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(54) **DOWNHOLE SEAL**

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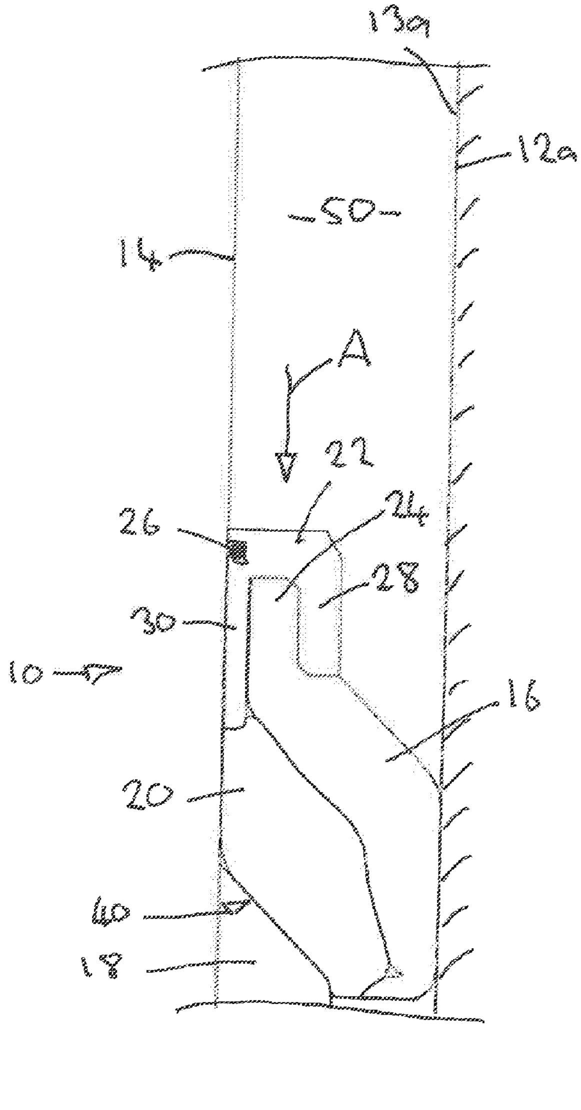
(57) **ABSTRACT**

A downhole seal assembly for establishing a seal against a bore wall includes a mandrel, a seal element mounted on the mandrel, a setting support member mounted on the mandrel, and at least one setting element mounted on the mandrel axially between the seal element and the setting support member. Relative axial movement between the seal element and the setting support member over a first actuation distance causes the seal element to be deflected radially outwardly by an axially adjacent setting element. Relative axial movement of the seal element and the setting support member over a subsequent actuation distance causes radial expansion of at least one setting element to further expand the seal element.



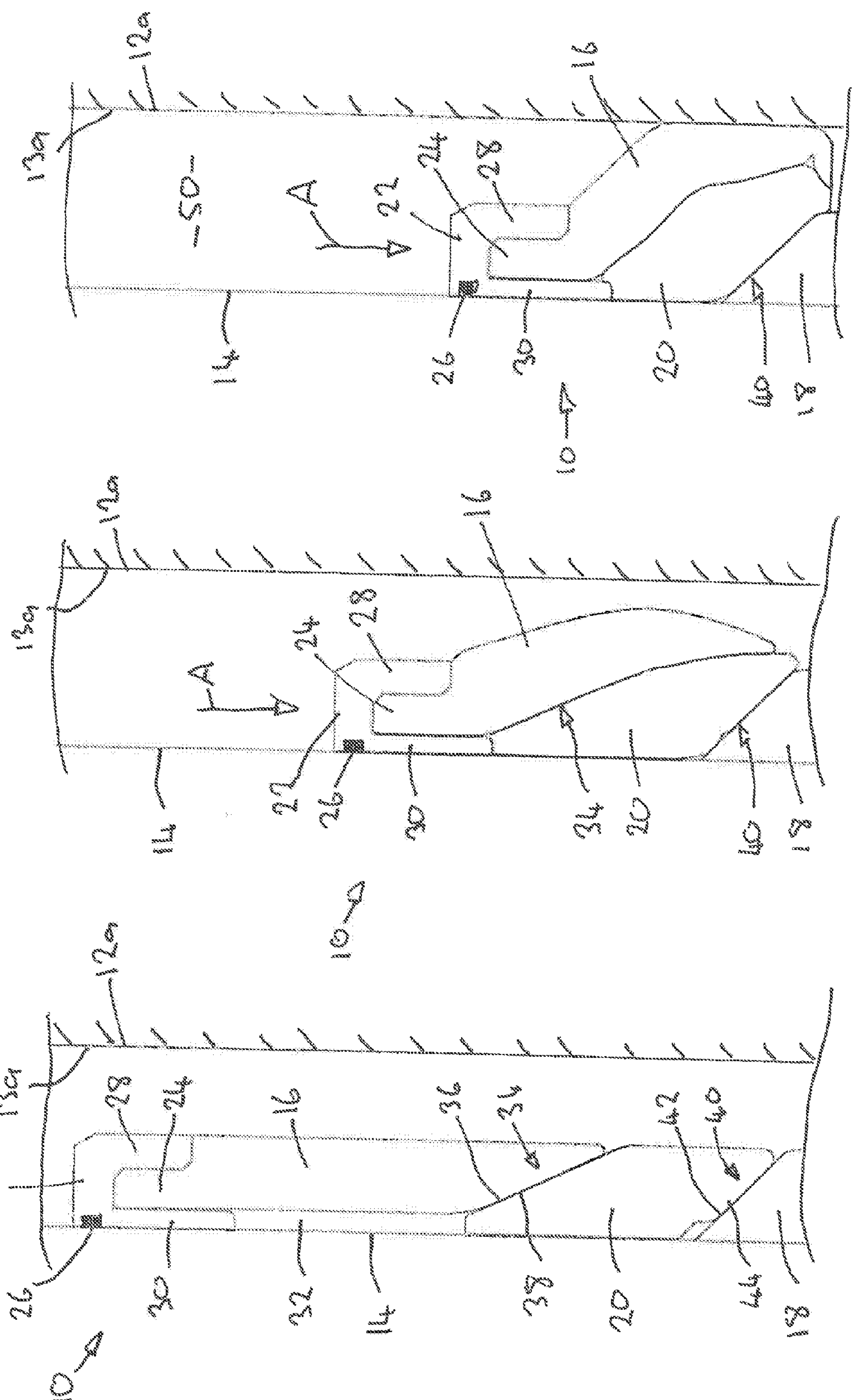


FIG. 1A

FIG. 1B

FIG. 1C

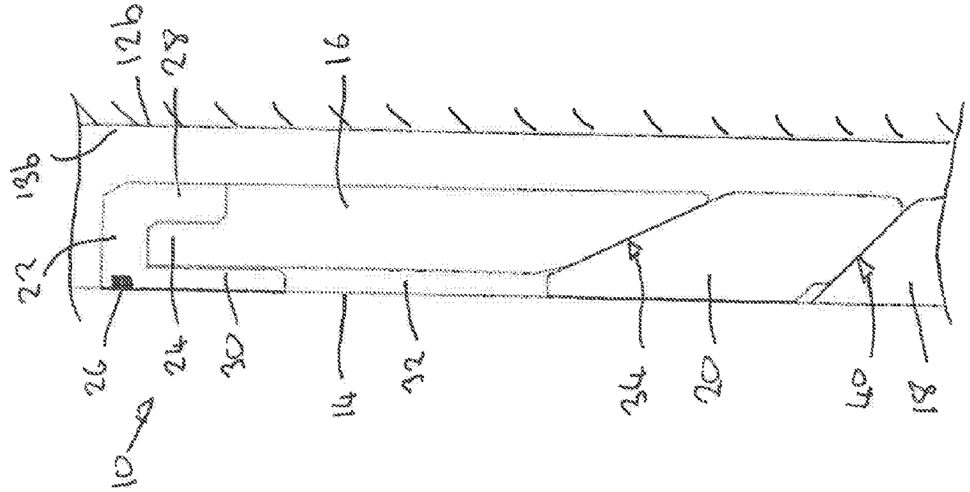


FIG. 2A

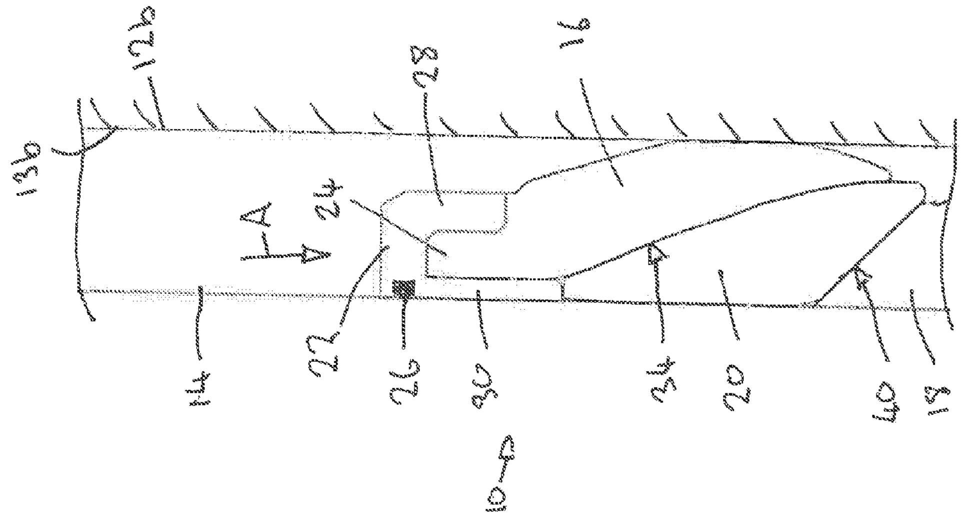


FIG. 2B

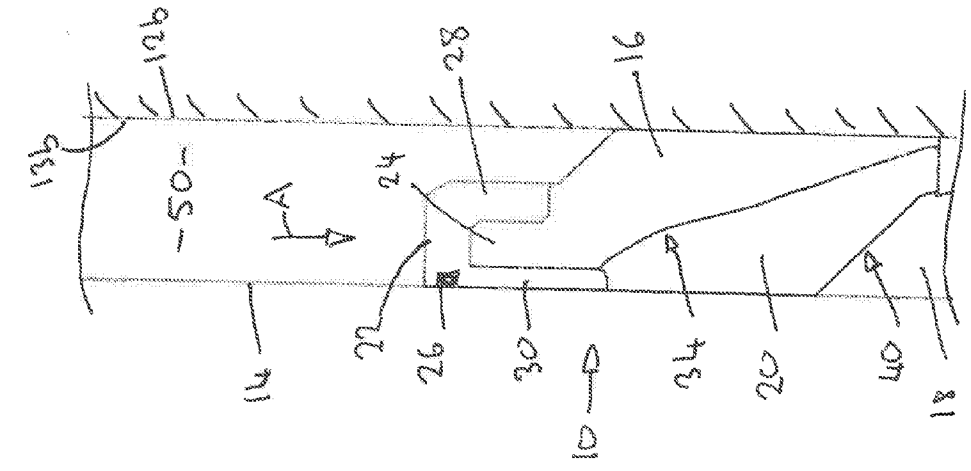


FIG. 2C

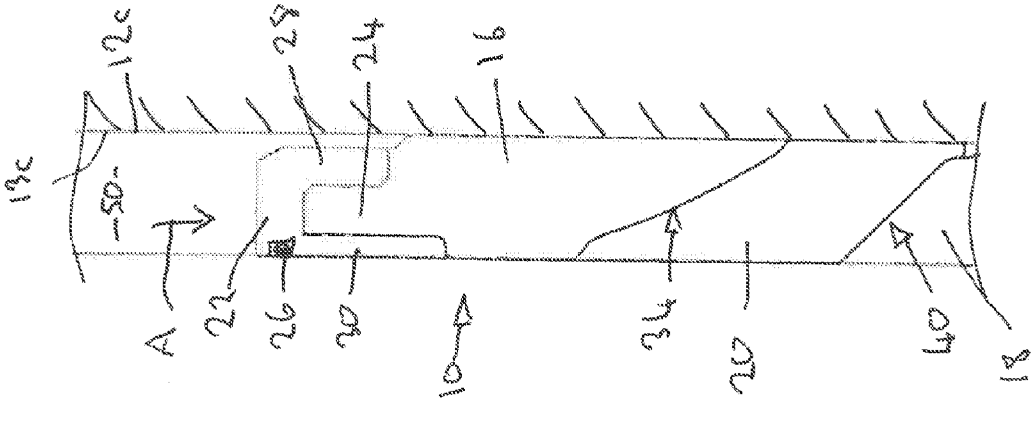


FIG. 3C

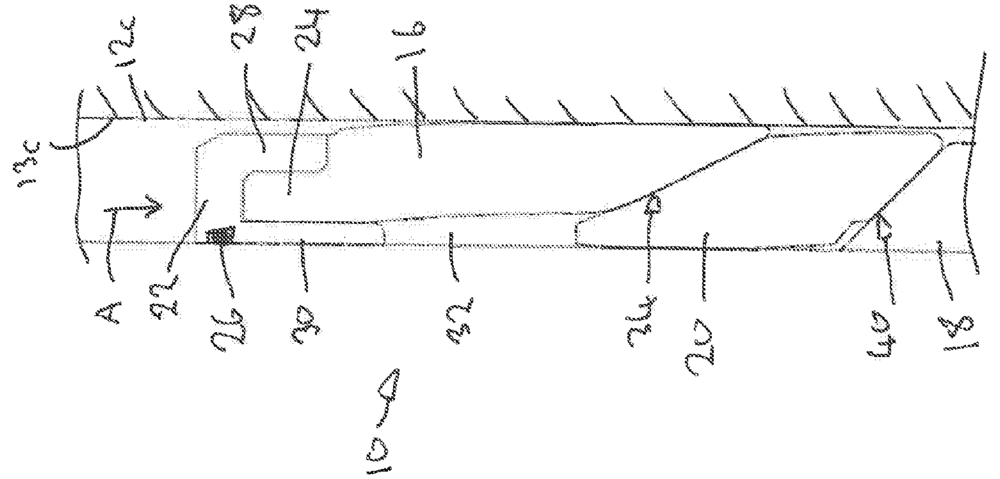


FIG. 3B

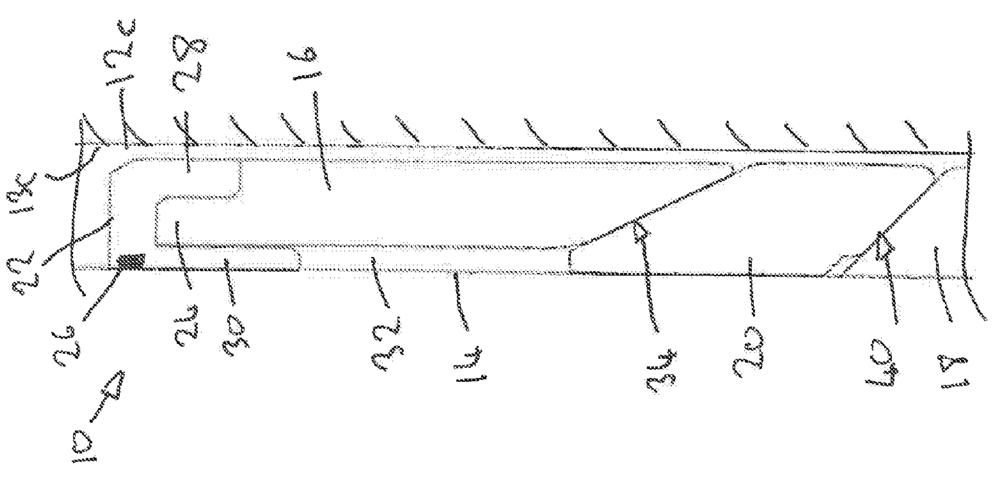


FIG. 3A

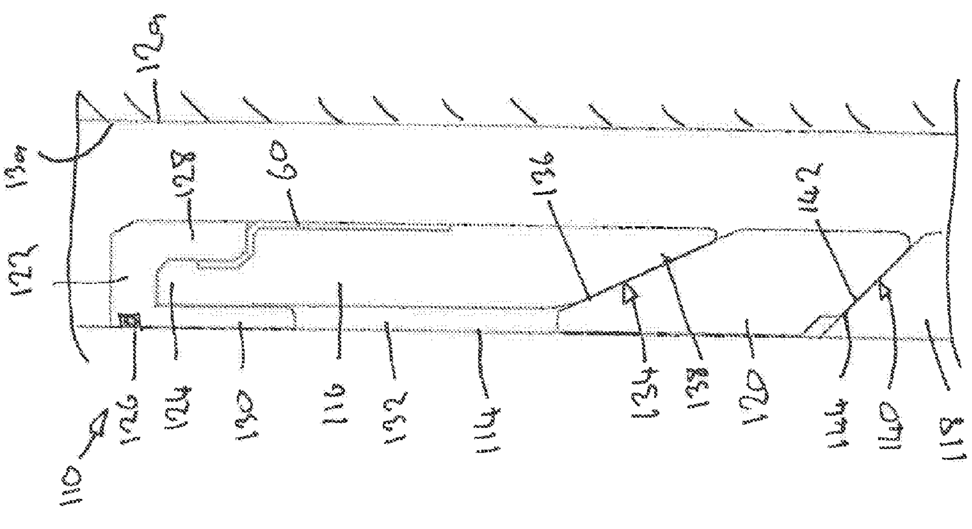


FIG. 4A

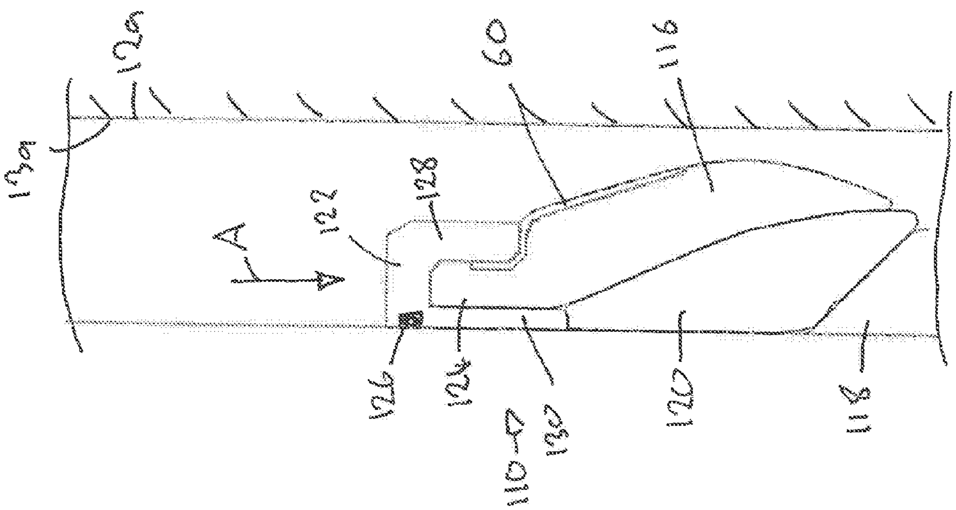


FIG. 4B

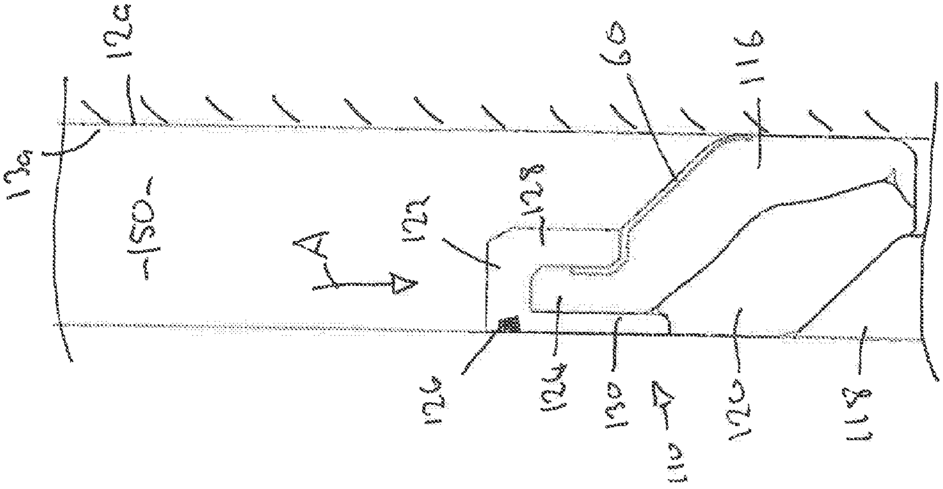


FIG. 4C

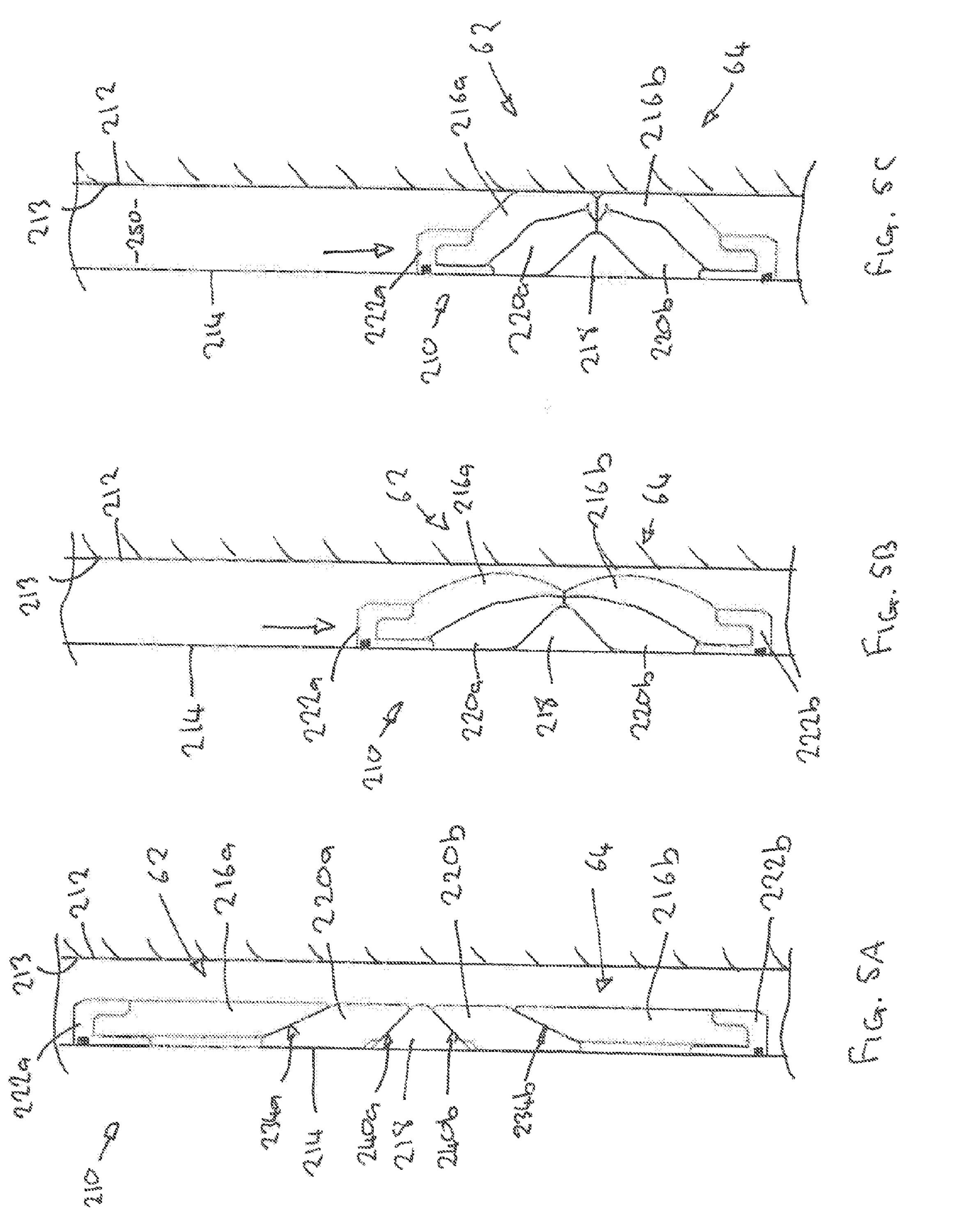


FIG. 5A

FIG. 5B

FIG. 5C

DOWNHOLE SEAL

REFERENCE TO RELATED APPLICATIONS

[0001] This application is a United States National Phase application of PCT Application No. PCT/GB2014/051377 filed on May 2, 2014, which claims priority to United Kingdom Application No. 1308043.7 filed on May 3, 2013.

FIELD OF THE INVENTION

[0002] The present invention relates to a downhole seal, and in particular to a downhole seal suitable for use in various bore sizes.

BACKGROUND TO THE INVENTION

[0003] Seal assemblies or packers are frequently used in the oil and gas industry for sealing an annulus in a wellbore, such as may exist between a bore wall and a mandrel. Such sealing may be achieved by use of annular components which are mounted on a mandrel and which extend between the mandrel and bore wall. Such annular sealing components may include annular sealing bands, cup seals, inflatable bladders, swellable elements and the like.

[0004] Conventional downhole seal assemblies are typically provided to accommodate quite specific bore diameters, and often a single seal assembly cannot be effectively used over a large bore diameter range. As such, it is typically necessary for an operator to run sealing assemblies which are quite precisely selected for the particular bore diameter at which the seal is required. This might require a large inventory of assemblies to be on-hand. In cases where an incorrect size of seal assembly is selected, or where the bore diameter is larger than expected, such as due to bore wash-out and the like, an inadequate seal may result.

[0005] Although some known seal assemblies might permit a degree of variability in terms of seal expansion, it is often the case that beyond the small design limits seal integrity is significantly compromised. For example, a seal which has been expanded beyond its design limits may provide very poor resistance to a pressure differential, and may be at serious risk of failure modes such as extrusion and the like.

SUMMARY OF THE INVENTION

[0006] An aspect of the present invention relates to a downhole seal assembly for establishing a seal against a bore wall. The seal assembly may be configured to permit a seal to be established in multiple different bore sizes. That is, the seal assembly may permit a suitable seal to be established over a range of bore sizes.

[0007] The seal assembly may include a seal element which is radially expandable to be engaged with a bore wall. The seal element may be mounted on a mandrel, such as a tubular mandrel.

[0008] The seal assembly may further include a setting element. The setting element may be mounted on the mandrel.

[0009] The seal element may be radially expanded by being deflected radially outwardly by the setting element when relative axial movement is established between the seal element and the setting element. In such an arrangement the seal element may be radially stacked on the setting element to become radially expanded.

[0010] The setting element may be radially expandable. Radial expansion of the setting element may function to radially expand the seal element, for example when the seal element, or a portion thereof, is radially stacked on the setting element.

[0011] Maximum radial expansion of the seal element may be achieved by a combination of the seal element being radially deflected by the setting element, and radial expansion of the setting element.

[0012] In some embodiments, the seal assembly may be sequentially actuated, firstly by being radially deflected by the setting element, and secondly by the setting element being radially expanded.

[0013] Maximum radial expansion of the seal element may be achieved in response to at least first and second sequential actuation events. During the first actuation event expansion of the seal element may be predominantly achieved by radial deflection of said seal element by the setting element. During the second actuation event expansion of the seal element may be predominantly achieved by radial expansion of the setting element.

[0014] The seal element may be actuated to be radially expanded by application of an axial force.

[0015] In some embodiments, only partial actuation of the seal element may be necessary to provide a seal against a bore wall. For example, full sealing engagement of the seal element with a bore wall may be achieved following only a first actuation event.

[0016] An aspect of the present invention relates to a downhole seal assembly for establishing a seal against a bore wall, including a seal element, a setting support member, and a setting element mounted axially between the seal element and the setting support member. The seal element is configured to be radially expanded by at least one of radial deflection by the setting element and radial expansion of the setting element.

[0017] Relative axial movement between the seal element and the setting element may cause the seal element to be deflected radially outwardly by the setting element. Further or subsequent relative axial movement between the seal element and the setting element may cause radial expansion of the setting member to further expand the seal element.

[0018] An aspect of the present invention relates to a downhole seal assembly for establishing a seal against a bore wall, including a mandrel, a seal element mounted on the mandrel, a setting support member mounted on the mandrel, and at least one setting element mounted on the mandrel axially between the seal element and the setting support member, Relative axial movement between the seal element and the setting support member over a first actuation distance causes the seal element to be deflected radially outwardly by an axially adjacent setting element, and relative axial movement of the seal element and the setting support member over a subsequent actuation distance causes radial expansion of at least one setting element to further expand the seal element.

[0019] The axially adjacent setting element may be defined as the primary setting element.

[0020] In use, the downhole seal assembly may be positioned within a bore, such as a wellbore, pipe line or the like and axial movement established between the seal element and setting support member to cause the seal element to be radially expanded into engagement with a wall of the bore.

[0021] The downhole seal assembly may be configured for use within an open hole. The seal assembly may be defined as an open hole seal assembly. Alternatively, or additionally, the downhole seal assembly may be configured for use within a cased or lined bore.

[0022] A maximum radial expansion of the seal element may be achieved by both radial deflection of the seal element by the setting element and radial expansion of the setting element. Such maximum permitted radial expansion may be achieved by relative axial movement of the seal element and the seal support member over a maximum axial setting distance.

[0023] In some applications, the maximum expansion of the seal element may be required to establish a seal within a bore. However, in other applications such maximum expansion may not be necessary to achieve a seal within a bore. For example, full sealing engagement of the seal element with a bore wall may be achieved following relative axial movement between the seal element and the setting support member over a portion of the first actuation distance, the full first actuation distance, or the full first actuation distance plus a portion of the subsequent actuation distance.

[0024] Accordingly, the seal assembly may be self-regulating to permit a seal to be established in multiple different bore sizes. In this way, a single seal assembly may have application over a relatively wide range of bore dimensions. Such an arrangement may provide an operator with improved assurance of an appropriate seal being established, for example by removing sensitivities of selecting an incorrect size of seal, the bore being smaller or larger than expected, and the like. Further, such an arrangement may minimize the required inventory of sealing assemblies when multiple bore sizes must be accommodated.

[0025] In use, relative axial movement between the seal element and the setting support member may be performed until the seal element is sufficiently engaged with a bore wall. In some instances only a proportion of a maximum permitted range of relative axial movement between the seal element and setting support member (or only a proportion of the maximum available radial expansion of the seal element) may be necessary or permitted to achieve sealing.

[0026] As defined above, relative axial movement between the seal element and the setting support member over the first actuation distance causes the seal element to be deflected radially outwardly by the adjacent or primary setting element. As such, physical radial deflection of the seal element permits said seal element to be initially expanded.

[0027] Further, relative movement between the seal element and the setting support member over the subsequent actuation distance may cause further expansion of the seal element by radial expansion of at least one setting element. That is, radial expansion of at least one setting element may act to further expand the seal element.

[0028] In some embodiments, relative movement of the seal element and the setting support member over at least a portion of the subsequent actuation distance may cause axial compression of the seal element. Such axial compression of the seal element may cause radial expansion thereof, for example by radial buckling, bulging or the like. In some embodiments, such axial compression may radially expand the seal element to close any gaps originally defined between the seal element and the mandrel.

[0029] In use, at least two mechanisms for expanding the seal element may be established by a common actuation event, specifically the relative axial movement of the seal element and the setting support member. Requiring only a single actuation event to establish at least two expansion mechanisms may permit a simpler, more robust seal assembly to be provided, minimising sensitivities to failure due to complex and multiple seal actuators. Further, providing at least two expansion mechanisms may assist to provide a more robust seal, at least when a higher expansion ratio is required. That is, large expansion ratios may not rely exclusively on a single expansion mechanism.

[0030] Relative axial movement between the seal element and the setting support member over the first actuation distance causes the seal element to be deflected radially outwardly by the primary setting element, and relative movement over the subsequent actuation distance may cause further expansion of the seal element by radial expansion of the same primary setting element.

[0031] In some embodiments, at least one setting element may undergo a degree of radial expansion during relative axial movement of the seal element and setting support member over the first actuation distance. However, in such embodiments, radial expansion of the seal element during relative axial movement of the seal element and setting support member over the first actuation distance may nevertheless be predominantly achieved by the seal element being deflected radially outwardly by at least one setting element.

[0032] During relative axial movement of the seal element and setting support member over the first actuation distance expansion of the seal element may be predominantly achieved by radial deflection of said seal element by the setting element. During relative movement of the seal element and the setting support member over the subsequent actuation distance expansion of the seal element may be predominantly achieved by radial expansion of the setting element.

[0033] The seal assembly may be configured such that the seal element preferentially expands by being radially deflected by the primary setting element, prior to radial expansion, or significant radial expansion, of at least one setting element. Such an arrangement may facilitate sequential or staged expansion of the sealing element, initially by radial deflection, and subsequently by expansion of a setting element. Various arrangements may be provided to permit such preferential initial expansion of the seal element, examples of which will be specified in more detail below, and may include variable material properties, such as stiffness, variable geometries, such as deflection ramp angles and the like.

[0034] The seal element may be configured to be deflected radially outwardly and over an outer surface of the adjacent setting element. In such an arrangement the seal element and the adjacent setting element may be configured to become radially stacked. Such radial stacking of the seal element and the adjacent setting element may permit subsequent radial expansion of the adjacent setting element to cause further radial expansion of the seal element.

[0035] In some embodiments, the seal assembly may include a single setting element.

[0036] In some embodiments, the seal assembly may include a plurality of setting elements. In such embodiments, the setting element which is axially adjacent to the seal element may define the primary setting element. In such embodiments, a plurality of setting elements may be configured to be radially stacked relative to each other to expand the seal element.

[0037] At least one setting element may be configured to provide support to the seal element when said seal element is in a radially expanded position. This may assist the seal element to accommodate operational pressures and forces when extended and in sealing engagement with a bore wall. For example, such an arrangement may provide a degree of stability to the seal element when expanded, which may assist in resistance to extrusion forces and the like. Such support from at least one setting element may also permit the seal assembly to be appropriately used to accommodate larger expansion ratios.

[0038] The entire seal element may be configured to be radially expanded. For example, the entire seal element may be configured to be displaced outwardly by the primary setting element. In such an arrangement the entire seal element may be configured to be deflected radially outwardly and over the outer surface of the primary setting element.

[0039] In some embodiments, only a portion of the seal element may be configured to be radially expanded. For example, only a portion of the seal element may be configured to be displaced outwardly by the primary setting element. In such an arrangement only a portion of the seal element may be configured to be deflected radially outwardly and over the outer surface of the primary setting element.

[0040] In some cases the size of the bore in which the seal assembly is mounted may determine the length of the seal element which is radially expanded.

[0041] In some embodiments, the seal element may include or define a fixed region which is radially fixed, and thus prevented from radial expansion, and a free end region which is configured to be radially expanded by being deflected radially outwardly by the adjacent setting element. In such embodiments, the free end region may be configured to be deflected radially outwardly and over the outer surface of the adjacent setting element.

[0042] The fixed region may be positioned intermediate opposing ends of the seal element.

[0043] In one embodiment, the fixed region may be positioned at one end region of the seal element, opposite the free end region.

[0044] The seal element may be configured to define a cup or lip seal when in an expanded configuration. Such an arrangement may be achieved by the provision of a fixed region and free end region of the seal element. In such an arrangement an additional sealing effect may be achieved by the action of fluid pressure internally of the seal element, thus contributing to the force pressing the seal element against the bore wall.

[0045] In some embodiments, a fixed end region of the seal element may be sealingly engaged with the mandrel. Such an arrangement may minimize leakage between the seal element and the mandrel. Further, such an arrangement may permit pressure to be contained internally of the seal element, which may assist to press the seal element against the bore wall.

[0046] Also, the provision of a fixed region which is sealingly engaged with the mandrel may minimize any requirement to rely exclusively on the seal element eventually becoming sealing engaged with the mandrel during actuation of the seal element, as might be the case in convention compressible packers.

[0047] The seal element and the adjacent setting element may be generally arranged axially relative to each other, for example in end-to-end relationship, when the seal element is in the retracted configuration.

[0048] The seal element and the adjacent setting element may define a seal deflection interface therebetween configured to permit the seal element to be deflected radially outwardly by the adjacent setting element during relative axial movement between the seal element and the setting support member. The seal deflection interface may include an interengaging ramp structure.

[0049] In one embodiment, the seal element and the adjacent setting element may each define a ramp surface to facilitate deflection of the seal element. The ramp surfaces may be defined by tapered or bevelled regions. The ramp surface of the seal element may define an inwardly tapered region of the seal element. Where the seal element includes or defines a free end, said ramp surface may be provided on the free end. Such a ramp surface provided on a free end may function to provide a degree of relief between the seal element and the adjacent setting element when the seal element is expanded. Such an arrangement may assist to permit the seal element to function as a cup seal when expanded.

[0050] The ramp surface of the adjacent setting element may define an outwardly tapered region of said setting element.

[0051] At least one setting element, for example the adjacent setting element, may be radially expanded by being axially compressed during relative axial movement between the seal element and the setting support member over the subsequent actuation distance. That is, axial compression may cause radial expansion, buckling and/or bulging of the setting element.

[0052] At least one setting element may be axially compressed against the setting support member. At least one setting element may be directly compressed against the setting support member, for example by directly engaging the setting support member.

[0053] At least one setting element may be indirectly compressed against the setting support member, for example via one or more further setting support members or other intermediate component(s).

[0054] At least one setting element, for example the primary setting element, may be radially expanded by being radially deflected outwardly during relative movement between the seal element and the setting support member over the subsequent actuation distance.

[0055] The seal assembly may include a deflecting member for use in radially deflecting at least one setting element. The deflecting member may be for use in radially deflecting the adjacent setting element.

[0056] The deflecting member may be defined by the setting support member. As such, the setting support member may be configured to radially displace at least one setting member during relative axial movement of the seal element and the setting member, at least over the subsequent actuation distance.

[0057] In some embodiments, the deflecting member may be defined by a further setting element.

[0058] The deflecting member and at least one setting element may define a setting deflection interface therebetween configured to permit the at least one setting element, for example the adjacent setting element, to be deflected radially outwardly by the deflecting member. The setting deflection interface may include an interengaging ramp structure.

[0059] In one embodiment, a setting element and the deflecting member may each define a ramp surface to facilitate deflection of the setting element. The ramp surfaces may be defined by tapered or bevelled regions. The ramp surface of the setting element may define an inwardly tapered region of the setting element. The ramp surface of the deflecting member may define an outwardly tapered region of the setting deflecting member.

[0060] In one embodiment, the seal element and the adjacent setting element may define a seal deflection ramp interface therebetween, and the adjacent setting element and the deflecting member may define a setting deflection ramp interface therebetween.

[0061] The seal deflection ramp interface and the setting deflection ramp interface may each be configured to encourage radial deflection of the seal element before radial deflection of the adjacent setting element. Such an arrangement may facilitate sequential or staged actuation of the seal element.

[0062] The seal deflection ramp interface and the setting deflection ramp interface may each define a ramp angle relative to a longitudinal axis of the mandrel. Each ramp angle may be substantially similar. However, in some embodiments, the ramp angles may be different.

[0063] In one embodiment, the seal deflection ramp interface may define a shallower ramp angle than the setting deflection interface. Such an arrangement may function to encourage radial deflection of the seal element prior to radial deflection of the adjacent setting element

[0064] In one embodiment, the adjacent setting element may be stiffer than the seal element. Such an arrangement may function to encourage radial deflection of the seal element prior to radial expansion of the adjacent setting element. In such an embodiment, differences in stiffness may be a function of differences in geometry. Alternatively, or additionally, differences in stiffness may be a function of differences in material properties, such as material type.

[0065] In some embodiments, both of the setting support member and the seal element may be axially moveable relative to the mandrel, such that movement of both the setting support member and the seal element establishes relative axial movement therebetween.

[0066] In some embodiments, one of the setting support member and the seal element may be axially moveable relative to the mandrel, and the other of the setting support member and the seal element may be axially fixed relative to the mandrel.

[0067] In some embodiments, the setting support member may be axially fixed relative to the mandrel. Accordingly, the setting support member may define an axially fixed reaction point within the seal assembly. In such embodiments, the seal element may be axially moveable towards the setting support member to establish relative axial movement therebetween.

[0068] In some embodiments, the seal element may be axially fixed relative to the mandrel. For example, one axial end region of the seal element may be axially fixed relative to the mandrel. In such embodiments, the setting support member may be axially moveable towards the seal element to establish relative movement therebetween.

[0069] At least one setting element may be axially moveable relative to the mandrel.

[0070] The seal assembly may include an actuator arrangement for establishing relative axial movement between the seal element and the setting support member. The actuator arrangement may include a piston assembly, such as an annular piston assembly, ram or the like.

[0071] The seal element may be generally cylindrical when in the retracted configuration. In such an arrangement the seal element may be arranged substantially coaxially with the mandrel.

[0072] The seal element may define an annular gap with the mandrel, at least when the seal element is in its retracted configuration. Such an annular gap may assist interaction with a setting element, for example the adjacent setting element.

[0073] The seal assembly may include an actuation member, such as an actuation ring mounted on the mandrel and axially adjacent the seal element. The actuation ring may be mounted on or adjacent one axial end region of the seal element, for example a radially fixed axial end of the seal element.

[0074] The actuation ring may axially support the seal element, for example to facilitate relative axial movement of the seal element and the setting support member.

[0075] In some embodiments, the actuation ring may be axially fixed relative to the mandrel. In such embodiments, relative axial movement may be achieved by axial movement of the setting support member towards the actuation ring.

[0076] In some embodiments, the actuation ring may be axially moveable relative to the mandrel. In such embodiments, relative axial movement may be achieved by axial movement of the actuation ring towards the setting support member.

[0077] A seal arrangement may be provided between the mandrel and the actuation ring. The seal arrangement may include one or more seal members, such as one or more o-rings or the like. The provision of a seal arrangement may effectively permit the seal element to be sealed relative to the mandrel. Such an arrangement may minimize leakage between the seal element and the mandrel. Further, such an arrangement may permit pressure to be contained internally of the seal element, which may assist to press the seal element against the bore wall.

[0078] The actuation ring may be secured to the seal element, for example by integrally forming, fusing, adhesive bonding, interference fitting or the like. This may permit sealing to be achieved between the seal element and the actuation ring.

[0079] The actuation ring may be configured to radially fix one end region of the seal element.

[0080] The actuation ring may include an outer retaining structure, such as an outer tubular structure extending along an outer surface of the seal element, for example along a portion of the outer surface at one end region of the seal element. Such an outer retaining structure may radially retain an end region of the seal element.

[0081] The seal actuation ring may include an inner actuation structure, such as an inner tubular structure extending along a portion of the inner surface of the seal element. The inner actuation structure may be arranged between the seal element and the mandrel.

[0082] When the seal element is in its retracted or non-expanded configuration the actuation structure of the actuation ring may be axially separated from at least one setting element, such as the adjacent setting element. During relative axial movement between the seal element, specifically the actuation ring, and the setting support member the actuation structure of the actuation ring may eventually engage at least one setting element, such as the adjacent setting element. Such engagement may define the full extent of the first actuation distance.

[0083] The actuation structure of the actuation ring may be configured to actuate a setting element, such as the adjacent setting element, following engagement therewith, to cause said setting element to be radially expanded. The actuation structure of the actuation ring may be configured to actuate a setting element, such as the adjacent setting element, over the subsequent actuation distance.

[0084] The actuation structure may be configured to axially compress a setting element, such as the adjacent setting element. The actuation structure may be configured to axially move the setting element, such as the adjacent setting element. Such axial movement may permit the setting element to be radially deflected, for example by a deflecting member. The actuation structure may be configured to radially deflect a setting element, such as the adjacent setting element.

[0085] The seal element may include or define a unitary component. In some embodiments, the seal element may include multiple components assembled or arranged together to define the seal element.

[0086] The seal element may include regions of increased stiffness. Such regions may provide stability and/or strength within the seal element, for example to assist in resisting operational forces, such as extrusion forces.

[0087] The seal element may include an elastic material. The seal element may include an elastomeric material, such as a rubber.

[0088] The seal element may include a single or uniform material. In some embodiments, the seal element may include multiple materials.

[0089] The seal element may include an elastomeric compound, such as a rubber compound. The seal element may include a single or uniform elastomeric compound.

[0090] In some embodiments, the seal element may include multiple different elastomeric compounds. Such compounds may be intimately mixed, for example during manufacture, such as during moulding, prior to vulcanisation, or the like.

[0091] In some embodiments, such compounds may be provided in separate layers. A degree of intimate mixing at an interface region between different layers may be provided. Alternatively, or additionally, a bond may be provided between different layers.

[0092] At least two compounds may be provided to facilitate or accommodate different operational conditions. For example, at least one compound may preferentially resist extrusion forces. At least one compound may preferentially accommodate sealing. At least one compound may preferentially resist erosion, such as during intimate contact with a bore wall, for example during deployment of the seal assembly.

[0093] The seal element may include a swellable material, such as a swelling elastomer.

[0094] At least one setting element may include regions of increased stiffness. Such regions may provide stability and/or strength.

[0095] At least one setting element may include an elastic material. At least one setting element may include an elastomeric material, such as a rubber.

[0096] At least one setting element may include a single or uniform material. In some embodiments, at least one setting element may include multiple materials.

[0097] In some embodiments, at least one setting element may include multiple different elastomeric compounds.

[0098] At least one setting element may include a swellable material, such as a swelling elastomer.

[0099] At least one setting element may be configured to engage a bore wall. In some embodiments, at least one setting element may be configured to contribute to providing a seal against a bore wall.

[0100] At least one setting element may include an inner tubular structure, such as a metallic tubular structure, for example provided in the form of a spacing can. In some embodiments, such an inner tubular structure may be configured to be engaged by an actuation structure of an actuation ring.

[0101] The setting support member may include a rigid material.

[0102] The setting support member may include a metal material.

[0103] The setting support member may include an elastic material.

[0104] The setting support member may include an elastomeric material.

[0105] The setting support member may include rubber. Beneficially, the provision of an elastic material may facilitate setting in large bore sizes.

[0106] The seal assembly may include a back-up or seal support arrangement configured to provide axial support to the seal element when said seal element is in the extended configuration. Such axial support may be provided to assist the seal element to resist operational axial forces, such as extrusion forces.

[0107] The seal support arrangement may extend over at least a portion of the outer surface of the seal element.

[0108] The seal support arrangement may include an annular structure.

[0109] The seal support arrangement may include a petal structure.

[0110] The seal support arrangement may include a plurality of circumferentially arranged petals or tabs, such as generally axially extending petals or tabs.

[0111] The seal support arrangement may be reconfigurable between a retracted configuration and an extended configuration. The seal support arrangement may be configured in its extended configuration simultaneously with radial expansion of the seal element.

[0112] The mandrel may include or define a tubular structure.

[0113] The mandrel may include or define a unitary structure, such that all components of the seal assembly may be mounted on this unitary structure.

[0114] In some embodiments, the mandrel may include multiple components. Individual components of the seal assembly may be distributed over different mandrel components.

[0115] The seal assembly may include first and second sealing arrangements mounted on the mandrel, wherein each sealing arrangement includes a seal element mounted on the mandrel, a setting support member mounted on the mandrel, and at least one setting element mounted on the mandrel axially between the seal element and the setting support member.

[0116] The features of each sealing arrangement may be provided as defined above.

[0117] The first and second sealing arrangements may be mounted adjacent each other on the mandrel. The first and second sealing arrangements may be configured to be actuated by a common actuation event. For example, the first and second sealing arrangements may be configured to be moved axially relative to each other to be actuated to establish as seal within a bore.

[0118] In use, the first and second seal arrangements may provide mutual support to each other, for example to assist in resisting operational forces, such as extrusion forces.

[0119] In some embodiments, a single or common setting support member may be provided, which forms part of each sealing arrangement.

[0120] The first and second sealing arrangements may be arranged in a front-to-front orientation. In such an arrangement respective free end regions of the individual seal elements of each arrangement may face each other.

[0121] In an alternative embodiment, the first and second sealing arrangements may be arranged in a back-to-back orientation. In such an arrangement respective radially fixed end regions of the individual seal elements of each arrangement may face each other.

[0122] An aspect of the present invention relates to a method for establishing a seal in a bore using a seal assembly according to any other aspect.

[0123] An aspect of the present invention relates to a method for establishing a seal against a wall of a bore, including locating a seal assembly within the bore, wherein the seal assembly includes a seal element and a seal support element, wherein a maximum unconstrained expansion of the seal element is achieved by a combination of radial deflection of the seal element by the setting element, and subsequent radial expansion of the setting element, and expanding the seal element to sealingly engage a wall of the bore.

[0124] An aspect of the present invention relates to a method for establishing a seal within a bore, including (a) running a mandrel into a bore, wherein the mandrel carries a seal element, a setting support member, and at least one setting element positioned axially between the seal element and the setting support member, (b) causing relative axial movement between the seal element and the setting support member over a first actuation distance to cause the seal element to be deflected radially outwardly by a setting element, and (c) causing relative axial movement of the seal element and the setting support member over a subsequent actuation distance to cause radial expansion of at least one setting element to further expand the seal element.

[0125] Step (c) may only be performed in the event that step (b) does not result in sealing engagement of the seal element with a bore wall.

[0126] In some embodiments, when step (c) is note required, the method may include the further step of (d) axially compressing the seal element, for example against a setting element, to establish or improve sealing engagement with a bore wall.

[0127] The method may permit a seal to be provided in bores of different sizes using a common seal assembly.

[0128] An aspect of the present invention relates to a downhole seal assembly, including a radially expandable seal element, a radially expandable setting element, and an actuator configured to radially stack at least portions of the seal element and the setting element, and to radially expand the setting element.

[0129] Features defined in relation to one aspect may be provided in combination with any other aspect. It should be understood that the features defined above in accordance with any aspect of the present invention or below in relation to any specific embodiment of the invention may be utilized, either alone or in combination with any other defined feature, in any other aspect or embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0130] These and other aspects of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

[0131] FIGS. **1**A to **1**C show sequential stages of actuation of a seal assembly within a bore of a first diameter, according to an embodiment of the present invention;

[0132] FIGS. **2**A to **2**C show sequential stages of actuation of the same seal assembly within a bore of a second, smaller diameter;

[0133] FIGS. **3**A to **3**C show sequential stages of actuation of the same seal assembly within a bore of a third, still smaller diameter;

[0134] FIGS. **4**A to **4**C show sequential stages of actuation of a seal assembly according to an alternative embodiment of the present invention; and

[0135] FIGS. **5**A to **5**C show sequential stages of actuation of a seal assembly according to a further alternative embodiment of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[0136] FIG. **1**A is a diagrammatic illustration of one side of a downhole seal assembly, generally identified by reference numeral **10**, shown in a retracted configuration and run into an open hole wellbore **12***a*. As will be described in further detail below, the seal assembly **10** is configured for use in establishing a seal against a wall **13***a* of the wellbore **12***a*. Further, the seal assembly **10** may be suitable for use in providing a seal over a range of bore sizes.

[0137] The seal assembly **10** includes a mandrel **14**, which may be tubular in form, and may facilitate connection of the seal assembly **10** with a tubing string (not shown), such as a production string or the like. The seal assembly **10** further includes a seal element **16**, a setting support or deflecting member **18**, and a setting element **20**, all mounted on the mandrel **14** and axially arranged relative to each other, with the setting element **20** being interposed between the seal element **16** and the setting support member **18**.

[0138] The seal element **16** includes a deformable material, such as an elastomeric material, such as rubber. In the specific embodiment illustrated, the setting element **20** also includes a deformable material, such as a rubber. However, in the specific embodiment shown, the setting element **20** is stiffer than the seal element **16** (this could be achieved by being thicker, formed of a stiffer material or the like). In the embodiment shown, the setting support member **18** includes a rigid material, such as a metal material. However, it will be recognized that the setting support member **18** may alternatively include an elastomeric material.

[0139] In the embodiment shown, the setting support member is axially fixed relative to the mandrel **14**, whereas both the seal element **16** and the setting element **20** are axially moveable relative to the mandrel **14**.

[0140] The seal assembly **10** further includes an axially moveable metallic actuation ring **22** mounted on the mandrel

14 and bonded to the upper end region **24** of the seal element. An o-ring seal **26** is provided between the actuation ring **22** and the mandrel **14**.

[0141] The provision of this bonding and the o-ring **26** facilitates or assures sealing between the seal element **16** and the mandrel **14**. This may remove any reliance for the seal element to become sealingly engaged with the mandrel during an actuation event, as might be the case in conventional seal arrangements, such as in conventional axially compressible packers. In such known compressible packers initial compression typically first moves the packer element outwardly into engagement with the bore wall (for example, by buckling), with further compression expanding the packer radially inwardly to create a seal on the mandrel, with the result that contact forces and thus sealing on the mandrel can be low, perhaps resulting in a seal which is prone to leakage.

[0142] Also, the provision of the bonding and the o-ring **26** may provide or assure sealing against the mandrel such that the seal element **16** may be permitted to function in the manner of a cup or lip seal once expanded, as will be described in more detail below.

[0143] As will also be described in further detail below, the actuation ring **22** may be moved axially towards the setting support member **18** to cause radial expansion of the seal element **16** into sealing engagement with the bore wall **13***a*.

[0144] The actuation ring **22** includes an outer tubular wall structure **28**, which extends along a portion of an outer surface of the seal element **16**, thus radially restraining the upper end region **24**.

[0145] The actuation ring **22** further includes an inner tubular structure **30**, which extends along a portion of an inner surface of the seal element **16**, and within an annular region **32** defined between the seal element **16** and the mandrel **14**. As will be described in detail below, the inner tubular structure **30** functions as an actuator structure to actuate or cause radial expansion of the setting element **20**. However, when the seal assembly **10** is in its relaxed configuration as shown in FIG. **1**A, the inner tubular structure **30** is axially separated from the setting element **20**.

[0146] The seal element **16** and the setting element **20** define a seal deflecting ramp interface **34** therebetween. More specifically, the seal element **16** includes an inwardly facing ramp or tapered surface **36**, and the setting element **20** includes a complementary outwardly facing ramp or tapered surface **38**. As will be described in further detail below, the seal deflecting ramp interface **34** permits the seal element **16** to be deflected radially outwardly during relative axial movement of the seal element **16** and the setting element **20**.

[0147] In a similar manner, the setting element **20** and the setting support member **18** define a setting deflecting ramp interface **40** therebetween. More specifically, the setting element **20** includes an inwardly facing ramp or tapered surface **42**, and the setting support member **18** includes a complementary outwardly facing ramp or tapered surface **44**. As will be described in further detail below, the deflecting ramp interface **40** permits the setting element **20** to be deflected radially outwardly during relative axial movement of the setting element **20** and setting support member **18**.

[0148] In the present embodiment, the seal deflecting ramp interface **34** defines a shallower ramp angle than the setting deflecting ramp interface **40**. Such an arrangement preferentially encourages the seal element **14** to be radially deflected before the setting element **20**.

[0149] In the embodiment shown, in FIG. **1**A, the seal assembly **10** is positioned within a bore **12***a* of relatively large diameter compared to the seal assembly **10**.

[0150] Actuation of the seal assembly **10** may be achieved by axial movement of the actuation ring **22** in the direction of arrow A, as illustrated in FIG. **1**B, towards the setting support member **18**. Such axial movement of the actuation ring **22** may be achieved by a setting arrangement (not shown), such as an annular piston arrangement.

[0151] In FIG. **1**B, the actuation ring **22** has axially moved the seal element **16** over a first actuation distance such that the seal element **16** has become radially deflected and thus expanded by the ramp interface **34**, to extend over the outer surface of the setting element **20**. At the end of the first actuation distance the inner tubular structure **30** is brought into initial engagement with the setting element **20**.

[0152] It should be noted that although some degree of radial deflection and expansion of the setting element **20** may also have occurred during movement of the actuation ring **22** over this first actuation distance, this is minimal compared to the extent of radial deflection of the seal element **16**.

[0153] As illustrated in FIG. **1**B, expansion of the seal element **16** by virtue only of the radial deflection by the setting element **20** is insufficient to permit the seal element **16** to engage the bore wall **13***a*. As such, the actuation ring **22** may be moved further in the direction of arrow A by a subsequent actuation distance, as shown in FIG. **1**C, to cause the setting element **20** to become radially expanded, thus further expanding the seal element **16** into sealing engagement with the bore wall **13***a*. In such a configuration a seal may be established within the annulus **50** defined between the mandrel **14** and the bore wall **13***a*.

[0154] During movement over this subsequent actuation distance, the actuation ring **22** may apply an axial force against the setting element **20**, directly via engagement with the tubular structure **30**, and also indirectly via the upper region **24** of the seal element **16**. This axial force may cause the setting element **20** to be radially deflected and expanded by the ramp interface **40**. Further, this axial force may axially compress the setting element **20**, establishing expansion by a degree of radial bulging.

[0155] When in the fully set position, as shown in FIG. **1**C, the setting element **20** may provide a degree of stability to the seal assembly, assisting to resist operational conditions, such as axial extrusion forces and the like.

[0156] In the sealing configuration shown in FIG. **1**C, the seal element **16** may define or function as a cup or lip seal. In this respect, pressure from below (relative to the orientation of the drawings) may be applied on the inner face of the seal element **16**, thus assisting to increase the pressing force of the seal element **16** against the bore wall **13***a*. In this respect, the o-ring seal **26**, in combination with the bonding between the actuation ring **22** and the seal element **16**, permits this pressure to be contained internally of the seal element **16**.

[0157] The particular arrangement of the seal assembly **10** permits expansion of the seal element **16** to be achieved with a relatively low setting load, in comparison to convention packer arrangements, such as axially compressible packers. Requiring a lower setting force/load may have the advantages of simplifying the setting mechanism or improving the seal if the setting load is as high as would be required for a standard compression element. Such may be particularly advantageous in an irregular borehole as would often be the case with open hole.

[0158] As noted above, the seal assembly **10** may be suitable for use in establishing a seal in bores of different diameters. For example, FIGS. **2**A to **2**C illustrate sequential stages of setting the same seal assembly **10** against a bore wall **13***b* of a smaller diameter bore **12***b*. In the example illustrated in FIG. **2**A, the bore **12***b* may define an extrusion gap with the assembly **10** which is around 60% of that in FIG. **1**A.

[0159] In FIG. **2**A, the seal assembly **10** is initially provided in its retracted configuration and located at the required position within the bore **12***b*. The actuation ring **22** is then moved in the direction of arrow A over the first actuation distance, as illustrated in FIG. **2**B, to cause the seal element **16** to be radially deflected by the setting element **20**. In this example such initial expansion of the seal element **16** is sufficient to permit the seal element **16** to engage the bore wall **13***b*. However, the contact pressure may be insufficient to provide the necessary pressure resistance, and as such further axial movement of the actuation ring **22** over a subsequent actuation distance in the direction of arrow A, as illustrated in FIG. **2**C, may cause a degree of radial expansion of the setting element **20**, and thus further expansion of the seal element **16**, increasing the contact pressure, and contact area, of the seal element **16** with the bore wall **13***b*. As before, the seal element **16** may define or operate also as a cup or lip seal when in the expanded configuration of FIG. **2**C.

[0160] FIGS. **3**A to **3**C illustrate sequential stages of setting the same seal assembly **10** against the bore wall **13***c* of a yet smaller diameter bore **12***c*. In the example illustrated in FIG. **3**A, the bore **12***c* may define an extrusion gap with the assembly **10** which is around 15% of that in FIG. **1**A.

[0161] In FIG. **3**A, the seal assembly **10** is initially provided in its retracted configuration and located at the required position within the bore **12***c*. The actuation ring **22** is then initially moved in the direction of arrow A, as illustrated in FIG. **3**B, to cause the seal element **16** to be radially deflected by the setting element **20** and engage the bore wall **13***c*. In the present example, the actuation ring **22** is only required to move a short distance to facilitate engagement with the bore wall **13***c*, and is only minimally deflected over the outer surface of the setting element **20**. Further, axial movement of the actuation ring **22** in the direction of arrow A, as illustrated in FIG. **3**C, causes a degree of radial deflection of the setting element **20**, and also causes both the seal element **16** and the setting element **20** to be axially compressed and thus to be radially expanded to completely fill the annulus **50** between the bore wall **13***c* and the mandrel, and establish a robust seal.

[0162] As illustrated in FIG. **3**C, the setting element **20** is directly engaged with the bore wall **13***c*. This may contribute to the sealing effect of the seal assembly **10**.

[0163] Reference is now made to FIGS. **4**A to **4**C, which illustrate the sequential setting of a seal assembly **110**, according to an alternative embodiment of the present invention, within the same bore **12***a* first illustrated in FIG. **1**A. The seal assembly **110** is similar to assembly **10** first shown in FIG. **1**A and as such like features share like reference numerals, incremented by 100.

[0164] Accordingly, the seal assembly **110** includes a mandrel **114**, a seal element **116**, a setting support member **118** and a setting element **120**. An actuation ring **122** (which is in the same form as ring **22** of seal assembly **10** and thus includes outer and inner tubular structures **128**, **130**) is bonded to an upper end region **124** of the seal element and is used to axially move the seal element **116** to initiate actuation of the seal assembly **110**. A first ramp interface structure **134** is provided between the seal element **116** and setting element (with respective ramp surfaces **136**, **138**), and a second ramp interface structure **140** is provided between the setting element **120** and setting support member **118** (with respective ramp surfaces **142**, **144**).

[0165] The seal assembly **110** further includes a seal back-up arrangement in the form of an annular support structure **60**, which extends partially over the outer surface of the seal element **116** from its upper end region **124**. As illustrated in FIGS. **4**B and **4**C, as the seal element **116** is radially expanded, so too is the support structure **60**. The support structure **60** in the embodiment shown is formed of a metallic material, and provides axial support to the seal element **116** when expanded, to assist in resisting axial forces, such as extrusion forces. Although not shown in detail, the support structure **60** may be defined by a petal support structure.

[0166] In other, non-illustrated embodiments, the function of the support structure **60** may be achieved by a variation in the material properties of the seal element **116**. For example, the material of the sealing element may be of increased stiffness in selected locations.

[0167] Reference is now made to FIGS. **5**A to **5**C, which illustrate the sequential setting of a seal assembly **210**, according to an alternative embodiment of the present invention, within a bore **212**. The seal assembly **210** is similar to assembly **10** first shown in FIG. **1**A and as such like features share like reference numerals, incremented by 200.

[0168] The seal assembly **210** includes first and second seal arrangements **62**, **64** arranged on a mandrel **214** in a front-to-front orientation. Each seal arrangement is generally provided in the same form as the seal assembly **10** first shown in FIG. **1**A. The first seal arrangement **62** includes a first seal element **216***a*, a first setting element **220***a* and a first actuation ring **222***a*. Similarly, the second seal arrangement **64** includes a second seal element **216***b*, a second setting element **220***b* and a second actuation ring **222***b*.

[0169] The seal assembly **210** further includes a setting support member **218**, which is interposed between the first and second seal arrangements **62**, **64**.

[0170] The first seal arrangement **62** includes a first seal deflecting ramp interface **234***a*, and a first setting deflecting ramp interface **240***a*. Similarly, the second seal arrangement **64** includes a second seal deflecting ramp interface **234***b* and a second setting deflecting ramp interface **240***b*.

[0171] As illustrated in FIG. **5**B, initial actuation of the seal assembly **210** may be achieved by establishing relative axial movement between the first and second actuation rings, to cause the first and second seal elements **216***a*, **216***b* to be initially deflected radially outwardly by the respective first and second setting elements **220***a*, **220***b*. Further relative axial movement of the first and second actuation rings **222***a*, **222***b*, as illustrated in FIG. **5**C, causes the setting elements **220***a*, **220***b* to be radially expanded, thus causing the respective seal elements **216***a*, **216***b* to be further radially expanded into engagement with the wall **213** of the bore **212**.

[0172] When in this expanded and set position shown in FIG. **5**C, the first and second seal arrangements **62**, **64** may provide mutual support to each other, assisting to resist operational conditions and forces, such as extrusion forces.

[0173] It should be understood that the embodiments described herein are merely exemplary and that various modifications may be made thereto without departing from the scope of the present invention. For example, in alternative embodiments multiple setting elements may be provided.

[0174] The foregoing description is only exemplary of the principles of the invention. Many modifications and variations of the present invention are possible in light of the above teachings. The preferred embodiments of this invention have been disclosed, however, so that one of ordinary skill in the art would recognize that certain modifications would come within the scope of this invention. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. For that reason the following claims should be studied to determine the true scope and content of this invention.

1. A downhole seal assembly for establishing a seal against a bore wall, comprising:
- a mandrel;
- a seal element mounted on the mandrel;
- a setting support member mounted on the mandrel; and
- at least one setting element mounted on the mandrel axially between the seal element and the setting support member,
- wherein relative axial movement between the seal element and the setting support member over a first actuation distance causes the seal element to be deflected radially outwardly by an axially adjacent setting element, and relative axial movement of the seal element and the setting support member over a subsequent actuation distance causes radial expansion of at least one setting element to further expand the seal element.

2. (canceled)

3. The seal assembly according to claim **1**, configured such that the seal element preferentially expands by being radially deflected by the primary setting element, prior to radial expansion of the at least one setting element.

4. The seal assembly according to claim **1**, wherein the seal element is configured to be deflected radially outwardly and over an outer surface of the adjacent setting element such that the seal element and the adjacent setting element become radially stacked.

5. The seal assembly according to claim **1**, wherein the seal element is configured to define a cup or lip seal when in an expanded configuration.

6. The seal assembly according to claim **1**, wherein the seal element comprises a fixed region which is radially fixed, and a free end region which is configured to be radially expanded by being deflected radially outwardly by the adjacent setting element.

7. The seal assembly according to claim **6**, wherein at least one of:
- the fixed region is positioned intermediate opposing ends of the seal element;
- the fixed region is positioned at one end region of the seal element, opposite the free end region; and
- the fixed region of the seal element is sealingly engaged with the mandrel.

8-9. (canceled)

10. The seal assembly according to claim **1**, wherein the seal element and the adjacent setting element are generally arranged axially relative to each other in end-to-end relationship, when the seal element is in the retracted configuration.

11. The seal assembly according to claim **1**, wherein at least one of:
- the seal element and the adjacent setting element define a seal deflection interface therebetween configured to permit the seal element to be deflected radially outwardly by the adjacent setting element during relative axial movement between the seal element and the setting support member;
- the seal element and the adjacent setting element define a seal deflection interface therebetween configured to permit the seal element to be deflected radially outwardly by the adjacent setting element during relative axial movement between the seal element and the setting support member, the seal deflection interface comprising an interengaging ramp structure; and
- the seal element and the adjacent setting element each define a ramp surface to facilitate deflection of the seal element.

12-13. (canceled)

14. The seal assembly according to claim **1**, wherein said at least one setting element is at least one of:
- axially compressible during relative axial movement between the seal element and the setting support member over the subsequent actuation distance to be radially expanded; and
- radially expanded by being radially deflected outwardly during relative movement between the seal element and the setting support member over the subsequent actuation distance.

15. (canceled)

16. The seal assembly according to claim **1**, comprising a deflecting member for use in radially deflecting at least one setting element.

17. The seal assembly according to claim **16**, wherein at least one of:
- the deflecting member is defined by the setting support member;
- the deflecting member is defined by a further setting element;
- the deflecting member and at least one setting element define a setting deflection interface therebetween configured to permit the at least one setting element to be deflected radially outwardly by the deflecting member;
- the deflecting member and at least one setting element define a setting deflection interface therebetween configured to permit the at least one setting element to be deflected radially outwardly by the deflecting member, and wherein the setting deflection interface comprises an interengaging ramp structure; and
- the setting element and the deflecting member each define a ramp surface to facilitate deflection of the setting element.

18-21. (canceled)

22. The seal assembly according to claim **16**, wherein one of:
- the seal element and the adjacent setting element define a seal deflection ramp interface therebetween, and the adjacent setting element and the deflecting member define a setting deflection ramp interface therebetween; and
- the seal element and the adjacent setting element define a seal deflection ramp interface therebetween, and the adjacent setting element and the deflecting member define a setting deflection ramp interface therebetween, and wherein the seal deflection ramp interface and the setting deflection ramp interface each define a ramp angle relative to a longitudinal axis of the mandrel,

wherein the seal deflection ramp interface defines a shallower ramp angle than the setting deflection ramp interface.

23. (canceled)

24. The seal assembly according to claim **1**, wherein one of:

both of the setting support member and the seal element are axially moveable relative to the mandrel, such that movement of both the setting support member and the seal element establishes relative axial movement therebetween; and

one of the setting support member and the seal element is axially moveable relative to the mandrel, and the other of the setting support member and the seal element is axially fixed relative to the mandrel.

25. (canceled)

26. The seal assembly according to claim **1**, comprising an actuator arrangement for establishing relative axial movement between the seal element and the setting support member.

27. The seal assembly according to claim **1**, wherein the seal element defines an annular gap with the mandrel, at least when the seal element is in its retracted configuration.

28. The seal assembly according to claim **1**, comprising an actuation ring mounted on the mandrel and axially adjacent the seal element.

29. The seal assembly according to claim **28**, wherein at least one of:

the actuation ring axially supports the seal element;

the actuation ring radially retrains one end region of the seal element;

a seal arrangement is provided between the mandrel and the actuation ring;

the actuation ring is secured to the seal element by at least one of integrally forming, fusing, adhesive bonding and interference fitting; and

the actuation ring comprises an outer retaining structure extending along a portion of the outer surface at one end region of the seal element.

30-33. (canceled)

34. The seal assembly according to claim **28**, wherein the actuation ring comprises an inner actuation structure extending along a portion of the inner surface of the seal element.

35. The seal assembly according to claim **34**, wherein at least one of:

when the seal element is in its retracted configuration the inner actuation structure of the actuation ring is axially separated from at least one setting element, and during relative axial movement between the seal element and the setting support member the inner actuation structure of the actuation ring eventually engages the at least one setting element;

when the seal element is in its retracted configuration the inner actuation structure of the actuation ring is axially separated from at least one setting element, and during relative axial movement between the seal element and the setting support member the inner actuation structure of the actuation ring eventually engages the at least one setting element, and wherein engagement between the at least one setting element and the inner actuation structure of the actuation ring defines the full extent of the first actuation distance;

the inner actuation structure of the actuation ring is configured to actuate a setting element following engagement therewith to cause said setting element to be radially expanded;

the inner actuation structure is configured to axially compress a setting element; and

the inner actuation structure is configured to axially move the setting element to permit said setting element to be radially deflected.

36-39. (canceled)

40. The seal assembly according to claim **1**, comprising a back-up arrangement configured to provide axial support to the seal element when said seal element is in the extended configuration.

41. The seal assembly according to claim **1**, comprising first and second sealing arrangements mounted on the mandrel, wherein each sealing arrangement comprises:

a seal element mounted on the mandrel;

a setting support member mounted on the mandrel; and

at least one setting element mounted on the mandrel axially between the seal element and the setting support member.

42. The seal assembly according to claim **41**, wherein the first and second sealing arrangements are at least one of;

mounted adjacent each other on the mandrel;

configured to be actuated by a common actuation event; and

arranged in a front-to-front orientation relative to each other such that respective free ends of the seal elements face each other.

43-44. (canceled)

45. The seal assembly according to claim **1**, wherein the setting support member comprises at least one of;

a rigid material;

a metal material;

an elastic material; and

an elastomeric material.

46-48. (canceled)

49. A method for establishing a seal against a wall of a bore, comprising:

locating a seal assembly within the bore, wherein the seal assembly comprises a seal element and a seal support element, wherein a maximum unconstrained expansion of the seal element is achieved by a combination of radial deflection of the seal element by the setting element, and subsequent radial expansion of the setting element; and

expanding the seal element to sealingly engage a wall of the bore.

50. A method for establishing a seal within a bore, comprising:

(a) running a mandrel into a bore, wherein the mandrel carries a seal element, a setting support member; and at least one setting element positioned axially between the seal element and the setting support member; and

(b) causing relative axial movement between the seal element and the setting support member over a first actuation distance to cause the seal element to be deflected radially outwardly by a setting element.

51. The method according to claim **50**, wherein in the event that step (b) does not result in sealing engagement of the seal element with a bore wall, the method comprises:

(c) causing relative axial movement of the seal element and the setting support member over a subsequent actuation distance to cause radial expansion of at least one setting element to further expand the seal element.

52. The method according to claim **50**, comprising the further step of:

(d) axially compressing the seal element to establish or improve sealing engagement with a bore wall.

53. A downhole seal assembly for establishing a seal against a bore wall, comprising:

a seal element;

a setting support member; and

a setting element mounted axially between the seal element and the setting support member,

wherein the seal element is configured to be radially expanded by at least one of radial deflection by the setting element and radial expansion of the setting element.

54. The seal assembly according to claim **53**, wherein the setting support member comprises at least one of:

a rigid material;

a metal material;

an elastic material; and

an elastomeric material.

55-57. (canceled)

58. A downhole seal assembly, comprising:

a radially expandable seal element;

a radially expandable setting element; and

an actuator configured to radially stack at least portions of the seal element and the setting element, and to radially expand the setting element.

* * * * *