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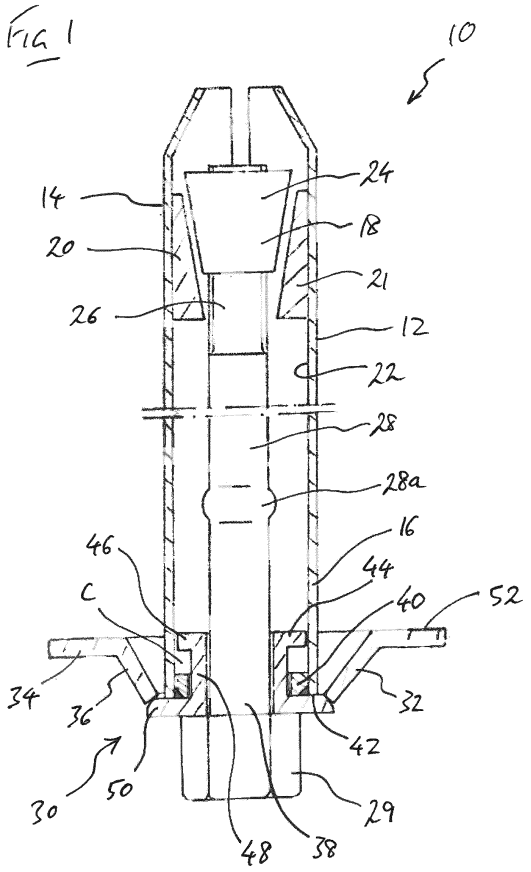
# (54) A ROCK BOLT

(57) A rock bolt 10 comprising: an elongate, generally circular tube 12, the tube 12 having a leading end 14 and a trailing end 16, an expander mechanism 18 disposed within the tube 12 in the region of the leading end 14, an elongate tendon 28 disposed longitudinally within the tube 12 and in connection at or towards a first end 26 of the tendon 28 with the expander mechanism 18 and in connection at or towards a second 38 and opposite end of the tendon 28 with an anchor arrangement 30 positioned at the trailing end 16 of the tube 12, the tendon 28 being actuatable to actuate the expander mechanism 18 and to remain connected between the expander mechanism 18 and the anchor arrangement 30 while the expander mechanism 18 is actuated, wherein the anchor arrangement 30 includes a couple 44, 54, 66 which, under tensile loading of the tendon 28, has a first mode of operation that allows movement of the anchor arrangement 30 axially away from the trailing end 16 of the tube 12 and enabling further expansion of the expander mechanism 18, and a second mode of operation that couples the anchor arrangement 30 to the tube 12 preventing further movement of the anchor arrangement 30 axially away from the trailing end 16 of the tube 12.

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## Description

### Technical Field

**[0001]** The present invention relates to a rock bolt for use in rock strata or a rock body for the purpose of stabilising the strata or body against fracture or collapse. This is sometimes termed "ground support". Such rock bolts are used extensively in the mining, tunnelling and excavation industries for supporting rock walls against fracture or collapse.

### Background of the Invention

**[0002]** The discussion of the background to the invention that follows is intended to facilitate an understanding of the invention. However, it should be appreciated that the discussion is not an acknowledgement or admission that any aspect of the discussion was part of the common general knowledge as at the priority date of the application.

**[0003]** The present applicant has developed rock bolts in the past and examples of these bolts are provided in Australian Patent Nos 2016363530 and 2018265326. Rock bolts according to these patents have been used for ground support over many years and have been proven to provide efficient and reliable anchorage within rock strata. In addition, these rock bolts can be installed in a relatively short time using conventional drill bits and drill rods.

**[0004]** The commercial versions of rock bolts of Australian Patent Nos 2016363530 and 2018265326 employ a split tube with an expander mechanism located internally at a leading end of the tube and an anchor arrangement at the opposite or trailing end. The rock bolts are inserted by percussion hammering into a hole that has been pre-drilled to be slightly smaller than the outside diameter of the split tube so that the tube is forced to resiliently contract to fit into the hole and so that the tube frictionally engages the facing wall or surface of the hole along the length of the tube once the tube is inserted.

**[0005]** The expander mechanism is activated once the rock bolt has been inserted into the hole and increases the frictional engagement of the tube with the facing wall of the hole, particularly at the leading end of the rock bolt. The expander mechanism is attached to a threaded end of a rod that extends to the anchor arrangement. The opposite end of the rod at the anchor arrangement has a fixed nut and the expander mechanism is activated by rotating the nut to rotate the rod to shift the expander mechanism in a manner that causes it to expand.

**[0006]** The anchor arrangement includes a rock plate that is pressed against the face of the rock about the hole by the nut when the nut is tightened to activate the expander mechanism. The rock plate applies a compressive force to the rock face which resists displacement of the rock strata. During a rock displacement, the anchor arrangement moves away from the trailing end of the tube allowing further expansion of the expander mechanism (if possible) and allowing elongation of the rod.

**[0007]** Further examples of rock bolts developed by the present applicant include those disclosed in Australian Patent Nos 2010223134 and 2015273708. Commercial versions of these rock bolts also employ a split tube with an expander mechanism located internally at a leading end of the tube and an anchor arrangement at the opposite or trailing end. The rock bolts are also inserted by percussion hammering into a hole that has been predrilled to be slightly smaller than the outside diameter of the split tube and the expander mechanism is activated once the rock bolt has been inserted into the hole by rotating a nut at the anchor arrangement that connects to the expander mechanism by a rod. In these rock bolts, a ring is welded to the trailing end of the tube and the rock plate engages the ring. These rock bolts thus operate differently during rock displacement given that the anchor arrangement cannot move away from the trailing end of the tube. In these rock bolts, tensile load during rock displacement is shared by the rod and the tube, whereas in the rock bolts of Australian Patent Nos 2016363530 and 2018265326, the tensile load is mainly reacted by the rod alone. However, in these rock bolts, there is no opportunity for further expansion of the expander mechanism during rock displacement.

**[0008]** The present applicant has engaged in development to provide an improved rock bolt.

### Summary of the Invention

**[0009]** A rock bolt according to the present invention has an elongate, generally circular tube with leading and trailing ends and an expander mechanism disposed within the tube in the region of the leading end. An elongate tendon is disposed longitudinally within the tube and in connection at or towards a first end of the tendon with the expander mechanism and in connection at or towards a second and opposite end of the tendon with an anchor arrangement positioned at the trailing end of the tube. The tendon is actuatable to actuate the expander mechanism and to remain connected between the expander mechanism and the anchor arrangement while the expander mechanism is actuated. The anchor arrangement includes a couple which, with the rock bolt installed in a body of rock and the tendon being under tensile loading, has 1) a first mode of operation that allows relative movement of the anchor arrangement axially away from the trailing end of the tube and enabling further expansion of the expander mechanism, and 2) a second mode of operation that couples the anchor arrangement to the tube preventing further relative movement of the anchor arrangement axially away from the trailing end of the tube.

**[0010]** A rock bolt according to the present invention advantageously includes first and second modes of operation (or phases of operation but the terms "mode" or "modes" will be used hereinafter) in which the first mode

of operation allows for further expansion of the expander mechanism during rock displacement and thus allows for an increase in the frictional engagement of the rock bolt with the wall of the hole during rock displacement. This first mode of operation is considered to be advantageous particularly during dynamic rock displacement such as during a seismic event, such that a part of the shock load that is applied to the rock bolt can be absorbed by expansion of the expander mechanism. In this respect, expander mechanisms of rock bolts are usually wedge arrangements in which a fixed wedge or wedges, or expander elements, which is the terminology that will be used herein, are attached to the inside surface of the tube and a movable wedge or expander element is attached to the end of the tendon. Relative movement between the fixed and movable expander elements expands the tube. During a rock displacement, the first mode of operation allows the movable expander element to move relative to the fixed expander element or elements in an expansion direction in order to absorb some of the shock loading caused by the rock displacement and so cushions the load applied to the rock bolt.

**[0011]** Alternatively, if the rock body within which the rock bolt is installed does not permit the expander mechanism to expand during rock displacement, so that the movable expander element is restrained against or prevented from moving relative to the fixed expander element or elements in an expansion direction, the first mode of operation also permits the tendon to elongate. Elongation of the tendon will likewise absorb some of the shock loading caused by rock displacement.

**[0012]** Still alternatively, in the first mode of operation, there can be a component of relative movement between the movable expander element and the fixed expander element or elements and a component of elongation of the tendon.

**[0013]** The second mode of operation couples the expander mechanism to the tube. The second mode of operation takes place after initiation of the first mode of operation. In some forms of the invention, or under some rock displacement events, the first mode of operation terminates and the second mode of operation commences, or the first mode of operation terminates and that initiates the second mode of operation. In other forms of the invention, or under other rock displacement events, the second mode of operation terminates continuation of the first mode of operation. That is, the first mode of operation continues up until the second mode of operation is initiated, when the expander mechanism becomes coupled to the tube preventing the further movement of the anchor arrangement axially away from the trailing end of the tube.

**[0014]** The prevention of further relative movement of the anchor arrangement axially away from the trailing end of the tube would typically mean that the expander mechanism no longer expands, although the reaction of the rock bolt under a rock displacement is complex and so further expansion of the expander mechanism can take place. It is to be noted that the present invention does not require that further expansion of the expander mechanism is terminated once the second mode of operation commences. If further expansion of the expander mechanism can be achieved during the second mode of operation, improved anchorage of the rock bolt within the hole will likely result. One example of where this can occur is where the rock bolt is loaded and the tube exceeds its yield strength before the tendon so that the tube elongates more than the tendon.

**[0015]** Coupling of the anchor arrangement to the tube results in further or additional tensile load that is applied to the rock bolt during the second mode of operation being shared by the elongate tendon and the tube, rather than the tendon carrying, bearing or supporting substantially the entire tensile load, which occurs in the first mode of operation. The tendon continues to carry the tensile load that is applied during the first mode of operation, but the tendon shares the further or additional tensile load that is applied during the second mode of operation. Beneficially, this means that the size or tensile strength of the tendon can be reduced to achieve the same overall strength for the rock bolt. Or it means that the size or tensile strength of the tendon can be retained with an increase in the overall strength of the rock bolt. The elongate tendon can be a cable or a rigid rod, including a steel bar, such as a ribbed steel bar.

**[0016]** The second mode of operation couples the anchor arrangement to the tube. The second mode of operation can thus use or employ a couple for that purpose. The couple can take any suitable form and in some forms of the present invention, in the second mode of operation, the couple engages or interacts with a tube abutment formed or provided at the trailing end of the tube. In the first mode of operation, the couple is disconnected or disengaged from or unconstrained by the tube abutment.

**[0017]** In a particular form of the invention, the anchor arrangement includes a rock plate and a movable couple that couples the anchor arrangement to the tube, the movable couple being coupled to the tube for axial movement relative to the tube between first and second axially spaced positions and the movable couple being engaged by the rock plate. The first mode of operation involves the movable couple moving between first and second axially spaced positions and the second mode of operation commencing when the movable couple has reached the second of the axially spaced positions. In this form of the invention, the rock bolt can comprise

an elongate, generally circular tube, the tube having a leading end and a trailing end,

an expander mechanism disposed within the tube in the region of the leading end,

an elongate tendon disposed longitudinally within the tube and in connection at or towards a first end of the tendon with the expander mechanism and in connection at or towards a second and opposite end of the tendon with an anchor arrangement positioned

at the trailing end of the tube,

the anchor arrangement including a rock plate for bearing against the surface of a rock body into which the rock bolt is inserted, the tendon being actuatable to actuate the expander mechanism and to remain connected between the expander mechanism and the anchor arrangement while the expander mechanism is actuated,

the anchor arrangement further including a movable couple that couples the anchor arrangement to the tube, the movable couple being coupled to the tube for axial movement relative to the tube between first and second axially spaced positions, the movable couple being engaged by the rock plate.

**[0018]** In the above arrangement, the anchor arrangement includes a rock plate. It is to be noted that a rock bolt according to the present invention can be provided with a rock plate, or a rock plate can be fitted later.

**[0019]** The tube abutment can be a ring that is fixed to the trailing end of the tube. The ring can be similar to the kind currently used on prior art rock bolts for engagement or interaction with a rock plate. The ring can be round or circular in cross-section, although in some forms of the invention, a ring of generally square cross-section will be employed. The ring can extend fully about the circumference of the tube including bridging across any longitudinal split in the tube and so forming a continuous ring. A continuous ring beneficially reinforces the tube during installation and when the rock bolt is loaded, to resist opening of the split and premature failure of the tube. The ring can be fixed to an internal surface of the tube and the couple can be accommodated partially or fully within the tube at the trailing end. Alternatively, the ring can be fixed to an external surface of the tube, i.e. to a radial outside surface of the tube, or to the axial edge of the tube at the trailing end (or to both) and the couple can be accommodated partially or fully outside of the tube at the trailing end.

**[0020]** The abutment can be fixed to the trailing end of the tube at or near the trailing edge of the tube. The abutment can be located fully within the tube, or fully outside the tube, or it can be located partially inside and outside the tube. The abutment can be fixed in place from inside or outside the tube, for example it can be fixed to one or both of the internal and external surfaces of the tube. In this latter arrangement, the abutment can extend radially to either side of the trailing edge of the tube, so that the abutment overlies the tube edge to each side (internal and external) of the tube edge. The abutment can include a circular groove to accept the edge of the tube before being fixed to the tube, such as by welding or other suitable fixing. In this form of the invention, the couple can engage either of the internal or external part of the abutment in the second mode of operation, or there can be engagement with each of the internal and external parts of the abutment.

**[0021]** Alternative abutments include one or more discrete and separate abutment sections that are fixed to the trailing end or edge of the tube. There may be two or more discrete and separate abutment sections that are fixed to the trailing end or edge of the tube, internally or externally. Alternatively, the trailing end or edge of the tube can be folded over to form a flange, or the tube end can be forged to form an abutment relative to the tube inboard of the forged end. The abutment could be formed by crimping or flaring the trailing end of the tube so that the tube is pushed inwardly or outwardly in the crimped area and so that the couple engages the crimped area in the second mode of operation. The abutment could be formed by a threaded ring or cap that is threaded onto the trailing end of the tube or that is otherwise connected or fixed to the trailing end. Discrete and separate abutment sections can alternatively be provided by cutting integral tabs out of the wall of the tube and bending them radially outwards or inwards. While these tabs can form the abutment, alternatively, they can be used to support an abutment (a ring for example).

**[0022]** It will be appreciated that while a single abutment, such as a ring can be provided or formed at the trailing end or edge of the tube, in alternative arrangements, multiple abutments can be formed at the trailing end or edge of the tube in any suitable manner. The abutment or abutments can be fixed to the tube such as by welding or other suitable fixing, or can be formed integrally such as by folding, forging or crimping.

**[0023]** In the broadest sense, the abutment can take any form that presents for engagement of the couple in the second mode of operation.

**[0024]** The couple can also be formed in any suitable manner. The couple can be located internally of the tube and can extend closely about the tendon. Alternatively, couple can be located externally of the tube and be radially spaced from the tendon. Still alternatively, the couple can be located partly internally of the tube to extend about the tendon and also partly externally of the tube.

**[0025]** The couple can include an abutment for engaging the tube abutment in the second mode of operation. The couple abutment can be a flange, a ring or it can be discrete and separate couple abutment sections.

**[0026]** Alternatively, the couple can include a cylindrical or tubular portion and the couple abutment can extend from the cylindrical or tubular portion radially inwardly or outwardly. The cylindrical or tubular portion can be a sleeve or a part sleeve. A part sleeve can include a longitudinal split, for example to align with a longitudinal split in the tube (if provided).

**[0027]** The couple abutment could for example, be a cylindrical flange or ring that extends radially inwardly or outwardly from the cylindrical or tubular portion. Alternatively, the couple abutment could be multiple abutment sections that extend radially inwardly or outwardly from the cylindrical or tubular portion. The number of abutment sections can be two or more. The couple abutment can be fixed to the cylindrical or tubular portion such as by welding or other suitable fixing, or it can be formed inte-

grally such as by folding, forging, crimping or casting.

**[0028]** The couple can be segmented for ease of attachment to the tube. That is, segmentation can facilitate attachment of the couple to the tube where the couple needs to fit past a tube abutment which is not possible when the couple is formed as a single unit. In these circumstances, a couple formed as a cylindrical or tubular sleeve may be formed in multiple longitudinal segments, such as two, three or four segments, which are each separately attached to the tube, placing the abutment of the couple on the correct side of the abutment of the tube. In this respect and as an example, the tube abutment can be located within the tube at the trailing end of the tube and the abutment of the couple needs to be positioned further inboard of the tube, past the tube abutment and toward the leading end of the tube, but respective abutments will clash during installation. To allow the abutment of the couple to be positioned past the tube abutment, the couple can be formed in segments as described above, allowing the segments to be inserted at an angle between the tendon and the tube abutment so that the abutments of the couple segments can clear the tube abutment and move past the tube abutment further into the tube.

**[0029]** The couple abutment described above can be a first abutment for engaging the tube abutment in the second mode of operation. The couple can further include a second abutment, axially spaced from the first abutment, for engaging the trailing end or trailing edge of the tube prior to initiation of the first mode of operation, where the trailing edge of the tube is the very end surface of the tube and the trailing end can be the end region of the tube. In this form of the invention, the second abutment can be formed in any of the same ways that the first abutment is formed. In some forms of the invention, the first abutment of the couple is located inside the tube and the second abutment has a greater radial diameter than the first abutment so that the second abutment can overlie the trailing edge of the tube. In these forms of the invention, a radially outer edge or periphery of the second abutment can be engaged by the rock plate. In these forms of the invention, the rock bolt can be driven into a rock body with the second abutment in bearing engagement with the trailing end of the tube. Upon a rock displacement, the second abutment will be shifted from bearing engagement with the trailing end of the tube as the anchor arrangement moves axially away from the trailing end of the tube in the first mode of operation. The first abutment will thus move toward the tube abutment and into engagement with the tube abutment if sufficient rock displacement occurs thus initiating the second mode of operation.

**[0030]** In some forms of the invention, the tube abutment is attached to the trailing edge of the tube and so in those forms of the invention, the second abutment engages the tube abutment as the rock bolt is driven into a rock body prior to initiation of the first mode of operation.

**[0031]** In other forms of the invention, the couple includes first and second axially spaced abutments separated by a sleeve, and the couple is attached to the tube about the outside of the tube. In these forms of the invention, the first abutment can be in engagement with the rock plate of the anchor arrangement and can remain in engagement with the rock plate during the first and second modes of operation. The first abutment can move toward and eventually engage the tube abutment in the first mode of operation. In this arrangement, the second abutment can engage the trailing edge of the tube, or the tube abutment, prior to the first mode of operation commencing.

**[0032]** The first abutment can extend radially inwardly from a cylindrical or tubular portion (a sleeve for example). The first abutment and the cylindrical or tubular portion can be machined from a one piece blank. Alternative arrangements include that the first abutment is rolled over relative to the cylindrical or tubular portion to extend radially inward. Or the first abutment can be formed according to abutments discussed above for other couples. Thus, for example, the first abutment can be a ring that is fixed to the cylindrical or tubular portion, such as by welding or other suitable fixing.

**[0033]** The second abutment can also be formed according to abutments discussed above for other couples. In some forms, the second abutment is a ring or disc (a washer for example) that can be fixed to the cylindrical or tubular portion, or can be placed into bearing engagement with the cylindrical or tubular portion. The ring or disc can include an opening through which the tendon extends and this can be a central opening.

**[0034]** In the discussion above, where reference to a tube edge is made, in most forms of the invention this will comprise the edge of the tube itself. However, the tube edge can include tube parts that are fixed to the trailing end of the tube and that form an edge that presents for engagement by the couple.

**[0035]** The present invention also includes a method of rock bolt operation, the rock bolt comprising a rock bolt as described above and the method of operation being characterised in that:

under tensile loading of the tendon, the couple has:

a. a first mode of operation that allows movement of the anchor arrangement axially away from the trailing end of the tube and enabling further expansion of the expander mechanism, and

b. a second mode of operation that couples the anchor arrangement to the tube preventing further movement of the anchor arrangement axially away from the trailing end of the tube.

## Brief Description of the Drawings

**[0036]** In order that the invention may be more fully understood, some embodiments will now be described with reference to the figures in which:

Figure 1 is a longitudinal cross-sectional view of a rock bolt according to a first embodiment of the present invention.

Figures 2 to 4 show the rock bolt of Figure 1 in sequence between the first and second modes of operation.

Figure 5 is a perspective view of a segmented couple of the rock bolt of Figure 1.

Figure 6 is a plan view of the couple of Figure 5.

Figure 7 is a cross-sectional view of the trailing end of a rock bolt according to a further embodiment of the present invention.

Figure 8 is a cross-sectional view of the trailing end of a rock bolt according to a further embodiment of the present invention.

**Detailed Description**

**[0037]** Fig 1 illustrates in cross-sectional view, a rock bolt 10 according to the present invention. The rock bolt 10 comprises an elongate generally circular tube 12 that has a leading end 14 and a trailing end 16.

**[0038]** An expander mechanism 18 is disposed within the tube 12 at the leading end 14. The expander mechanism 18 comprises a pair of fixed expander elements (hereinafter "fixed elements") 20, 21 that are fixed to the inside surface 22 of the tube 12. The expander mechanism 18 further includes a central and movable expander element or mandrel (hereinafter "central element") 24 that is threadably attached to a leading end 26 of an elongate tendon 28. The leading and 26 of the tendon 28 is threaded for connection of the central expander element 24. An arrangement similar to that shown in Figure 1 is disclosed in Australian patent application 2018265326, mentioned earlier herein.

**[0039]** The expander mechanism 18 is shown in a disengaged or disconnected state in Figure 1. This state occurs when the rock bolt 10 is driven into a hole that has been pre-drilled into a body of rock and before the expander mechanism 18 is activated. It is to be noted that the tube 12 is split longitudinally to enable the tube 12 to expand and contract and the hole that is drilled will usually be drilled to an inner diameter which is less than the outer diameter of the tube 12 so that the tube 12 radially contracts as it is inserted into the hole. This allows the tube 12 to frictionally grip the wall of the hole even before the expander mechanism 18 has been expanded.

**[0040]** Once the rock bolt 10 has been inserted into a hole to a sufficient depth that brings the rock plate 32 into engagement with the rock surface 52, or at least to a position closely adjacent the rock surface 52, the expander mechanism 18 can be activated to shift the central element 24 downwardly as shown in Figure 1 so that side edges of the central element 24 engage facing surfaces of the fixed elements 20 and 21. A similar arrangement is shown in Figures 1 and 2 of Australian patent application 2018265326.

**[0041]** The expander mechanism 18 is activated by rotating the nut 29 of the rock bolt 10, which also rotates the tendon 28 as the nut 29 and the tendon are fixed together to rotate together. Rotation of the nut 29 and the tendon 28 causes the central element 24 to move downwardly on the threaded, leading end 26 of the tendon 28. The nut 29 is rotated to a predetermined torque and interaction between the fixed elements 20, 21 and the central element 24 causes expansion of the tube 12 into firm engagement with facing surfaces of the hole.

**[0042]** The end of the tendon 28 opposite to the expander mechanism 18 connects to an anchor arrangement 30 at the trailing end 16 of the tube 12. The anchor arrangement 30 includes a rock plate 32 that includes a rock engaging portion 34 and a bolt engaging portion 36. The bolt engaging portion 36 engages with a couple 44 of the rock bolt 10 as will be described later herein. As indicated above, the nut 29 connects to the trailing end 38 of the tendon 28 and is fixed to the trailing end 38, so that rotation of the nut 29 rotates the tendon 28. In Figure 1, the tendon 28 is a solid steel bar.

**[0043]** The rock bolt 10 includes a ring 40 attached to the inside surface 22 of the tube 12 at the trailing end 16. The ring 40 forms an abutment of the tube 12 (a "tube abutment"). The ring 40 can the attached to the inside surface 22 such as by welding or other suitable fixing. In Figure 1 the ring 40 is attached at the very end of the tube 22 so that the ring 40 is adjacent the trailing edge 42 of the tube 12. The ring 40 is shown to have square cross-section, but could have alternative cross-sections such as circular.

**[0044]** The rock bolt 10 includes a couple 44. The couple 44 has a first abutment 46 that extends from a cylindrical sleeve 48. The sleeve 48 is a close but loose fit about the tendon 28 so that the tendon 28 can freely move axially relative to the sleeve 48. The first abutment 46 extends generally perpendicular to the axis of the sleeve 48. The couple 44 has a second abutment 50 that is spaced axially from the first abutment 46 so that a channel C is formed between the first and second abutments.

**[0045]** It can be seen in Figure 1 that the ring 40 is positioned within the channel C and adjacent to the second abutment 50. This is the starting or initial position of the ring 40 after installation of the rock bolt 10 in a drilled hole. It can be also seen in Figure 1 that the second abutment 50 has a greater radial diameter relative to the first abutment 46. This is because the first abutment 46 is located within the tube 12 and at a maximum, can have an outer diameter no larger than the inner diameter of the tube 12. However, to allow the couple 44 to move freely axially within the tube 12, the outer diameter of the first abutment 46 should be less than the inner diameter of the tube 12. The dimension of the outer diameter of

the first abutment 46 should also take into account that the tube 12 will contract radially as it is inserted into a hole and so the maximum outer diameter of the first abutment 46 should be slightly less than the inner diameter of the tube 12 once the tube 12 has been inserted into the hole. In contrast, the second abutment 50 overlies the trailing edge 42 of the tube 12 to extend radially beyond the tube 12 for engagement by the bolt engaging portion 36 of the rock plate 32.

**[0046]** As discussed above, the rock bolt 10 of Figure 1 is shown prior to the expander mechanism 18 being activated but with the rock plate 32 pressed against the face 52 of the rock body within which a hole has been pre-drilled and the rock bolt 10 has been inserted. During insertion of the tube 12, the tube 12 will have radially contracted, partially closing the longitudinal split, so that upon insertion, the tube 12 already engages the facing surface of the hole with a significant frictional load. The expander mechanism 18 can be expanded by rotating the nut 29 to bring the central element 24 into firm engagement with the fixed elements 20, 21 and to expand the diameter of the tube 12 to the extent available with the torque applied. The amount of torque that can be applied will vary depending on the rock body and hole conditions. Figure 2 illustrates the rock bolt 10 with the expander mechanism 18 having been activated. The rock bolt 10 can remain in this position with the rock plate 32 bearing against the face of the rock body and applying a compressive load to the rock face that resists rock falls.

**[0047]** Upon a rock displacement within the rock body, the face 52 of the rock body will tend to move outwardly and will apply increased pressure to the rock plate 32 which the rock plate 32 is intended to resist. The rock plate 32 will push against the second abutment 50 of the couple 44 and if there is sufficient load applied to the rock plate 32, the rock plate 32 will push the second abutment 50 away from bearing engagement the trailing edge 42 and from the ring 40. This disconnection from trailing edge 42 is the commencement of the first mode of operation, in which the anchor arrangement 30 moves axially away from the trailing end 16 of the tube 12.

**[0048]** The sequence of the first mode of operation is shown in Figures 2 to 4. Figure 2 represents the fully installed condition of the rock bolt 10 in which the expander mechanism 18 has been activated but the second abutment 50 is in bearing engagement with the trailing edge 42. Accordingly, comparing Figure 1 to Figure 2, the central element 24 has been shifted downwardly on the thread of the leading end 26 of the tendon 28 and into firm wedged engagement with the fixed elements 20, 21. The central element 24 has been shifted by rotation of the nut 29 which rotates the tendon 28. The expander mechanism 18 is now fully expanded.

**[0049]** Moreover, the rock plate 32 has been firmly pushed into engagement with the rock body surface 52 and the ring 40 remains within the channel C and adjacent the second abutment 50. The second abutment 50 remains engaged by the bolt engaging portion 34 of the rock plate 32 and also remains engaged with the trailing edge 42 of the tube 12.

**[0050]** Upon a rock displacement, such as during a seismic and non-seismic event, an increased load will be applied to the rock bolt 10 through the rock plate 32. The tendon 28 will be placed in greater tension and this will tend to cause the central element 24 to pull axially further through the fixed elements 20, 21 and for the tendon 28 to elongate (stretch). In either case, the anchor arrangement 30 will move away from the trailing end 16 (and the trailing edge 42). This movement is the movement that occurs in the first mode of operation of the rock bolt 10. This initial movement is illustrated in Figure 3 which shows that the second abutment 50 has shifted away from the ring 40 and the trailing edge 42. In fact, the overall couple 44 has shifted so that each of the sleeve 48 and the first abutment 46 have shifted with the second abutment 50. In the shifted position, the ring 40 is now proximal the first abutment 46, although slightly spaced away from the first abutment 46. The movement shown in Figure 3 would likely be in the region of about 5mm to 15mm. The movement shown in Figure 3 is also an example only so that the couple 44 could shift a greater or lesser amount so that the first abutment 46 could be closer to or further away from the ring 40. In the Figure 3 position, the tendon 28 is still carrying or supporting substantially all of the tensile load resulting from the rock displacement.

**[0051]** Figure 4 illustrates further movement of the anchor arrangement 30 moving away from the trailing end 16 of the tube 12. In Figure 4, the first abutment 46 has now moved to a position in which it is in engagement with the ring 40. This is the maximum movement of the anchor arrangement 30 away from the trailing end 16 of the tube 12 because once the first abutment 46 is engaged by the ring 40, the couple 44 is coupled to the tube 12. Upon engagement between the first abutment 46 and the ring 40, the first mode of operation is complete and the second mode of operation can commence if required.

**[0052]** Movement of the anchor arrangement 30 away from the trailing end 16 of the tube 12 occurs for the extent necessary to counteract load applied to the rock bolt 10 by the rock displacement. The anchor arrangement 30 might only move away from the trailing end 16 for a portion of the axial length of the channel C so that the first abutment 46 will stop short of the ring 40 as shown in Figure 3. For example, the load applied to the rock bolt 10 by the rock displacement may only be sufficient for the anchor arrangement 30 to travel to the position shown in Figure 3, or the travel may be less than the travel shown in Figure 3. The rock bolt 10 may settle into a position in which the ring 40 is spaced from both of the first and second abutments 46 and 50 and remain in that position once the rock displacement has ended. However, the rock bolt 10 allows for the anchor arrangement 30 to move away from the trailing end 16 for the full axial length of the channel C and until the first abutment 46 engages the ring 40, if the load applied to the rock bolt 10 by the

rock displacement is sufficient.

**[0053]** If the anchor arrangement 30 does move away from the trailing end 16 for the full axial length of the channel C so that the first abutment 46 moves into engagement with the ring 40, the first mode of operation ceases and the second mode of operation commences. In the second mode of operation, the anchor arrangement 30 and the tube 12 become coupled together thus preventing further movement of the anchor arrangement 30 axially away from the trailing end 16 of the tube 12. The tensile load applied to the rock bolt 10 by the rock displacement is now shared by the tendon 28 and the tube 12, rather than the tendon 28 counteracting substantially the entire tensile load, which occurs in the first mode of operation. This is advantageous for the reasons discussed earlier herein. The movement shown for the first abutment 46 to travel into engagement with the ring 40 will be in the region of about 10mm to 15mm.

**[0054]** Figures 2 to 4 show no further relative movement between the central element 24 and the fixed elements 20, 21 beyond the initial installed condition of the rock bolt 10. This indicates that in the illustrated examples, the position of the central element 24 in Figure 2, which is the initial installed position in which the expander mechanism 18 has been activated, remains the same under the particular rock displacement that the rock bolt 10 is subject to in the illustrated example. In that rock displacement, the tube 12 is unable to further expand, meaning that the rock strata about the rock bolt 10 withstands tube expansion. In this case, movement of the couple 44 is directly related to the amount of elongation in the tendon 28.

**[0055]** This will not always be the case and so in other examples, the central element 24 could move further into the fixed elements 20, 21, forcing them further apart and thus potentially increasing or at least maintaining the friction load between the outside surface of the tube 12 and the facing surface of the hole. In that case, movement of the couple 44 can be directly related to the amount of movement of the central element 24.

**[0056]** Still further, and more likely, movement of the couple 44 could relate to the combination of movement of the central element 24 further into the fixed elements 20, 21 and elongation in the tendon 28.

**[0057]** Movement of the couple 44 as shown in the sequence of Figures 2 to 4 advantageously is expected to absorb dynamic loading during rock displacement in a manner that cushions the impact on the rock bolt 10. The rock bolt 10 has a first phase in which the anchor arrangement 30 is not coupled to the trailing end 16 of the tube 12 and so the anchor arrangement 30 can move away from the trailing end 16 (the first mode of operation) and then a second phase (the second mode of operation) in which the anchor arrangement 30 is coupled to the trailing end 16. The rock bolt 10 thus improves the reaction to load from rock displacement and thus the support provided to restrain rock displacement because the rock bolt 10 can grip the rock face of the hole better by first allowing the movement of the first mode of operation whereby initial loading of the bolt is taken by the tendon 28 so that the expander mechanism 18 improves the grip of the rock bolt with the facing rock surface, and then the rock bolt 10 becomes stiffer and stronger by the coupling of the anchor arrangement 30 to the tube 12 in the second mode. Both stiffness and strength are very valuable characteristics for rock reinforcement devices.

**[0058]** The couple 44 can be formed in multiple segments for ease of attachment to the tube 12. In the cross-sectional view of Figure 1, it will be appreciated that if the couple 44 is formed in one piece and the ring 40 is a complete circle, it will not be possible for the first abutment 46 to be inserted past the ring 40. Accordingly, forming the couple 44 in two or more segments facilitates insertion. Figures 5 and 6 show the couple 44 in three segments 53 of equal arcuate dimensions, ie they each have an arc of about, or slightly less that 120°. Figure 5 shows the three segments assembled together in perspective view, while Figure 6 shows them slightly spaced apart in plan view looking from the first abutment 46.

**[0059]** For insertion of the couple 44 past the ring 40, each segment 53 can be inserted at an angle to allow the first abutment sections 46 of each segment 53 to move past the ring 40 and then the segments can be realigned axially with the tendon 28. The arcs of the segments 53 can be less than 120° and for example can be 100° or less to facilitate assembly. Gaps formed between the segments 53 will not necessarily compromise the load capacity of the couple 44 and the gaps will naturally reduce as the rock bolt 10 is inserted into a hole and the tube 12 radially reduces.

**[0060]** Alternative arrangements could include forming both the ring 40 and the first abutment 46 as slotted whereby non-slotted sections of the first abutment 46 can fit through slotted sections of the ring 40 and whereafter, the couple 44 is rotated to misalign the slotted and non-slotted sections to maintain the first abutment 46 inside of the ring 40. This arrangement would likely however require the couple 44 to be prevented from rotating once installed so as to prevent inadvertent disengagement of the couple 44 from the tube 12.

**[0061]** The tendon 28 includes an expanded section or "bump" 28a (see Figure 1). The expanded section 28a is located toward the trailing end 38 of the tendon 28 and is formed as a safety feature of the rock bolt 10 to prevent or at least minimise the risk of a broken section of the tendon 28 ejecting from the rock bolt 10 when the rock bolt 10 is installed in a hole and the tendon 28 breaks under extreme load. The expanded section 28a has a width dimension that is selected to be greater than the inside diameter of the sleeve 48 of the couple 44 so that the expanded section 28a will be prevented from passing through the couple 44 upon breakage of the tendon 28. With the majority of the length of the tendon 28 being on the side of the expanded section 28a towards the expander mechanism 18, the likelihood is that if the tendon 28 breaks, it will break between the expander mechanism

18 and the expanded section 28a and so the section of the tendon 28 that will start to eject will include the expanded section 28a. The ejecting portion of the tendon 28 will thus eject until the expanded section 28a reaches the couple 44 and the ejection is arrested. The bump can be forged into a solid rod tendon.

**[0062]** Figure 7 shows a modified couple 54 disposed at the trailing end 16 of the tube 12. In Figure 7, the tube 12 has the same construction as shown in Figure 1 and so the tube 12 includes a ring 40 fixed, such as by welding or other suitable fixing to the inside surface at the trailing end 16. Likewise, the tendon 28 of Figure 7 is of the same construction as shown in Figure 1 and so the tendon 28 has a nut 29 fixed to the trailing end thereof. The couple 54 interacts with a rock plate 32 of the same form as the rock plate 32 of Figure 1. It follows that the parts of the rock bolt 10 of Figure 1 that are present in Figure 7 are given the same reference numeral.

**[0063]** The couple 54 forms the only change to the rock bolt 10 shown in Figure 1. The couple 54 has a sleeve 58 and a first abutment 60 that are each of generally the same construction as the sleeve 48 and a first abutment 46 of the rock bolt 10 of Figure 1. The couple 54 also has a second abutment 61 that is formed in two parts comprising a first flange 62 and a second flange 64. The second flange 64 nests with the first flange 62. The second flange 64 would bear, in the positions of the rock bolt 10 shown in Figures 1 and 2, against the trailing edge 42 of the tube 12 and against the rock engaging portion 34 of the rock plate 32.

**[0064]** The couple 54 can be formed segmented for ease of attachment to the tube similar to described above in relation to the couple 44. The sleeve 58, the integral first abutment 60 and the first flange 62, and the second flange 64 may be formed in multiple longitudinal segments, such as two, three or four segments, which are each separately inserted into the tube 12. The couple 54 possibly has manufacturing advantages by the first abutment 60 and the first flange 62 being formed as flanges having the same or very similar dimensions. This is expected to make manufacture of the flanges on the sleeve 58, such as by forging, easier. This compares with the couple 44 in which the second abutment 50 is formed as a flange of greater diameter than the first abutment 46, which is expected to be more difficult to manufacture.

**[0065]** Figure 8 shows a further modified couple 66 disposed at the trailing end 16 of the tube 12. In Figure 8, the tube 12 has the same construction as shown in Figure 1, but a different form of ring 68 is attached to the trailing edge 42 of the tube 12. It follows again, that the parts of the rock bolt 10 of Figure 1 that are present in Figure 8 are given the same reference numeral.

**[0066]** The ring 68 extends radially to either side of the trailing edge 42 of the tube 12 so that it is partially inside and outside the tube 12. A weld is made between the outside section of the ring 68 and the outside surface of the tube 12 adjacent the trailing edge 42 and it can be seen that the ring 68 includes a groove (which is a circular groove) to accept the part circular edge 42 (the tube 12 has a longitudinal split) of the tube 12 before the ring 68 is welded to the tube 12.

**[0067]** The outside radial section (or outer peripheral section) 70 of the ring 68 forms an abutment of the tube 12 (a "tube abutment"). The couple 66 includes a first abutment 72 that extends radially inwardly from a sleeve 74 and a second abutment 76 that is formed as a ring or disc, which can be described as a "washer", with a central opening for passage of the tendon 28. The second abutment 76 can be fixed to the facing circular surface of the sleeve 74, or it can be just a bearing or touching fit against the facing surface of the sleeve 74. In Figure 8, the sleeve 74 is attached as a separate part to the second abutment 76 and once the nut 29 is tightened, the sleeve 74 and the second abutment 76 are forced into firm bearing engagement.

**[0068]** In Figure 8, the rock plate 32 engages the first abutment 72, but it will be easily seen that the second abutment 76 could be extended radially, ie the external diameter increased, to engage the rock engaging portion 34. This would reduce the axial extension of the rock bolt from the wall surface 52.

**[0069]** The sleeve 74 can be formed as a single part and fitted to the trailing end 16 of the tube 12. The second abutment 76 can be formed separately from the sleeve 74 and as a continuous ring or disc rather than also being segmented.

**[0070]** The couple 66 is envisaged to allow for less complex rock bolt assembly, but it has the disadvantage of extra projection of the nut 29 from the face of the rock body rock wall. This may be problematic in restricted spaces but is not considered to be of significant concern.

**[0071]** It is to be noted that the nut 29 in each of the Figure 1, 7 and 8 arrangements bears firmly against the respective couples 44, 54 and 66 and where the couples are segmented, bearing engagement with the nut 29 assists to maintain the segments from coming apart. It is to be noted that a ring, disc or washer, the same as or similar to the second abutment 76 of Figure 8, could be interposed between the nut 29 of the Figure 1, 7 and 8 arrangements and the respective couples 44, 54 and 66 as a further step to maintain the segments of those couples together or to reinforce them.

**[0072]** It is also to be noted that the expanded section 28a described in relation to the Figure 1 arrangement is applicable to the Figure 7 and 8 arrangements. An expanded section 28a will be prevented from passing through the couple 54 and 66 upon breakage of the tendon 28. For example, an expanded section 28a will be prevented from passing through the ring 68 or the second abutment 76 of the couple 66 upon breakage of the tendon 28.

**[0073]** Figures 1, 7 and 8 show three different forms of couple. Clearly other forms are possible. What is important for the present invention, is that the rock bolt has the ability to operate in first and second modes of operation, or in first and second phases of operation, and

each of the illustrated couples provides this. The invention however, is not limited to the use of a couple that operates in the same general manner as the couples that have been illustrated, but rather, the invention requires the rock bolt to have a mechanism that provides the first and second modes or phases of operation and the manner in which this is achieved can employ a couple of the kind illustrated or can alternatively employ a different arrangement that achieves the same result, or that achieves the required two modes of operation but in a very different manner.

**[0074]** Where any or all of the terms "comprise", "comprises", "comprised" or "comprising" are used in this specification (including the claims) they are to be interpreted as specifying the presence of the stated features, integers, steps or components, but not precluding the presence of one or more other features, integers, steps or components.

**[0075]** Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. It is understood that the invention includes all such variations and modifications which fall within the spirit and scope of the present invention.

## Claims

**1.** A rock bolt (10) comprising:

an elongate, generally circular tube (12), the tube (12) having a leading end (14) and a trailing end (16),
an expander mechanism (18) disposed within the tube (12) in the region of the leading end (14),
an elongate tendon (28) disposed longitudinally within the tube (12) and in connection at or towards a first end (26) of the tendon (28) with the expander mechanism (18) and in connection at or towards a second (38) and opposite end of the tendon (28) with an anchor arrangement (30) positioned at the trailing end (16) of the tube (12), the tendon (28) being actuatable to actuate the expander mechanism (18) and to remain connected between the expander mechanism (18) and the anchor arrangement (30) while the expander mechanism (18) is actuated,

**characterised in that**:
the anchor arrangement (30) includes a couple (44, 54, 66) which, under tensile loading of the tendon (28), has

a first mode of operation that allows movement of the anchor arrangement (30) axially away from the trailing end (16) of the tube (12) and enabling further expansion of the expander mechanism (18), and

a second mode of operation that couples the anchor arrangement (30) to the tube (12) preventing further movement of the anchor arrangement (30) axially away from the trailing end (16) of the tube (12).

**2.** A rock bolt (10) according to claim 1, the second mode of operation commencing after the first mode of operation terminates.

**3.** A rock bolt (10) according to claim 1 or 2, the tube (12) having an abutment (40) at the trailing end (16) and the couple (44, 54, 66) engaging or interacting with the tube abutment (40) in the second mode of operation.

**4.** A rock bolt (10) according to claim 3, the tube abutment (40) being a ring that is fixed to the trailing end (16) of the tube (12).

**5.** A rock bolt (10) according to claim 4, the ring (40) being round, circular or generally square in cross-section.

**6.** A rock bolt (10) according to claim 4 or 5, the ring (40) extending fully about the circumference of the tube (12) including bridging across any longitudinal split in the tube (12).

**7.** A rock bolt (10) according to claim 3, the tube abutment (40) being fixed to the trailing end (16) of the tube (12) at or near the trailing edge (42) of the tube and extending radially to either side of the trailing edge (42) of the tube.

**8.** A rock bolt (10) according to any one of claims 4 to 6, the ring (40) being fixed to an internal surface of the tube (12), or an external surface of the tube (12), or to the axial edge of the tube (12) at the trailing end (16).

**9.** A rock bolt (10) according to any one of claims 4 to 6, the ring (40) being fixed to the axial edge of the tube (12) at the trailing end (16) and the abutment overlying the tube edge to each side of the tube edge.

**10.** A rock bolt (10) according to any one of claims 3 to 9, the couple (44, 54, 66) including an abutment (46, 60, 72) for engaging the tube abutment (40) in the second mode of operation, the couple abutment (46, 60, 72) being a flange, a ring or one or more discrete and separate abutment sections.

**11.** A rock bolt (10) according to claim 10, the couple (44, 54, 66) including a cylindrical or tubular portion (48, 58, 74) and the couple abutment (46, 60, 72) extending from the cylindrical or tubular portion (48, 58, 74) radially inwardly or outwardly.

**12.** A rock bolt (10) according to claim 11, the couple abutment (46, 60, 72) being a first abutment (46, 60, 72) for engaging the tube abutment (40) in the second mode of operation and the couple (44, 54, 66) further including a second abutment (50, 61, 76), axially spaced from the first abutment (46, 60, 72), for engaging the trailing end (16) or trailing edge (42) of the tube (12) prior to initiation of the first mode of operation.

**13.** A rock bolt (10) according to claim 12, the first abutment (46, 60) being located inside the tube (12) and the second abutment (50, 61) having a greater radial diameter than the first abutment (46, 60) so that the second abutment (50, 61) overlies the trailing edge (42) of the tube (12) and a radially outer edge or periphery of the second abutment (50, 61) being engageable by a rock plate (32).

**14.** A rock bolt (10) according to any one of claims 10 to 13, the couple (44) being segmented into multiple longitudinal segments (53), including two, three or four segments.

**15.** A method of rock bolt operation, the rock bolt (10) comprising:

an elongate, generally circular tube (12), the tube having a leading end (14) and a trailing end (16),
an expander mechanism (18) disposed within the tube (12) in the region of the leading end (14),
an elongate tendon (28) disposed longitudinally within the tube (12) and in connection at or towards a first end (26) of the tendon (28) with the expander mechanism (18) and in connection at or towards a second (38) and opposite end of the tendon (28) with an anchor arrangement (30) positioned at the trailing end (16) of the tube (12),
the anchor arrangement (30) including a rock plate (32) for bearing against the surface of a rock body into which the rock bolt (10) is inserted and a couple (44, 54, 66), the tendon (28) being actuatable to actuate the expander mechanism (18) and to remain connected between the expander mechanism (18) and the anchor arrangement (30) while the expander mechanism (18) is actuated,

the method of operation being **characterised in that**:
under tensile loading of the tendon (28), the couple (44, 54, 66) has:

a. a first mode of operation that allows movement of the anchor arrangement (30) axially away from the trailing end (16) of the tube (12) and enabling further expansion of the expander mechanism (18), and
b. a second mode of operation that couples the anchor arrangement (30) to the tube (12) preventing further movement of the anchor arrangement (30) axially away from the trailing end (16) of the tube (12).

FIG 1

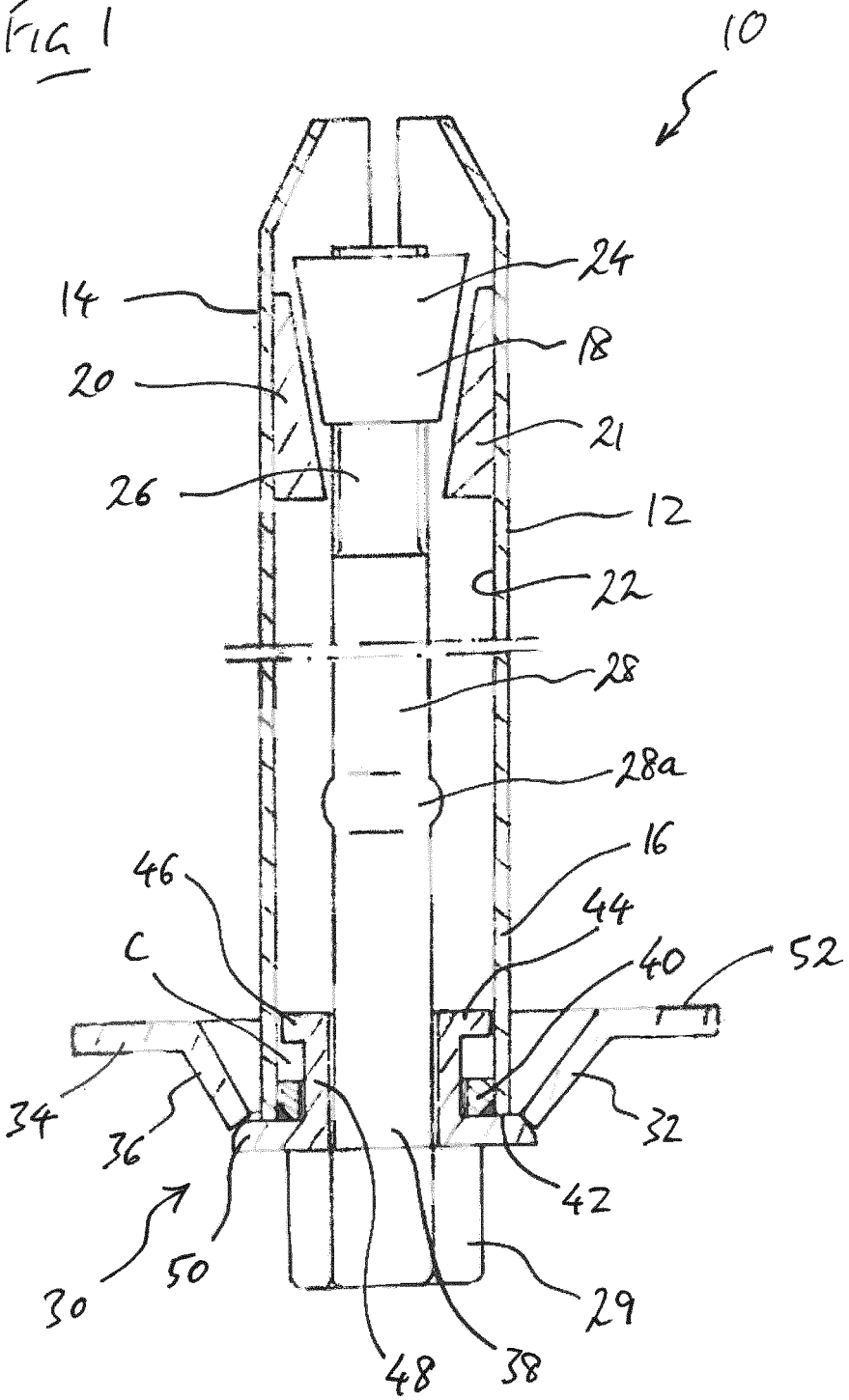
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FIG 2

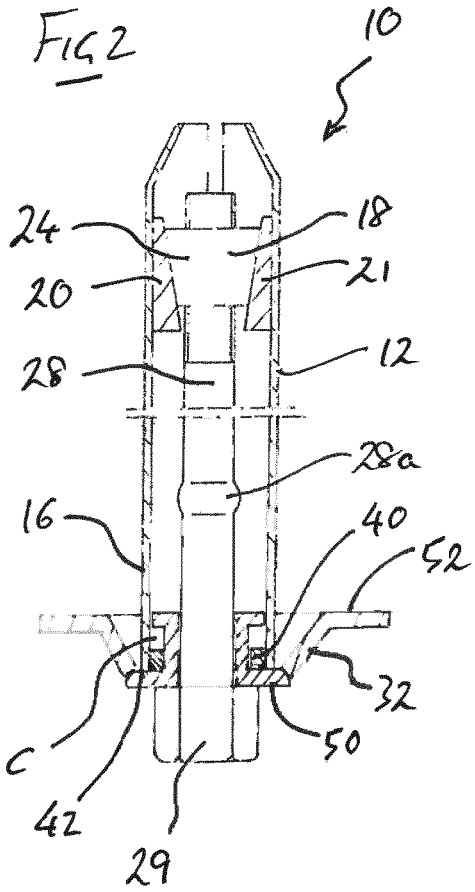



FIG 3

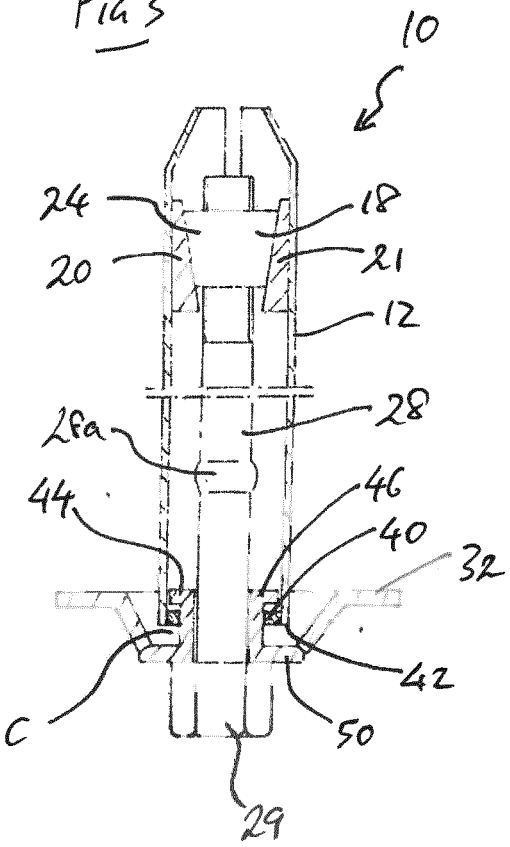



FIG 4

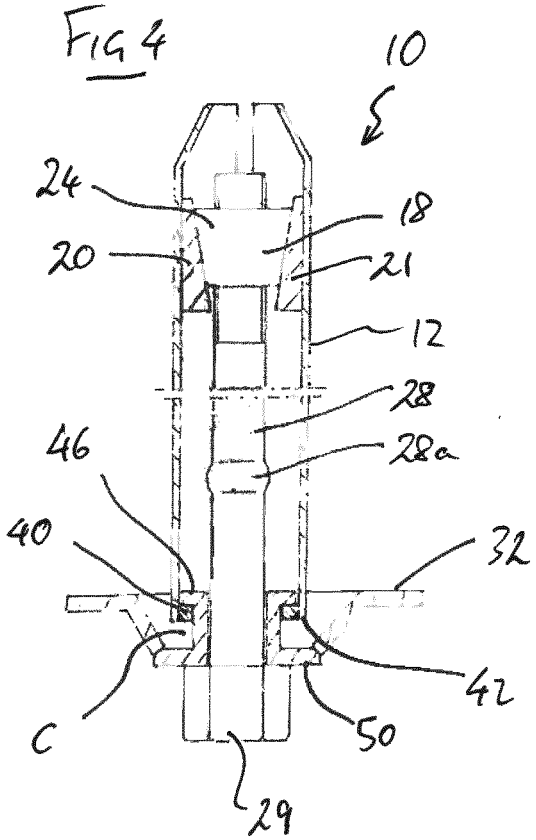


FIG 5

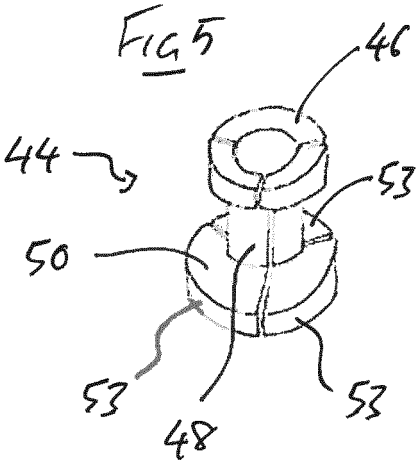



FIG 6

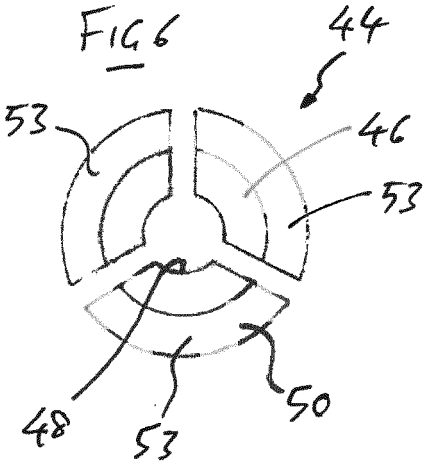



FIG 7

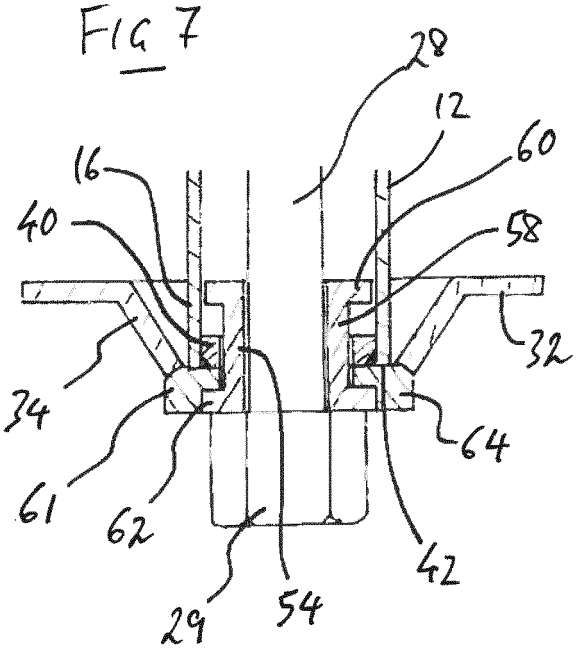
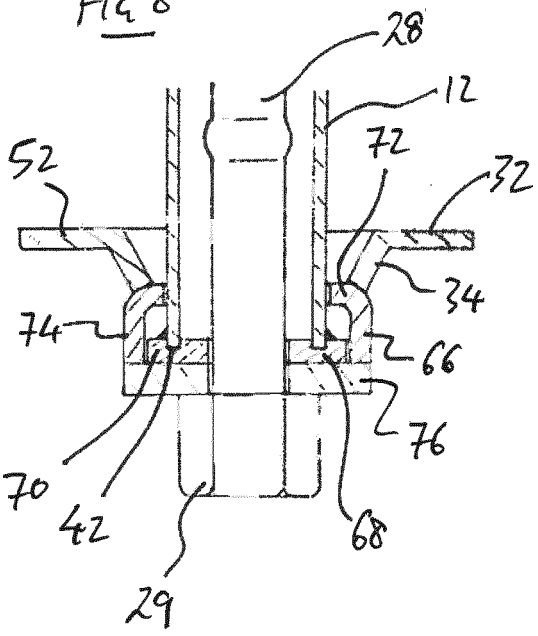



FIG 8



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Application Number
EP 23 16 4639

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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 28 August 2023 | Dantinne, Patrick |

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