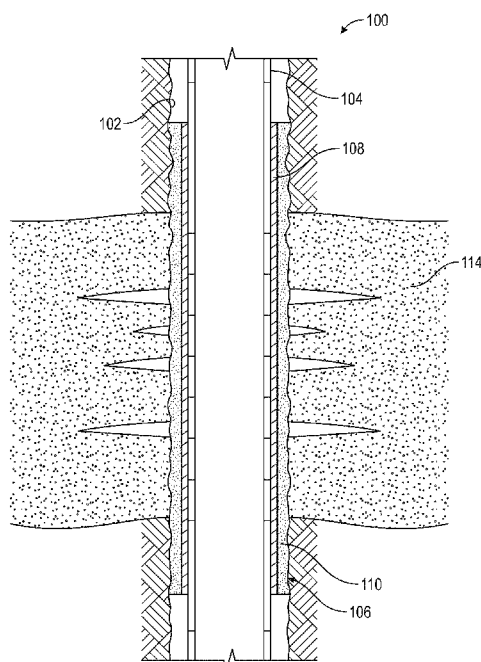


FIG. 1

(57) Abstract: A porous structural thermoset media is described herein. A method includes compressing a porous structural thermoset material having a first diameter to a second diameter that is smaller than the first diameter. The method also includes adding a containment material to the porous structural thermoset material, wherein the containment material provides a mechanical force to restrict expansion of the porous structural thermoset material in a radial direction.

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## POLYMERIC SAND SCREEN

### CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to US Provisional Patent Application having Serial No. 63/585,639, which was filed on September 27, 2023, US Provisional Patent Application having Serial No. 63/585,651, which was filed on September 27, 2023, US Provisional Patent Application having Serial No. 63/579,604, which was filed on August 30, 2023, US Provisional Patent Application having Serial No. 63/579,710, which was filed on August 30, 2023, US Provisional Patent Application having Serial No. 63/591,938, which was filed on October 20, 2023, US Provisional Patent Application having Serial No. 63/637,543, which was filed on April 23, 2024, US Provisional Patent Application having Serial No. 63/637,217, which was filed April 22, 2024, US Provisional Patent Application having Serial No. 63/550,716, which was filed on February 7, 2024, and US Provisional Patent Application having Serial No. 63/674,643, which was filed on July 23, 2024, each of which is incorporated herein by reference in its entirety.

### BACKGROUND

[0002] The present disclosure generally relates to porous structural thermoset media.

[0003] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it may be understood that these statements are to be read in this light, and not as admissions of prior art.

[0004] In many hydrocarbon wells, inflowing fluid passes through a sand screen which filters out particulates from the inflowing oil or gas. The sand screen prevents sand from entering the wellbore and reduces damage that may occur by erosion. Conventionally, sand

screens are made with a metallic mesh material. Once the sand screen is placed into the wellbore, gravel packs are pumped to fill the annulus between the screen and the formation.

**[0005]** In other instances, some metallic sand screens are expandable and are expanded downhole after placement in the wellbore. The result is a reduction in the annulus between the screen and the formation. The expandable screens in many instances have a limited expansion ratio, and the ability of the expandable screen to conform to borehole irregularities may not be satisfactory. Further, the ability of the expandable sand screen to resist borehole collapse may be reduced. Conventional sand screens are rated to resist greater external pressure than expandable sand screens, but can have reduced ability to conform to irregularities in the borehole. Expandable sand screens can better conform to irregularities in the borehole, however, they tend to resist less external pressure because of plastic deformation experienced by their metallic components.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0006]** These and other features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

**[0007]** FIG. 1 is a sectional view of a sand screen positioned in a wellbore, in accordance with an embodiment of the present disclosure;

**[0008]** FIG. 2 is a first embodiment of a method of shaping the porous structural thermoset material of FIG. 1 into a compressed form, in accordance with an embodiment of the present disclosure; and

**[0009]** FIG. 3 is a second embodiment of a method of shaping the porous structural thermoset material of FIG. 1 into a compressed form, in accordance with an embodiment of the present disclosure.

## DETAILED DESCRIPTION

[0010] Certain embodiments commensurate in scope with the present disclosure are summarized below. These embodiments are not intended to limit the scope of the disclosure, but rather these embodiments are intended only to provide a brief summary of certain disclosed embodiments. Indeed, the present disclosure may encompass a variety of forms that may be similar to or different from the embodiments set forth below.

[0011] As used herein, the term “coupled” or “coupled to” may indicate establishing either a direct or indirect connection (e.g., where the connection may not include or include intermediate or intervening components between those coupled), and is not limited to either unless expressly referenced as such. The term “set” may refer to one or more items. Wherever possible, like or identical reference numerals are used in the figures to identify common or the same elements. The figures are not necessarily to scale and certain features and certain views of the figures may be shown exaggerated in scale for purposes of clarification.

[0012] As used herein, the terms “inner” and “outer”; “up” and “down”; “upper” and “lower”; “upward” and “downward”; “above” and “below”; “inward” and “outward”; and other like terms as used herein refer to relative positions to one another and are not intended to denote a particular direction or spatial orientation. The terms “couple,” “coupled,” “connect,” “connection,” “connected,” “in connection with,” and “connecting” refer to “in direct connection with” or “in connection with via one or more intermediate elements or members.”

[0013] Furthermore, when introducing elements of various embodiments of the present disclosure, the articles “a,” “an,” and “the” are intended to mean that there are one or more of the elements. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements. Additionally, it should be understood that references to “one embodiment,” “an embodiment,” or “some embodiments” of the present disclosure are not intended to be

interpreted as excluding the existence of additional embodiments that also incorporate the recited features. Furthermore, the phrase A “based on” B is intended to mean that A is at least partially based on B. Moreover, unless expressly stated otherwise, the term “or” is intended to be inclusive (e.g., logical OR) and not exclusive (e.g., logical XOR). In other words, the phrase A “or” B is intended to mean A, B, or both A and B.

**[0014]** Present embodiments described herein generally relate to making and using a porous structural thermoset material. In some embodiments, this porous structural thermoset material can be used in sand control applications, among other applications. For example, one or more embodiments of the present disclosure relate to a porous structural thermoset material that is able to expand once deployed downhole to conform to an irregularly shaped wellbore for sand control operations. As further described below, the porous structural thermoset material according to one or more embodiments of the present disclosure exhibits permeability, robustness, and an expansion ratio that are favorable for sand control operations by allowing for support of the formation during the production of oil.

**[0015]** The present disclosure generally relates to using a porous structural thermoset material for sand control applications. More specifically, one or more embodiments of the present disclosure relate to a porous structural thermoset material that is able to expand once deployed downhole to conform to an irregularly shaped wellbore for sand control operations. The porous structural thermoset material according to one or more embodiments of the present disclosure also provides excellent thermal stability. As further described below, the porous structural thermoset material according to one or more embodiments of the present disclosure exhibits permeability, robustness, and an expansion ratio that are favorable for sand control operations.

**[0016]** The porous structural thermoset material utilized herein can include a network of pores inside of the structural thermoset material. Furthermore, techniques described herein allow for the generation of porous structural thermoset material, in a geometry which can be used as a sand screen, and that is compressed. The compressed porous structural thermoset material can be expanded when deployed downhole, for example, in a borehole.

By compressing the geometry of the porous structural thermoset material on the surface (e.g., during manufacture of the porous structural thermoset material), greater clearance during any running in hole (RIH) operation can be achieved.

[0017] With the foregoing in mind, FIG. 1 is a sectional view of a sand screen positioned in a wellbore according to one or more embodiments of the present disclosure is shown. Specifically, the wellbore 100 includes an open bore hole 102, a production tubing string 104, which may be a base pipe according to one or more embodiments, and a sand screen 106. While wellbore 100 is illustrated as being a substantially vertical, uncased well, it should be recognized that the subject disclosure is equally applicable for use in cased wellbores as well as in horizontal and/or inclined wellbores. The sand screen 106 includes a filter member 108 and a polymeric material, such as the porous structural thermoset material 110 according to one or more embodiments of the present disclosure. The sand screen 106 is shown positioned in the wellbore 100 adjacent a (producing) formation 114. In some embodiments, the sand screen 106 (and/or the porous structural thermoset material 110) can be, for example, an annular shaped member that can be disposed about the production tubing string 104. In addition, according to one or more embodiments of the present disclosure, the porous structural thermoset material 110 may be the only filtration agent without the use of any filter member 108. In one or more embodiments of the present disclosure, the filter member 108 can be configured for additional structural support of the porous structural thermoset material 110.

[0018] Still referring to FIG. 1, in a well completion method according to one or more embodiments of the present disclosure, at least one base pipe (e.g., production tubing string 104) may be covered with the porous structural thermoset material 110 according to one or more embodiments of the present disclosure. The porous structural thermoset material 110 covering the base pipe as the production tubing string 104 may be covered with a retainer before running the base pipe as the production tubing string 104 to a location in the wellbore 100. Upon exposure to a condition in the wellbore 100, the retainer may degrade and expose the porous structural thermoset material 110 to the wellbore fluids. In one or more

embodiments, various methods are employed to trigger expansion of the structural thermoset material 110. As the porous structural thermoset material 110 expands into and fills the annulus, the porous structural thermoset material 110 conforms to a wall of the wellbore 100. Because the porous structural thermoset material 110 is able to conform to the wellbore 100 wall in this way and has a permeability that is about equivalent to or greater than the permeability of the surrounding formation, the porous structural thermoset material 110 is able to allow formation fluids into the base pipe as the production tubing string 104 while filter debris including sand from fluids from the formation 114. After the downhole operation is complete, the porous structural thermoset material 110 may be detached from the base pipe as the production tubing string 104, and the base pipe as the production tubing string 104 may be lifted out of the wellbore 100.

**[0019]** In this manner, the porous structural thermoset material 110 can have many beneficial applications for downhole tools in the oilfield, in particular for a conformable sand screen as sand screen 106 used in oil and/or in gas operations. The porous structural thermoset material 110 can also be applied to/relevant to downhole tools involving a porous medium, such as for filtering or sealing applications. The porous structural thermoset material 110 can be porous, allowing downhole fluids to be produced through it. Simultaneously, the pores can be small enough that erosive sand particles can be captured before they enter the completions equipment. Once in the proper location downhole (e.g., in the wellbore 100 adjacent a formation 114), the porous structural thermoset material 110 can expand and conform to the wellbore 100. The high strength of the porous structural thermoset material 110 can also allow it to support the wellbore 100. This support can be especially important, for example, during drawdown, as suction created by pumps drawing fluids from the formation 114 can destabilize the formation 114. The structural strength of the porous structural thermoset material 110 can allow it, for example, to inhibit collapse during drawdown, ensuring sustained production from the well.

**[0020]** In this manner, the high mechanical strength of the porous structural thermoset material 110 is a desirable property for use in oilfield operations, allowing porous structural

thermoset material 110 to withstand large loads. In addition to the porous structural thermoset material 110 having high strength, it can also have desirable chemical compatibility. In some embodiments, the porous structural thermoset material 110, which is formed by irreversible chemical reactions to generate a crosslinked structure that does not melt (also called thermosetting polymers, thermoset resins, or thermosetting resins) can include (but are not limited to) the following chemistries and variants: polyesters, cyanate esters, epoxies, phenolics, methacrylates, melamines, vinyl esters, bismaleimides, thermoset cyclic polyolefins, polyimides, and benzoxazines. Furthermore, the compounds used in the generation of the porous structural thermoset material 110 can be thermally stable to high temperatures and can be resistant to chemical attack.

**[0021]** The present “structural thermoset” material can be mechanically as a rigid thermosetting polymer where the non-porous, bulk material (when cured to form a densely crosslinked network) has a modulus (compressive, flexural, tensile, or elastic) of at least, for example, approximately 0.7 GPa below the glass transition temperature ( $T_g$ ). In other embodiments, structural thermosets typically have a  $T_g$  above ambient. Additionally, some embodiments, the structural thermoset can be reinforced with ceramic or metallic particles of various types and/or geometries to enhance the mechanical properties of the cured porous structural thermoset material 110. This can include spherical, non-spherical, or high aspect ratio silica (both crystalline and amorphous), boron nitride, aluminosilicate, alumina, aluminum nitride, and zirconium tungstate. Metallic reinforcements can include a variety of ferrous and non-ferrous, with preference to corrosion resistant materials (i.e. nickel alloys, stainless steels, etc.). In this manner, in some embodiments, the mechanical strength, thermal stability, and thermal conductivity of the porous structural thermoset material 110 can be modified and improved through the addition of additional materials. Furthermore, other materials may be provided with the structural thermoset, for example, to allow for expansion of the material under certain conditions (e.g., when deployed downhole). These other materials will be discussed in greater detail below.

[0022] The structural thermoset material 110 can be made to be porous. The porous structure can have a variety of purposes, including: to allow fluid to pass through the material, to filter solid particles, and/or to create an interpenetrating composite network. In some embodiments, the interpenetrating thermoset composite network can have two or more materials with vastly different thermal, viscous, mechanical, electrical, or magnetic properties. For example, in the case of the porous structural thermoset material 110 used in a sand screen 106 (or as sand screen 106), the length scale of the pores of the porous structural thermoset material 110 could be larger in a radial direction relative to the length scale in the angular and axial directions. These differing length scales could facilitate high permeability in the radial direction while also supporting good sand retention properties. In some embodiments, a sand screen 106 made from the porous thermoset can be designed specifically for the size distribution of sands in the formation.

[0023] The pores of the porous structural thermoset material 110 can also have a non-uniform distribution. For example, a portion of the pores in the porous structural thermoset material 110 can have relatively smaller sizes, for example, to capturing sand more efficiently, while another portion of the pores in the porous structural thermoset material 110 can have larger sizes relative to the smaller sized pores. These larger sized pores would allow the porous structural thermoset material 110 to be more permeable relative to a porous structural thermoset material 110 made with only smaller sized pores.

[0024] In the case of a sand screen 106, for example, smaller sized pores could be located close to the formation 114 (e.g., along an outer portion of the porous structural thermoset material 110 that would be disposed most closely to and/or in direct contact with the formation 114) to inhibit sand ingress, while larger sized pores can be disposed in an inner region of the porous structural thermoset material 110 (e.g., in an inner portion of the porous structural thermoset material 110 that would be disposed most closely to and/or in direct contact with the production tubing string 104) to facilitate higher permeability. The distribution of pore sizes could be bimodal (a mixture of small and large pores), trimodal, or simply monomodal with a large standard deviation.

[0025] While generation of the porous structural thermoset material 110 into a sand screen 106 is described, it should be noted that other devices and/or configurations are envisioned. For example, the porous structural thermoset material 110 can be shaped into forms for separation operations (e.g., as a separator used in separating oil and water), filtration operations (e.g., as a filter on a pump used in oil and gas operations, as an actuator or actuator device (e.g., to move to open and close a valve), or in similar operations.

[0026] FIG. 2 illustrates a first embodiment of method of shaping the porous structural thermoset material 110 into a compressed form. For example, in block 116, a cross-sectional side view of the porous structural thermoset material 110 is illustrated. For purposes of illustration, the porous structural thermoset material 110 is illustrated as having an aperture 118 within the porous structural thermoset material 110. This aperture 118 (which can be filled with a removable support, for example) can have a diameter and/or circumference of a size approximately equivalent to the diameter and/or circumference of a tubular string 104 around which the sand screen 106 is to be disposed. That is, aperture 118 can be altered based on the environment into which the porous structural thermoset material 110 is to be used (i.e., the porous structural thermoset material 110 can be manufactured with an aperture 118 that matches the diameter and/or circumference of a tubular string 104 where it is to be deployed as part of a sand screen 106). Thus, block 116 represents the manufactured state of the porous structural thermoset material 110.

[0027] As illustrated in block 116, the porous structural thermoset material 110 has a shape that is annular (i.e., when manufacturing a sand screen 106 that is annular). That is, the porous structural thermoset material 110 extends along the aperture 118 in an axial direction 120 (mirroring how the porous structural thermoset material 110 will extend along a tubular string 104 in the axial direction 120 when in use), the porous structural thermoset material 110 extends away from the aperture 118 in a radial direction 122 (mirroring how the porous structural thermoset material 110 will extend away from tubular string 104 in the radial direction 122 and towards the formation 114 when in use), and the porous structural thermoset material 110 circumscribes the aperture 118 in a circumferential direction 124

(mirroring how the porous structural thermoset material 110 will circumscribe the tubular string 104 in the circumferential direction 124 when in use).

**[0028]** As additionally illustrated in FIG. 2, the aperture 118 can have a diameter 126 that, as noted above, corresponds to a diameter of a tubular string 104. Furthermore, during manufacture of the porous structural thermoset material 110, the diameter 126 can be changed to match a diameter of differing tubular strings 104. That is, the porous structural thermoset material 110 can be manufactured to various sizes that correspond to expected deployments.

**[0029]** Similarly, the porous structural thermoset material 110 can have a diameter 128 that extends beyond the diameter of a tubular string 104 (i.e., diameter 128 is greater than diameter 126). In some embodiments, the diameter 128 of the porous structural thermoset material 110 can be formed during manufacturing to approximately match an expected diameter of a borehole in which the porous structural thermoset material 110 (in sand screen 106) will be deployed. That is, during manufacture of the porous structural thermoset material 110, the diameter 128 can be designed and formed to predetermined sizes.

**[0030]** If the porous structural thermoset material 110 is deployed downhole while in its illustrated form in block 116, there can be potential issues. For example, there may be constraints during any running in hole (RIH) operation that will not allow for the deployment of the porous structural thermoset material 110 having diameter 128. Accordingly, in some embodiments, the porous structural thermoset material 110 can be compressed uphole to a smaller diameter for RIH operations.

**[0031]** Block 130 illustrates the porous structural thermoset material 110 as having been compressed. In conjunction with block 130, compression of the porous structural thermoset material 110 can be undertaken in some embodiments. This can be accomplished via use of a press 132 or another suitable device. In some embodiments, the compression process can be applied in different directions. Thus, in the case of manufacturing a sand screen 106 that is annular (i.e., has an annular shape), compression could be applied axially (i.e., in the axial

direction 120) or radially (i.e., in the radial direction 122) to generate the desired resultant shape.

**[0032]** This compression process can reduce the diameter of the porous structural thermoset material 110 from a diameter 128 to a diameter 134 of the porous structural thermoset material 110. In some embodiments, diameter 134 may be reduced by, for example, approximately 20%, 30%, 33%, 40%, 50%, 60%, 70%, 75%, or another amount with respect to diameter 128. In some embodiments, the reduction in diameter resulting in the porous structural thermoset material 110 having a diameter 134 via the compression applied to the porous structural thermoset material 110 can be set as part of the manufacturing process. For example, in some embodiments, the diameter 134 of the porous structural thermoset material 110 can be formed during manufacturing to approximately match a clearance amount available for an RIH operation. That is, during manufacture of the porous structural thermoset material 110, the diameter 134 can be selected and realized to match predetermined values.

**[0033]** Block 136 illustrates application of a film 138 to the compressed porous structural thermoset material 110. In some embodiments, the film 138 can constitute a degradable film that operates to provide resistance to the porous structural thermoset material 110 in the radial direction 122. For example, the film 138 can be applied to an outer surface of the porous structural thermoset material 110 and can resist expansion of the porous structural thermoset material 110 away from the aperture 118. In this manner the film 138 can operate to assist in containment of the compressed porous structural thermoset material 110 in its compressed form.

**[0034]** In some embodiments, the film 138 can be at least one of polyurethanes, polyesters, poly(lactic acid), poly(vinyl alcohol), a low density polyethylene (LDPE), a linear low density polyethylene (LLDPE), or another material that can be removable upon exposure to downhole fluids and heat (e.g., temperatures approximately from 70° C to 150° or higher). For those skilled in the art, there are a host of polymeric materials that are designed to degrade downhole through various mechanisms (hydrolysis, accelerated degradation,

depolymerization, etc.). In some embodiment, the film 138 can be a mixture of two or more types of removable materials. Thus, the film 138 can remain in place on the compressed form of the porous structural thermoset material 110 until deployed into position in a sand screen 106 downhole adjacent formation 114. At that time, environmental factors (e.g., heat), can operate to degrade the film 138, allowing the porous structural thermoset material 110 to expand outwardly in a radial direction 122 (i.e., away from the tubular string 104) towards the formation 114 so that the porous structural thermoset material 110, for example, interfaces with the formation 114. In some cases, heat can be supplied from not only the downhole environment, but from other supplied (e.g., artificial or man-made) sources.

**[0035]** The method illustrated in FIG. 2 as well as the resultant compressed form of the porous structural thermoset material 110 is useful in manufacturing, for example, a sand screen 106 that can be compressed for a RIH operation then expanded downhole when in position, i.e., adjacent formation 114. However, other techniques can be employed to generate a compressed form of the porous structural thermoset material 110.

**[0036]** FIG. 3 illustrates a second embodiment of method of shaping the porous structural thermoset material 110 into a compressed form. Similar to FIG. 2 discussed above, FIG. 3 includes block 116 as a cross-sectional side view of the porous structural thermoset material 110 having aperture 118 and having a diameter 128. However, in contrast with the method of FIG. 2, FIG. 3 illustrates block 140 as a portion of the compression method. In block 140, containment filler 142 (containment filler material) is added to the porous structural thermoset material 110.

**[0037]** Containment filler 142 can be a material that, for example, may be disposed inside pores of the porous structural thermoset material 110 and may operate to retain the compressed shape of the porous structural thermoset material 110 when it is compressed. In operation, the containment filler 142 inhibits the porous structural thermoset material 110 from expanding (e.g., in a radial direction 112 away from aperture 118) prematurely (i.e., prior to deployment, for example, downhole in a sand screen 106). In some embodiments, the containment filler can supplement the film 138 (i.e., film 138 can be disposed over the

porous structural thermoset material 110 having the containment filler 142) subsequent to it being compressed. Alternatively, the film 138 can be omitted and the containment filler 142 alone can restrict expansion by the porous structural thermoset material 110 (e.g., in a radial direction 112 away from aperture 118).

**[0038]** As a non-limiting example of this process, the containment filler 142 (i.e., the material within the pores of the porous structural thermoset material 110) can be wax. Alternatively, the containment filler 142 can instead be made of a more rigid polymeric material that melts, for example, LDPE, LLDPE, or another low-melting point polymeric material. In some embodiment, the containment filler 142 can be a mixture of two or more types of removable materials.

**[0039]** In conjunction with block 140, the porous structural thermoset material 110 can be heated and submerged in molten wax (or another material as the containment filler 142). Once the wax fills the pores of the porous structural thermoset material 110, the porous structural thermoset material 110 can be removed from the molten wax bath. Thereafter, in conjunction with block 144, the porous structural thermoset material 110 having the containment filler 142 is compressed and cooled. After cooling, the containment filler 142 solidifies, inhibiting the porous structural thermoset material 110 from expanding (e.g., in the radial direction 122 away from aperture 118).

**[0040]** Thus, block 144 illustrates the porous structural thermoset material 110 with the containment filler 142 as having been compressed. In conjunction with block 144, compression of the porous structural thermoset material 110 can be undertaken, for example, via use of press 132, or another suitable device. In some embodiments, the compression process can be applied in different directions. Thus, in the case of manufacturing a sand screen 106 that is annular (i.e., has an annular shape), compression could be applied axially (i.e., in the axial direction 120) or radially (i.e., in the radial direction 122) to generate the desired resultant shape.

[0041] This compression process can reduce the diameter of the porous structural thermoset material 110 with the containment filler 142 from a diameter 128 to a diameter 134 of the porous structural thermoset material 110 with the containment filler 142. In some embodiments, diameter 134 may be reduced by, for example, approximately 20%, 30%, 33%, 40%, 50%, 60%, 70%, 75%, or another amount with respect to diameter 128. In some embodiments, the reduction in diameter resulting in the porous structural thermoset material 110 having a diameter 134 via the compression applied to the porous structural thermoset material 110 can be set as part of the manufacturing process. For example, in some embodiments, the diameter 134 of the porous structural thermoset material 110 can be formed during manufacturing to approximately match a clearance amount available for an RIH operation. That is, during manufacture of the porous structural thermoset material 110, the diameter 134 can be selected and realized to match predetermined values.

[0042] Similar to the film 138 described above, the containment filler 142 in the pores of the porous structural thermoset material 110 can be removed downhole, for example, through degradation or dissolution, allowing the porous structural thermoset material 110 to expand in a radial direction 112 away from the tubular string 104 and to conform to the wellbore 100. That is, the containment filler 142 could dissolve in the liquid hydrocarbons downhole to allow expansion of the porous structural thermoset material 110. Thus, the porous structural thermoset material 110 having the containment filler 142 can remain in place in a compressed form until deployed into position in a sand screen 106 downhole adjacent formation 114. At that time, environmental factors (e.g., heat), can operate to degrade the containment filler 142, allowing the porous structural thermoset material 110 to expand outwardly in a radial direction 122 (i.e., away from the tubular string 104) towards the formation 114, so that the porous structural thermoset material 110, for example, interfaces with the formation 114.

[0043] In some embodiments, the porous structural thermoset material 110 can be mechanically as a rigid thermosetting polymer where the non-porous, bulk material (when cured to form a densely crosslinked network) has a modulus (compressive, flexural, tensile,

or elastic) of at least, for example, approximately 0.7 GPa below the glass transition temperature ( $T_g$ ). In other embodiments, structural thermosets typically have a  $T_g$  above ambient. Additionally, in conjunction with either of the method of FIG. 2 or FIG. 3 discussed above, the porous structural thermoset material 110 can be compressed for ease of deployment and while compressed, the porous structural thermoset material 110 can remain below its  $T_g$ . A mechanical force (e.g., the film 138 and/or the containment filler 142) allows the porous structural thermoset material 110 to remain in its compressed form, for example, to a desired diameter 134 for an RIH operation. This mechanical force provides a confinement pressure greater than that experienced downhole by the porous structural thermoset material 110 from, for example, formation collapse. Once compressed, the shape of the porous structural thermoset material 110 is maintained until deployed downhole, whereby environmental exposure degrades the film 138 and/or the containment filler 142, thus allowing for expansion of the porous structural thermoset material 110 and, accordingly, the sand screen 106.

**[0044]** By utilizing a rigid material as the porous structural thermoset material 110, through the extent of its lifecycle, the sand screen 106 can exhibit a relatively simple deployment. Additionally, after the porous structural thermoset material 110 (and, accordingly, the sand screen 106) expands when the mechanical containment (i.e., the film 138 and/or the containment filler 142) is removed, the resultant expanded sand screen 106 can exhibit a high modulus and, accordingly, additional treatments to increase the modulus of the sand screen 106 to support the formation 114 may be unneeded. Additionally, for example, the lack of additional treatment downhole of the sand screen 106 can also offer increased reliability. The sand screen 106 can be prepared on the surface, allowing for inspection of the sand screen 106 before deployment. Furthermore, the reduction of processes downhole can reduce and/or eliminate potential failure modes.

**[0045]** In some embodiments, in conjunction with either or both of the methods discussed above with respect to FIGS. 2 and 3, one or more additional materials can be added to the porous structural thermoset material 110. For example, in one or more

embodiments, a plasticizer could be added to the porous structural thermoset material 110. Addition of the plasticizer could promote plasticity and/or flexibility of the porous structural thermoset material 110, as well as, for example, reduce brittleness of the porous structural thermoset material 110. Examples of plasticizers that could be added to the porous structural thermoset material 110 include, for example, phthalates, such as high molecular weight (HMW) orthophthalates, low molecular weight (LMW) orthophthalates, or terephthalates, phosphates, carboxylic acid esters, epoxidized fatty acid esters, such as epoxides, and polymeric polyesters.

**[0046]** In some embodiments, before the compression process in block 130 of FIG. 2 and block 144 of FIG. 3, a plasticizer can be added to the porous structural thermoset material 110. For example, this can be part of block 116 of FIGS. 2 and 3 or block 140 of FIG. 3. When added to the porous structural thermoset material 110, the plasticizer can permeate the porous structural thermoset material 110, thus lowering the lowering the material's modulus or glass transition temperature ( $T_g$ ). In some embodiments, due to the reduced modulus resulting from the addition of addition of the plasticizer, the porous structural thermoset material 110 would be easier to compress. Moreover, inclusion of a plasticizer would reduce the mechanical force needed by the film 138 and/or the containment filler 142 to maintain a compressed form of the porous structural thermoset material 110. Additionally, the reduced  $T_g$  resultant from inclusion of the plasticizer could operate to support the expansion process of the porous structural thermoset material 110 downhole, ensuring the porous structural thermoset material 110 is in the elastic regime during deployment of the sand screen 106 and conforms to the wellbore 100. Furthermore, the lower modulus during the expansion process downhole could result in less stress exerted on the formation 114, thus reducing potential damage to the formation 114.

**[0047]** In some embodiments, after expansion of the sand screen 106 within the wellbore 100, the plasticizer could be extracted. This could be accomplished, for example, either by downhole fluids or by a fluid pumped downhole. The removal of the plasticizer would increase the modulus and  $T_g$  of the porous structural thermoset material 110, making

the resultant porous structural thermoset material 110 much stronger and more resistant to wellbore 100 collapse. For example, in many wells, the drawdown pressure is large enough to destabilize the formation 114 and cause the wellbore 100 to collapse. However, after the sand screen 106 is deployed and the plasticizer is removed, the resulting porous structural thermoset material 110 of the sand screen 106 could provide sufficient mechanical strength to support the formation 114 under these conditions.

**[0048]** The benefits of the plasticizer listed above can be achieved via more than one technique. In one embodiment, the plasticizer could be applied only to the manufacturing process and not in the deployment of the sand screen 106. For example, a solvent could saturate the sand screen 106, lowering its modulus. After compression and containment using the film 138 and/or the containment filler 142, the solvent could be extracted.

**[0049]** In another embodiment, compression by the film 138 and/or the containment filler 142, but before deployment, the sand screen 106 could be exposed to a fluid to lower the T<sub>g</sub>. This process could potentially be performed subsequent to manufacture, for example, when the sand screen 106 is removed from storage and taken to the wellhead. The lower T<sub>g</sub> could facilitate the expansion process downhole.

**[0050]** As discussed above, after the sand screen 106 is positioned downhole, it will expand outward radially (i.e., in a radial direction 122 away from tubular string 104) and will conform to the wellbore 100. This expansion can occur after (or potentially simultaneously with) the removal/degradation of any containment material (e.g., the film 138 and/or the containment filler 142). The conformation will stabilize the formation 114, ensuring any loose sections of rock do not separate from the formation 114 during production. Loose rock can damage completions equipment and the formation 114, as well as increase sand production and, thus, is to be avoided.

**[0051]** Conformation to the wellbore 100 is also useful for the sand screen 106 to support the wellbore 100 during drawdown. When production begins, the formation 114 can collapse onto the base pipe. For the sand screen 106 to resist the formation 114 collapse,

the sand screen 106 should directly contact the formation 114 so as to provide mechanical support. In general, the conformation of the sand screen 106 to the wellbore 100 limits formation 114 damage during production while also limiting sand production.

**[0052]** In one or more embodiments, as discussed above, the sand screen 106 is compressed before deployment. Accordingly, porous structural thermoset material 110 has residual internal stress held in check by the containment material (e.g., the film 138 and/or the containment filler 142). As the containment force provided by the containment material is reduced or removed (e.g., due to exposure of environmental factors downhole), the retained internal stress of the porous structural thermoset material 110 causes the sand screen 106 to expand radially (i.e., in the radial direction 122 towards formation 114). In some embodiments, as the containment material is entirely removed, the sand screen 106 will tend to expand until either the sand screen 106 encounters another force (e.g., the formation 114 that resists further expansion) or the residual internal stress of the porous structural thermoset material 110 is exhausted. As it is desirable for the sand screen 106 engage the formation 114 (i.e., to ensure that the expansion of the porous structural thermoset material 110 is halted by the formation and not as a result of exhaustion of the residual internal stress of the porous structural thermoset material 110), in some embodiments, the sand screen 106 is manufactured to exhibit low compression set while in constrained form, including, for example, during storage and deployment.

**[0053]** Additionally and/or alternatively, in one or more embodiments, one or more materials (i.e., an expansion material) can be added to the porous structural thermoset material 110 during its manufacture to facilitate expansion of the sand screen 106 in the downhole environment. For example, one or more materials that absorb fluid can be added to the porous structural thermoset material 110. The one or more materials added to the porous structural thermoset material 110 can be chosen to absorb one or more downhole fluids (e.g., brine, oil) or could be chosen to absorb engineered fluids injected downhole from the surface. In this manner, as the sand screen 106 is deployed it would expand as it absorbs particular fluid(s) that correspond to the material chosen to be added to the porous

structural thermoset material 110. That is, fluid swell of the sand screen 106, would be accomplished via the fluids being dissolved in the polymer matrix. In some embodiments, the entire polymer matrix could swell. Alternatively, in other embodiments, only a portion of the polymer matrix (e.g., a first region of the sand screen 106) would swell while other portions remain wholly unaffected or swell significantly less than the first region of the porous structural thermoset material 110.

**[0054]** Other techniques for expansion of the sand screen 106 are contemplated. For example, additionally and/or alternatively, in one or more embodiments, one or more materials (e.g., an expansion material) can be added to the porous structural thermoset material 110 during its manufacture to facilitate expansion of the sand screen 106 in the downhole environment. The material that is added could be a polymer or a filler, such as a mineral filler. The material would expand in the presence of downhole fluids (e.g., brine or water) or injected fluids (e.g., engineered fluids injected downhole from the surface) which would cause the sand screen to expand. In contrast to the technique described above regarding fluid swell of the sand screen 106, the present embodiments, the fluid introduced to cause expansion of the sand screen 106 is not dissolved in the polymer matrix. Instead, material itself would undergo a change, such as a chemical reaction, causing expansion of the sand screen 106.

**[0055]** As an example, a mineral filler (i.e., an expansion material) inside the polymer matrix could undergo a chemical addition reaction after exposure to a downhole fluid. The addition of mass to the filler particle could cause it to expand, particularly when the density of the reaction product is lower than the density of the reactant mineral filler. Furthermore, in some embodiments, growth of mineral filler particles on the microscopic level could cause expansion of the diameter of the sand screen on the macroscopic level.

**[0056]** In other embodiments, the filler could chemically decompose after exposure to downhole fluids and the density of the reaction products could be lower than the reactants (i.e., filler), which could cause the sand screen 106 to expand. An example of this type of reaction is the chemical degradation of azodicarbonamide or sodium bicarbonate. These

materials produce gas during decomposition, which are captured and creating air pockets within the porous structural thermoset material 110. The introduction of these air pockets in the porous structural thermoset material 110 induces expansion of the sand screen 106.

[0057] The technical effect of the disclosed embodiments includes improvements in deploying and/or activating expansion of a porous structural thermoset material 110. In some embodiments, this porous structural thermoset material 110 can be compressed to allow it to more easily be deployed downhole when used as a sand screen 106. Additionally, once downhole, properties of the sand screen 106 can cause expansion of the sand screen 106 when exposed to environmental conditions to allow the sand screen to expand and directly contact a formation. This expansion can be a result of the removal of containment material (e.g., a film 138 and/or a containment filler 142). The expansion can additionally and/or alternatively be in response to fluid exposure by the porous structural thermoset material 110 through absorption of one or more fluids by the porous structural thermoset material 110 or a reaction of materials of the porous structural thermoset material 110 to one or more fluids.

[0058] The subject matter described in detail above may be defined as set forth below.

[0059] A method, including compressing a porous structural thermoset material having a first diameter to a second diameter that is smaller than the first diameter; and adding a containment material to the porous structural thermoset material, wherein the containment material provides a mechanical force to restrict expansion of the porous structural thermoset material in a radial direction.

[0060] The method of the preceding claim, wherein adding the containment material to the porous structural thermoset material includes disposing a film on an outer surface of the porous structural thermoset material.

[0061] The method of the any of the preceding claims, wherein the film includes at least one of a low density polyethylene (LDPE) or a linear low density polyethylene (LLDPE) or any other degradable polymer.

[0062] The method of the any of the preceding claims, including adding the containment material to the porous structural thermoset material subsequent to compressing the porous structural thermoset material.

[0063] The method of the any of the preceding claims, including adding a plasticizer to the porous structural thermoset material to increase plasticity of the porous structural thermoset material.

[0064] The method of the any of the preceding claims, including adding the plasticizer to the porous structural thermoset material prior to compressing the porous structural thermoset material.

[0065] The method of the any of the preceding claims, wherein adding the containment material to the porous structural thermoset material comprises disposing containment filler material in pores of the porous structural thermoset material.

[0066] The method of the any of the preceding claims, wherein the containment filler material comprises at least one of a low density polyethylene (LDPE), a linear low density polyethylene (LLDPE), a polyvinyl alcohol (PVA), or a polymer with a melting temperature between approximately 70°C and 150°C.

[0067] The method of the any of the preceding claims, including adding the containment material to the porous structural thermoset material prior to compressing the porous structural thermoset material.

[0068] The method of the any of the preceding claims, including adding a plasticizer to the porous structural thermoset material to increase plasticity of the porous structural thermoset material.

[0069] The method of the any of the preceding claims, including adding the plasticizer to the porous structural thermoset material prior to compressing the porous structural thermoset material.

[0070] The method of the any of the preceding claims, including adding an expansion material to the porous structural thermoset material, wherein the expansion material is configured to absorb or react with a fluid to facilitate expansion of the porous structural thermoset material in the radial direction.

[0071] A device, including a porous structural thermoset material shaped into an annular shape, wherein the porous structural thermoset material comprises pores formed via removal of a removable material; and a containment material directly coupled to the porous structural thermoset material, wherein the containment material provides a mechanical force to restrict expansion of the porous structural thermoset material in a radial direction.

[0072] The device of the preceding claim, including a sand screen including the porous structural thermoset material.

[0073] The device of the any of the preceding claims, including a plasticizer added to the porous structural thermoset material to increase plasticity of the porous structural thermoset material.

[0074] The device of the any of the preceding claims, including an expansion material added to the porous structural thermoset material, wherein the expansion material is configured to absorb or react with a fluid to facilitate expansion of the porous structural thermoset material in the radial direction.

[0075] The device of the any of the preceding claims, wherein the containment material includes a film disposed on an outer surface of the porous structural thermoset material.

[0076] The device of the any of the preceding claims, wherein the containment material includes a containment filler material disposed in the pores of the porous structural thermoset material.

[0077] A method, including deploying a sand screen downhole in a wellbore, wherein the sand screen includes compressed porous structural thermoset material and a containment

material in contact with the compressed porous structural thermoset material, wherein the containment material provides a mechanical force to restrict expansion of the porous structural thermoset material in a radial direction.

[0078] The method of the preceding claim, including transmitting at least one fluid downhole to facilitate expansion of the compressed porous structural thermoset material in the radial direction.

[0079] Language of degree used herein, such as the terms “approximately,” “about,” “generally,” and “substantially” as used herein represent a value, amount, or characteristic close to the stated value, amount, or characteristic that still performs a desired function or achieves a desired result. For example, the terms “approximately,” “about,” “generally,” and “substantially” may refer to an amount that is within less than 10% of, within less than 5% of, within less than 1% of, within less than 0.1% of, and/or within less than 0.01% of the stated amount. As another example, in certain embodiments, the terms “generally parallel” and “substantially parallel” or “generally perpendicular” and “substantially perpendicular” refer to a value, amount, or characteristic that departs from exactly parallel or perpendicular, respectively, by less than or equal to 15 degrees, 10 degrees, 5 degrees, 3 degrees, 1 degree, or degree.

[0080] The foregoing description, for purpose of explanation, has been described with reference to specific embodiments. However, the illustrative discussions above are not intended to be exhaustive or to limit the disclosure to the precise forms disclosed. Many modifications and variations are possible in view of the above teachings. Moreover, the order in which the elements of the methods described herein are illustrated and described may be re-arranged, and/or two or more elements may occur simultaneously. The embodiments were chosen and described in order to best explain the principals of the disclosure and its practical applications, to thereby enable others skilled in the art to best utilize the disclosure and various embodiments with various modifications as are suited to the particular use contemplated.

**[0081]** Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

## CLAIMS

1. A method, comprising:  
compressing a porous structural thermoset material having a first diameter to a second diameter that is smaller than the first diameter; and  
adding a containment material to the porous structural thermoset material, wherein the containment material provides a mechanical force to restrict expansion of the porous structural thermoset material in a radial direction.
2. The method of claim 1, wherein adding the containment material to the porous structural thermoset material comprises disposing a film on an outer surface of the porous structural thermoset material.
3. The method of claim 2, wherein the film comprises at least one of a low density polyethylene (LDPE) or a linear low density polyethylene (LLDPE).
4. The method of claim 2, comprising adding the containment material to the porous structural thermoset material subsequent to compressing the porous structural thermoset material.
5. The method of claim 2, comprising adding a plasticizer to the porous structural thermoset material to increase plasticity of the porous structural thermoset material.
6. The method of claim 5, comprising adding the plasticizer to the porous structural thermoset material prior to compressing the porous structural thermoset material.
7. The method of claim 1, wherein adding the containment material to the porous structural thermoset material comprises disposing containment filler material in pores of the porous structural thermoset material.

8. The method of claim 7, wherein the containment filler material comprises at least one at least one of a low density polyethylene (LDPE), a linear low density polyethylene (LLDPE), a polyvinyl alcohol (PVA), or a polymer with a melting temperature between approximately 70°C and 150°C.
9. The method of claim 7, comprising adding the containment material to the porous structural thermoset material prior to compressing the porous structural thermoset material.
10. The method of claim 7, comprising adding a plasticizer to the porous structural thermoset material to increase plasticity of the porous structural thermoset material.
11. The method of claim 10, comprising adding the plasticizer to the porous structural thermoset material prior to compressing the porous structural thermoset material.
12. The method of claim 1, comprising adding an expansion material to the porous structural thermoset material, wherein the expansion material is configured to absorb or react with a fluid to facilitate expansion of the porous structural thermoset material in the radial direction.
13. A device, comprising:  
a porous structural thermoset material shaped into an annular shape, wherein the porous structural thermoset material comprises pores formed via removal of a removable material; and  
a containment material directly coupled to the porous structural thermoset material, wherein the containment material provides a mechanical force to restrict expansion of the porous structural thermoset material in a radial direction.
14. The device of claim 13, comprising a sand screen comprising the porous structural thermoset material.

15. The device of claim 13, comprising a plasticizer added to the porous structural thermoset material to increase plasticity of the porous structural thermoset material.

16. The device of claim 13, comprising an expansion material added to the porous structural thermoset material, wherein the expansion material is configured to absorb or react with a fluid to facilitate expansion of the porous structural thermoset material in the radial direction.

17. The device of claim 13, wherein the containment material comprises a film disposed on an outer surface of the porous structural thermoset material.

18. The device of claim 13, wherein the containment material comprises a containment filler material disposed in the pores of the porous structural thermoset material.

19. A method, comprising:

deploying a sand screen downhole in a wellbore, wherein the sand screen comprises compressed porous structural thermoset material and a containment material in contact with the compressed porous structural thermoset material, wherein the containment material provides a mechanical force to restrict expansion of the compressed porous structural thermoset material in a radial direction.

20. The method of claim 19, comprising transmitting at least one fluid downhole to facilitate expansion of the compressed porous structural thermoset material in the radial direction.

**1/2**

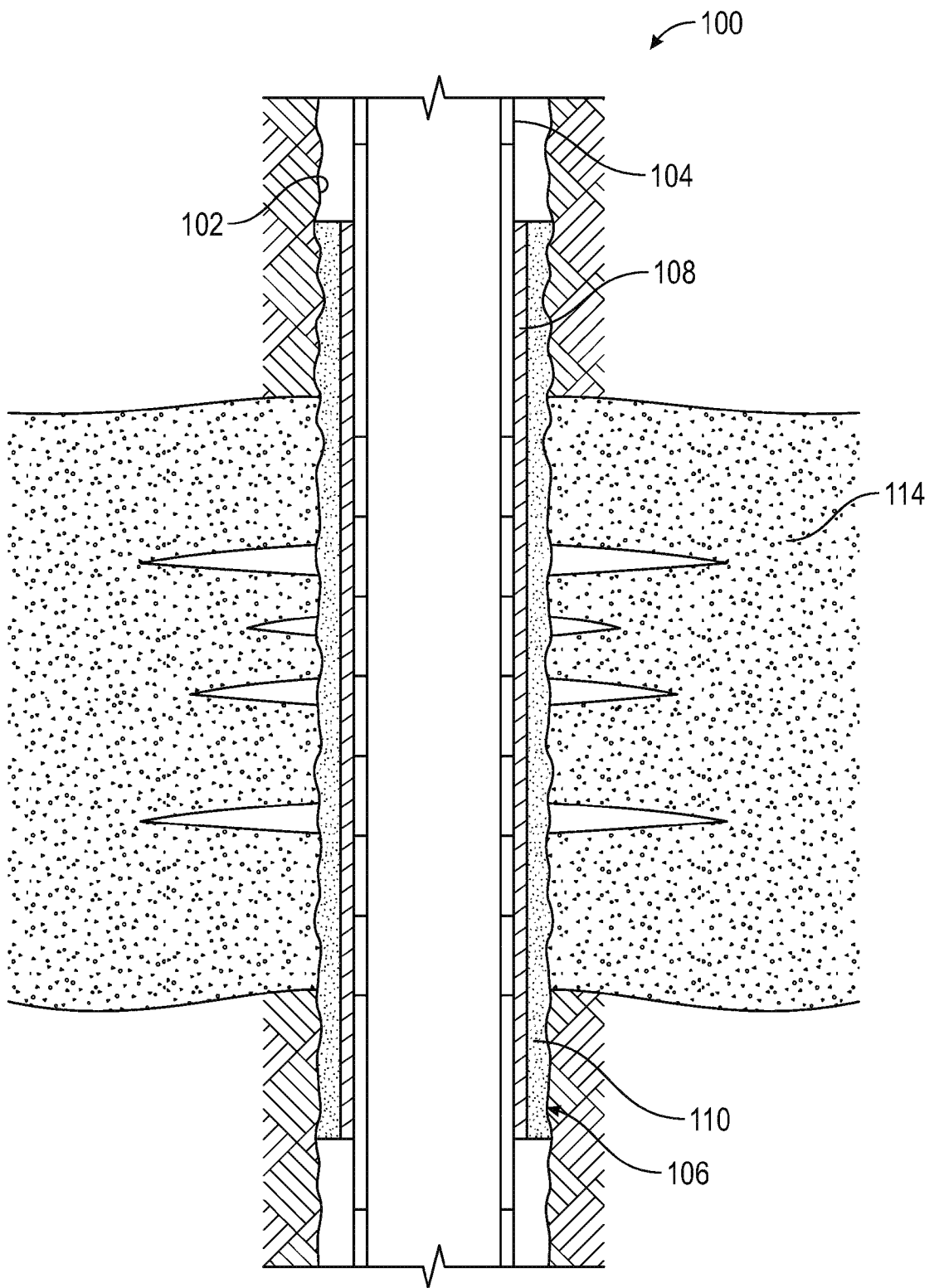
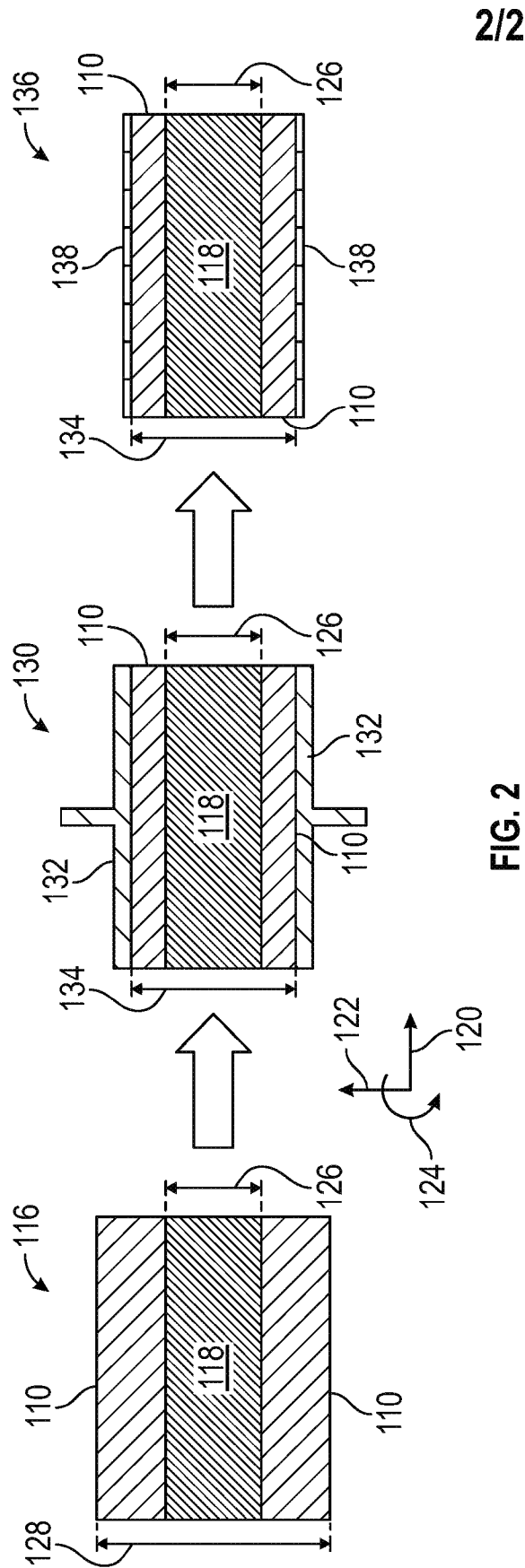
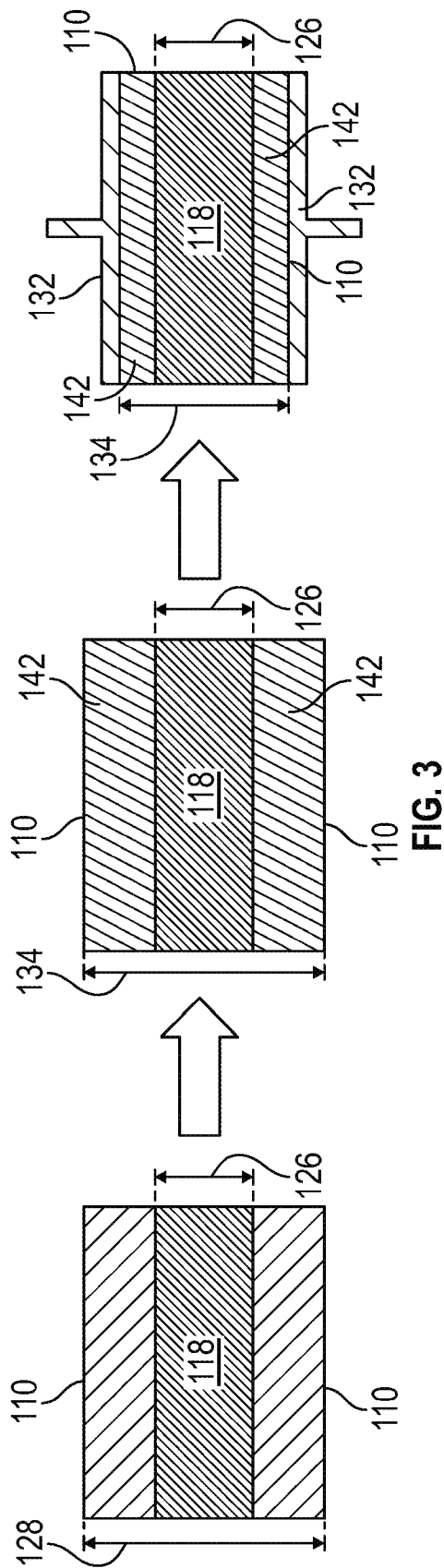


**FIG. 1**



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2024/044813

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|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| <b>A. CLASSIFICATION OF SUBJECT MATTER</b><br><b>E21B 43/08(2006.01)i; E21B 33/12(2006.01)i</b><br><br>According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                 |                                                                               |
| <b>B. FIELDS SEARCHED</b><br><br>Minimum documentation searched (classification system followed by classification symbols)<br>E21B 43/08(2006.01); B32B 3/12(2006.01); B32B 5/18(2006.01); C08K 3/08(2006.01); E03B 3/18(2006.01);<br>E21B 33/12(2006.01); E21B 41/00(2006.01); E21B 43/10(2006.01)<br><br>Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched<br>Korean utility models and applications for utility models<br>Japanese utility models and applications for utility models<br><br>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)<br>eKOMPASS(KIPO internal) & Keywords: wellbore, downhole, borehole, sand screen, porous, thermoset, compressing, containment, film, filler, expansion                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                 |                                                                               |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                 |                                                                               |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Citation of document, with indication, where appropriate, of the relevant passages                                              | Relevant to claim No.                                                         |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | US 2022-0127934 A1 (SCHLUMBERGER TECHNOLOGY CORPORATION) 28 April 2022 (2022-04-28)<br>paragraphs [0033]-[0050] and figures 1-8 | 13,14,16,17,19,20                                                             |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                 | 1-6,12,15                                                                     |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                 | 7-11,18                                                                       |
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| <input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                 |                                                                               |
| <p>* Special categories of cited documents:</p> <p>“A” document defining the general state of the art which is not considered to be of particular relevance</p> <p>“D” document cited by the applicant in the international application</p> <p>“E” earlier application or patent but published on or after the international filing date</p> <p>“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>“O” document referring to an oral disclosure, use, exhibition or other means</p> <p>“P” document published prior to the international filing date but later than the priority date claimed</p> <p>“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</p> <p>“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</p> <p>“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</p> <p>“&amp;” document member of the same patent family</p> |                                                                                                                                 |                                                                               |
| Date of the actual completion of the international search<br><b>12 December 2024</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                 | Date of mailing of the international search report<br><b>13 December 2024</b> |
| Name and mailing address of the ISA/KR<br><b>Korean Intellectual Property Office<br/>189 Cheongsa-ro, Seo-gu, Daejeon<br/>35208, Republic of Korea</b><br>Facsimile No. +82-42-481-8578                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                 | Authorized officer<br><b>PARK, Tae Wook</b><br>Telephone No. +82-42-481-3405  |

## INTERNATIONAL SEARCH REPORT

International application No.

**PCT/US2024/044813**

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages           | Relevant to claim No. |
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**INTERNATIONAL SEARCH REPORT**  
**Information on patent family members**

International application No.

**PCT/US2024/044813**

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