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(54) A two-stage rock bolt & method of use

(57) A rock bolt (15, 115, 215) able to withstand two levels of tension within its tendon (16) is disclosed. The rock bolt is used in a tunnel (1) where the rock is subject to squeezing. After an initial installation with initial tension, plates (4) carried by the rock bolts are permitted to be squeezed together. Then a higher tension is created in the tendons (16) and the plates used to construct a concrete lining (9). The rock bolt preferably has first and second anchors. The first anchor can be chemical (grout) or mechanical (50). The second anchor (30, 40) is able to be triggered (36) by a pull chord (23) after the initial squeezing has taken place. An electric circuit (92, 93) is located in a breather tube (91) to signal that no more grout should be inserted via a grout tube (21).

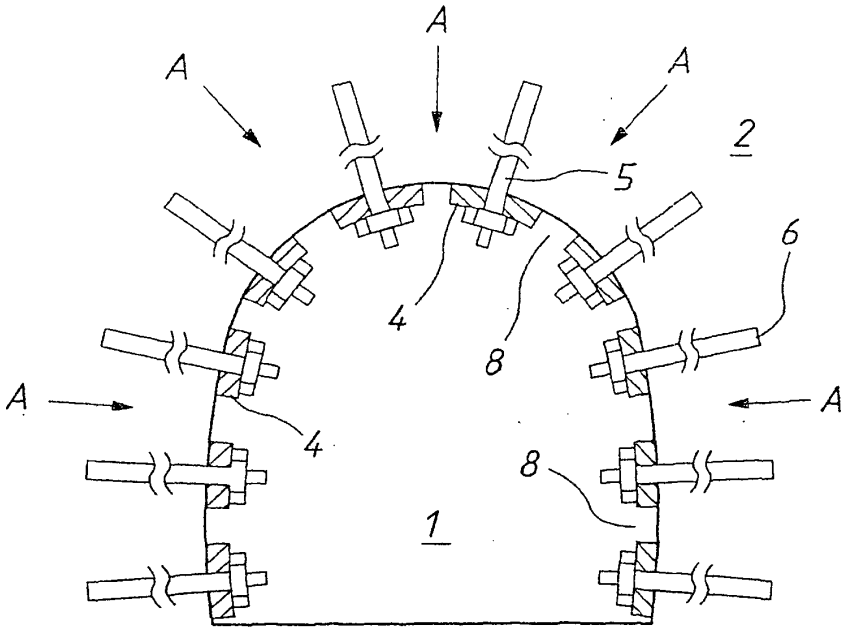

FIG. 1

EP 2 110 511 A1

Description

Field of the Invention

[0001] The present invention relates to tunnelling through rock subject to squeezing, and to a two-stage rock bolt suitable for use in such tunnelling.

Background Art

[0002] In some localities such as the Alps in Europe, the rock formations are not static. Instead, in the event that a tunnel is driven through the rock, then the rock is subject to "squeezing". What this means is that the rock is to some extent plastic and moves under the force or pressure applied to the rock by the overlying strata in such a way as to squeeze or reduce the cross-sectional area of the tunnel. Naturally, such rock strata is fraught with difficulty for tunnellers and is normally avoided. As a consequence, either tunnels for transport purposes, or tunnels for mining purposes, have generally hitherto not being built in such rock strata.

Genesis of the Invention

[0003] The genesis of the present invention is a desire to provide both a method whereby such tunnelling can be carried out, a two-stage rock bolt for use in carrying out the method, and a method of tensioning the two-stage rock bolt.

Summary of the Invention

[0004] In accordance with a first aspect of the present invention there is disclosed a method of preparing for concrete lining a tunnel through rock subject to squeezing, said method comprising the steps of:

(i) if necessary, forming said tunnel,
(ii) placing a plurality of spaced apart plates over the interior of said tunnel, each of said plates being secured by a two-stage rock bolt,
(iii) allowing said squeezing rock to initially deform said rock bolts and drive said plates into edge abutment,
(iv) placing said rock bolts into a final tensioned condition, and
(v) using said edge abutting plates to comprise, or support, formwork for said concrete lining.

[0005] In accordance with a second aspect of the present invention there is disclosed a two-stage rock bolt for use in rock subject to squeezing, said rock bolt comprising a tendon, a first anchor means adapted to be anchored in a hole in said rock, and having associated therewith a pinch means through which said tendon can pass by deforming, a second anchor means including a trigger means and carried by said tendon adjacent said first anchor means, and an elongate release extending alongside said tendon from said trigger means beyond said rock, said release being operable to activate said trigger means to thereby actuate said second anchor means.

[0006] In accordance with a third aspect of the present invention there is disclosed a method of tensioning a two-stage rock bolt, said method comprising the steps of:

(i) "installing said rock bolt in a blind hole drilled in rock subject to squeezing,
(ii) activating a first anchor carried adjacent the tip of said rock bolt,
(iii) allowing tension to a first extent to be created in said rock bolt,
(iv) activating a second anchor carried adjacent said first anchor, and
(v) allowing tension in excess of said first extent to be created in said rock bolt.

[0007] In accordance with a fourth aspect of the present invention there is disclosed a method of grouting a rock bolt in a blind hole where a hollow breather tube is located alongside the rock bolt and extends between opposite ends of the hole to allow escape of air from the closed end of hole as grout is inserted into the open end of the hole, said method being characterised by the step of:

(i) inserting an electric circuit into said breather tube and extending beyond the end thereof,
(ii) said electric circuit including an indicator means at said open end of said hole and a sensor means at said closed end of said hole, said sensor means being activated by said grout reaching same to thereby indicate that said grout insertion should close.

[0008] Said sensor means may comprise a par of electrical contacts and said grout may be electrically conductive. Additional or alternatively, that indicator means may comprise a light. In particular that light may incorporate at least one light emitting diode (LED).

Brief Description of the Drawings

[0009] Three embodiments of the present invention will now be described with reference to the accompanying drawings in which:

Fig. 1 is a transverse cross-sectional view through a tunnel showing the position of steel plates prior to squeezing having taken effect,
Fig. 2 is a view similar to Fig. 1 but showing the position of the steel plates after squeezing has taken effect,
Fig. 3 is a longitudinal cross-sectional view through the tip of a two-stage cable tendon rock bolt of a first embodiment,

Fig. 4 is a longitudinal cross sectional view of the trailing end of the rock bolt of Fig. 3,

Fig. 5 is a view similar to Fig. 3 but of a rock bolt of a second embodiment, and

Fig. 6 is a truncated longitudinal cross-section through a third embodiment having the preferred grout breather tube.

Detailed Description

[0010] As seen in Fig. 1, a tunnel 1 is excavated from rock 2 which is the subject of squeezing forces indicated by arrows A. In order to prevent the tunnel 1 collapsing, in accordance with the preferred embodiment of the present invention steel plates 4 are located over the interior surface of the tunnel, each of the plates 4 being held in position by means of a two-stage rock bolt 5. Each rock bolt 5 is positioned in a blind hole 6 which is drilled radially into the rock 2.

[0011] In the situation illustrated in Fig. 1, prior to squeezing having taken place, there is a small gap 8 between each of the steel plates 4. However, in the situation illustrated in Fig. 2 where squeezing has both commenced and progressed to a certain degree, the movement of the rock 2 effectively eliminates the gaps 8 so that the steel plates 4 edge abut. The rock bolts 5 are two-stage rock bolts in that the first stage which arises immediately after installation of the rock bolts 5 permits the intended small movement of the rock 2 so as to carry out the squeezing to the requisite extent. Thereafter, once the gaps 8 have been eliminated, the rock bolt is tensioned to its final tension which is intended to ensure that no further squeezing of the rock 2 takes place. In the condition illustrated in Fig. 2, the steel plates 4 are edge abutted one against the other and thus form a suitable boundary which can be used for formwork for a concrete lining 9 indicated by broken lines in Fig. 2 and which is intended to provide the final support for the walls of the tunnel 1. Alternatively, the steel plates 4 can support formwork which is used in the construction of the concrete lining 9.

[0012] It will be appreciated that depending upon the nature of the rock 2, the steel plates 4 and rock bolts 5 may also be required on the floor of the tunnel, however, this is not illustrated in Figs. 1 and 2 in order not to overburden the diagrams.

[0013] Each of the rock bolts 5 in Figs. 1 and 2 has a leading end 11 and a trailing end 12. In Fig. 3 a longitudinal cross-section through the leading end 11 of the rock bolt 15 of a first embodiment is illustrated. The rock bolt 15 has a tendon 16 formed from a cable fabricated from steel wires. A portion of the tendon 16 intermediate two annular washers 17, 18 is provided with a tube 19, for example made from plastics material such as irrigation pipe extruded in high density polyethylene (HDPE). The tendon 16 is able to slide through the tube 19.

[0014] A grout tube 21 passes through the trailing washer 17. In addition, a secondary tube 22 also passes through both washers 17 and 18 and a pull cord 23 passes through the secondary tube 22.

[0015] The leading washer 18 is mounted on a pinch tube 25 (of the general type illustrated in Fig. 3 of US Patent No. 7,037, 046) which has a constricted interior passage 26 which is substantially S-shaped. The pinch tube 25 is longitudinally split so as to be formed from two portions which are clamped together about the tendon 16 and held in position by means of two keeper rings 27, 28.

[0016] Abutting the pinched tube 25 is a barrel 30 which has a tapered interior 31 which matches the taper on a frusto-conical wedge 40 which surrounds the tendon 16. The leading end of the barrel 30 is machined with an annular groove 33. A transversely split annular keeper 34 has a re-entrant annular flange 35 which is retained in the groove 33. The two parts of the annular keeper 34 overlap and are provided with two pairs of aligned orifices through each pair of which a corresponding pin 36A (Fig. 3 or 36B Fig. 5) is retained by means of a friction fit. Within the keeper 34 an O-ring 37 is retained in compression. In addition, the annular keeper 34 clamps on the wedge 40 and retains same in position with the internal diameter of the passage through the wedge 40 being sufficient to permit the tendon 16 to slide relative to the wedge 40. An important function of the intact keeper 34 is to maintain separation between the locking taper of the wedge 40 and the barrel 30.

[0017] The pull cord 23 is bifurcated (Fig.6) and one portion thereof 23A is connected to the pin 36A illustrated in Fig. 3. On the other side of the apparatus illustrated in Fig. 3, and therefore not visible in Fig. 3, is another pin 36B (illustrated in Fig. 5) which is connected to the other portion 23B of the bifurcated pull cord 23.

[0018] Turning now to Fig. 4, the trailing end 12 of the rock bolt 15 is illustrated. The trailing end of the tendon 16 passes through a central aperture 42 in the steel plate 4. Abutting against the steel plate 4 is a conventional locking mechanism in the form of an internally tapered barrel 130 and a frusto-conical wedge 140 which are capable of clamping the tendon 16 so as to place same in tension. The grout tube 21 passes through a corresponding opening in the plate 4 and a similar opening is provided for the pull cord 23.

[0019] After the blind hole 6 has been drilled, the leading end 11 of the first embodiment of the rock bolt 15 is passed into the hole 6 to the maximum extent permitted by the length of the tendon 16. The two annular washers 17 and 18 ensure that the tendon 16 is approximately centred in the blind hole 6 and also define an interior space into which grout is pumped in the direction of arrows B in Fig. 4 and C in Fig. 3. The grout fills the volume between the two washers 17 and 18 and thus provides a first anchor which retains the pinch tube 25 in position. Thereafter the tendon 16 can be lightly tensioned and locked by means of the barrel 130 and wedge 140, thereby completing the installation process.

[0020] As the rock 22 commences its squeezing ac-

tion, the steel plate 4 is moved to the left as seen in Fig. 4 thereby increasing the tension within the tendon 16 and forcing the tendon 16 through the interior passage 26 of the pinch tube 25. This requires the tendon 16 to be deformed, and preferably elastically deformed, and typically increases the tension within the tendon 16 to approximately 50kN.

[0021] Once the plates 4 are edge abutting as illustrated in Fig. 2, then the pull cord 23 can be manually tugged so as to dislodge both pins 36A and 36B which retain the annular keeper 34. As a consequence, the annular keeper 34 which now consists of two separate parts radially expands under the urging of the resilient O-ring 37 thereby permitting the wedge 40 to enter into the barrel 30 under the influence of the tension within the tendon 16. That is to say, the wedge 40 and barrel 30 are permitted by the rupturing of the keeper 34 to come closer together to form a second anchor which securely grasps the tendon 16 and is capable of withstanding significant tension, for example up to 300kN. As a consequence, further squeezing movement of the rock 2 is prohibited and the steel plates 4 remain in their abutting configuration illustrated in Fig. 2 but do not move inwardly any further.

[0022] If desired, the significant tension in the tendon 16 can be created using a substantially conventional cable jack.

[0023] A second embodiment of the rock bolt 5 is illustrated in Fig. 5 and takes the form of a rock bolt 115, only the leading end 111 being illustrated. The tendon 16, pull cord 23, pinch tube 25, barrel 30, annular keeper 34 and wedge 40 are as before.

[0024] Instead of the first anchor being formed from grout as in Fig. 3, in the arrangement of Fig. 5 a mechanical or point anchor 50 is provided. The anchor 50 consists of an outer shell 51 which is preferably longitudinally split into three portions and which has a serrated exterior surface 52. Located within the shell 51 is a tapered collet 53 which is urged to the left as seen in Fig. 5 by means of a spring 54 retained between a washer 55 and a nut 56. The collet 53 is shaped to mate with the pinch tube 25. The initial tension created within the tendon 16 following installation of the rock bolt 115 expands the shell 51 thereby anchoring the anchor 50 relative to the blind hole 6. As a consequence, the pinch tube 25 is fixed relative to the hole 6 in the same way that the grout of Fig. 3 fixes the pinch tube 25 relative to the hole 6 in the embodiment of Fig. 3.

[0025] At the trailing end of the rock bolt 115 the arrangement is the same as illustrated in Fig. 4 save that the grout tube 21 is absent. In all other respects the operation of the rock bolt 115 is the same as operation of the rock bolt 15.

[0026] In the third embodiment of a rock bolt 215 as illustrated in Fig. 6 the tendon 16, plate 4, barrel 130 and wedge 140 are as in Fig.4. Similarly, the washers 17 and 18 and pinch tube 25 are also as in Fig. 3. The grout tube 21 and the secondary tube 22 with its pull cord 23 are also as in Fig. 3.

[0027] In Fig. 6 a breather tube 91 is provided which extends through the plate 4 and through the washer 18. That is, the leading end of the breather tube 91 terminates in the space between the two washers 17, 18 which is to be filled with grout (not illustrated). In addition, the breather tube 91 has a pair of insulated wires 92 which run the length of the breather tube 91 and terminate at its leading end in a pair of electrical contacts 93. At the trailing end of the rock bolt 215 the wires 92 terminate in a battery 98 and a light 99 preferably in the form of a light emitting diode (LED).

[0028] In operation the apparatus of Fig. 6 functions as follows: Grout is pumped into the grout tube 21 as indicated by arrow B and exits from the grout tube 21 between the washers 17, 18 as indicated by arrow C. As a consequence air is expelled from between the washers 17, 18 entering the breather tube 91 as indicated by arrow D and exiting the breather tube to the rear of the plate 4 as indicated by arrow E.

[0029] If the overall length of the bolt 215 was short, say 1-5 metres, when the space between the washers 17,18 was full of grout, the grout would exit from the breather tube 92 (as indicated by arrow E) thereby signalling that no more grout should be pumped into the grout tube 21. However, where the overall length of the rock bolt 215 is larger (typically 30 metres or so) the resistance of the breather tube 92 to grout passing through it prevents this simple system from working satisfactorily. Instead, grout makes its way past one or both of the washers 17, 18 into places where it is not wanted and grout continues to be pumped into the grout tube 21 for want of a stop si gnal.

[0030] Such a stop signal is provided by the wires 92. When the grout reaches the spaced apart contacts 93, the grout (which is preferably water based) conducts sufficient electric current to activate the LED 99. This signals that the pumping of the grout should stop because the space between the washers 17, 18 is now full of grout. It is to be understood in this connection that the grout tube 21, pull cord 23 and breather tube 91 are preferably not located in the one vertical plate as indicated in Fig. 6 but are preferably radially spaced with approximately 120° spacing relative to the longitudinal axis of the tendon 16.

[0031] In addition, the contacts 93 preferably are placed in the upper most portion of the space between the washers 17, 18 to ensure that the grout which enters into this portion of the space reaches the contacts 93 last.

[0032] The foregoing describes only some embodiments of the present invention and modifications, obvious to those skilled in the art, can be made thereto without departing from the scope of the present invention. For example, although the tendon 16 is provided by means of a cable, the tendon 16 could equally be a solid rod or a tube.

[0033] The term "comprising" (and its grammatical variations) as used herein is used in the inclusive sense of "including" or "having" and not in the exclusive sense of

"consisting only of".

Claims

1. A two-stage rock bolt for use in rock subject to squeezing, said rock bolt (15, 115, 215) being **characterised in that** a tendon (16), a first anchor means (50) is adapted to be anchored in a hole (6) in said rock, and has associated therewith a pinch means (25) through which said tendon (16) can pass by deforming, a second anchor means (30, 40) includes a trigger means (36) and is carried by said tendon adjacent said first anchor means (50), and an elongate release (23) extends alongside said tendon from said trigger means beyond said rock, said release (23) being operable to activate said trigger means (36) to thereby actuate said second anchor means.

2. The rock bolt as claimed in claim 2 **characterised in that** said first anchor includes grout located between said hole and said tendon.

3. The rock bolt as claimed in claim 2 **characterised in that** said first anchor comprises a mechanical-or point anchor (50).

4. The rock bolt as claimed in any one of claims 1-3 **characterised in that** said pinch means comprises a longitudinally split tube having a constricted interior

5. The rock bolt as claimed in claim 4 **characterised in that** said constricted interior has a generally S-shaped configuration.

6. The rock bolt as claimed in any one of claims 1-5 **characterised in that** said pinch means is located between the tip of said rock bolt and said first anchor.

7. The rock bolt as claimed in claim 6 **characterised in that** said pinch means is located immediately adjacent, and abutting, said first anchor.

8. The rock bolt as claimed in any one of claims 1-7 **characterised in that** said elongate release comprises a pull chord.

9. The rock bolt as claimed in any one of claims 1-8 **characterised in that** said trigger means comprises a transversely split ring, two portions (27, 28) of said ring overlapping and including two pairs of aligned orifices, and a pin (36) retained in each said pair of aligned orifices by a friction fit whereby removal of said pin activates said trigger means.

10. The rock bolt as claimed in claim 9 **characterised in that** a resilient means (37) urges said split ring portions apart.

11. The rock bolt as claimed in claim 10 **characterised in that** said resilient means comprises an O-ring in compression.

12. The rock bolt as claimed in any one of claims 1-11 **characterised in that** said trigger means is located between first and second co-operating portions of said second anchor.

13. The rock bolt as claimed in claim 12 **characterised in that** said trigger means when triggered permits said first and second co-operating portions to commence their co-operation.

14. The rock bolt as claimed in claim 12 or 13 **characterised in that** said first portion is a barrel (30) having a tapered interior and said second portion is a frusto-conical wedge (40) which mates with said tapered interior.

15. The rock bolt as claimed in any one of claims 1-14 **characterised in that** said first anchor permits a loading of said tendon (16) of approximately 50kN and said second anchor permits a loading of said tendon of approximately 300kN.

16. The rock bolt as claimed in any one of claims 1-15 **characterised in that** said tendon is a cable.

17. The rock bolt as claimed in any one of claims 1-15 **characterised in that** said tendon is solid.

18. A method of tensioning a two-stage rock bolt, said method being **characterised by** the steps of:

    (i) installing said rock bolt (15, 115, 215) in a blind hole drilled in rock subject to squeezing,
    (ii) activating a first anchor (50) carried adjacent the tip of said rock bolt,
    (iii) allowing tension to a first extent to be created in said rock bolt,
    (iv) activating a second anchor(30,40) carried adjacent said first anchor, and
    (v) allowing tension in excess of said first extent to be created in said rock bolt.

19. The method as claimed in claim 18 **characterised in that** said tension to said first extent is created by rock squeezing and deformation of the tendon of said rock bolt.

20. The method as claimed in claim 18 or 19 **characterised in that** said tension beyond said first extent is created by rock squeezing.

21. The method as claimed in claim 18 or 19 **character-**

ised in that said tension beyond said first extent is created by applying a mechanical force to the tendon of said rock bolt.

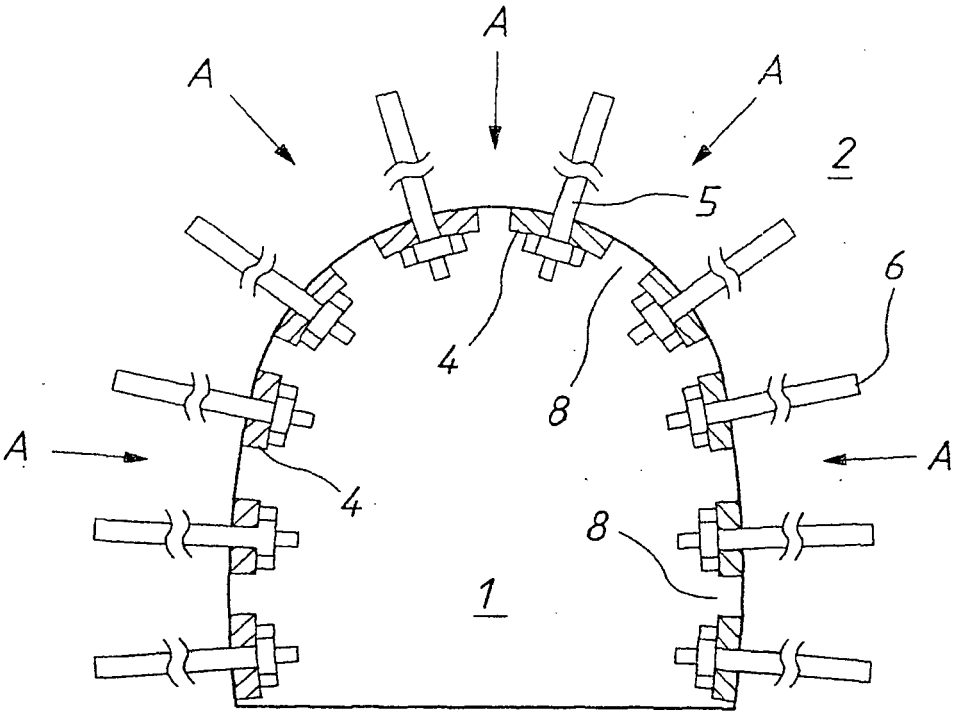

FIG. 1

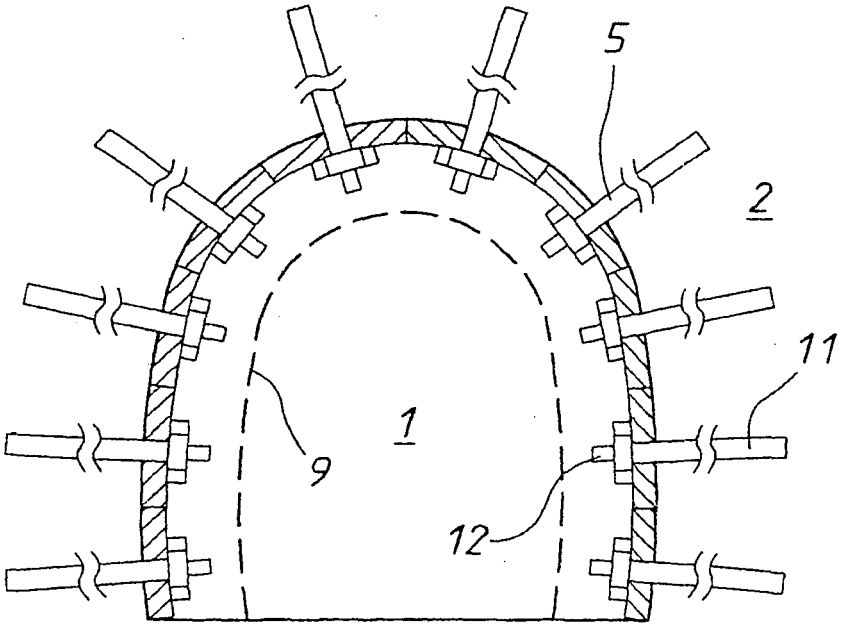

FIG. 2

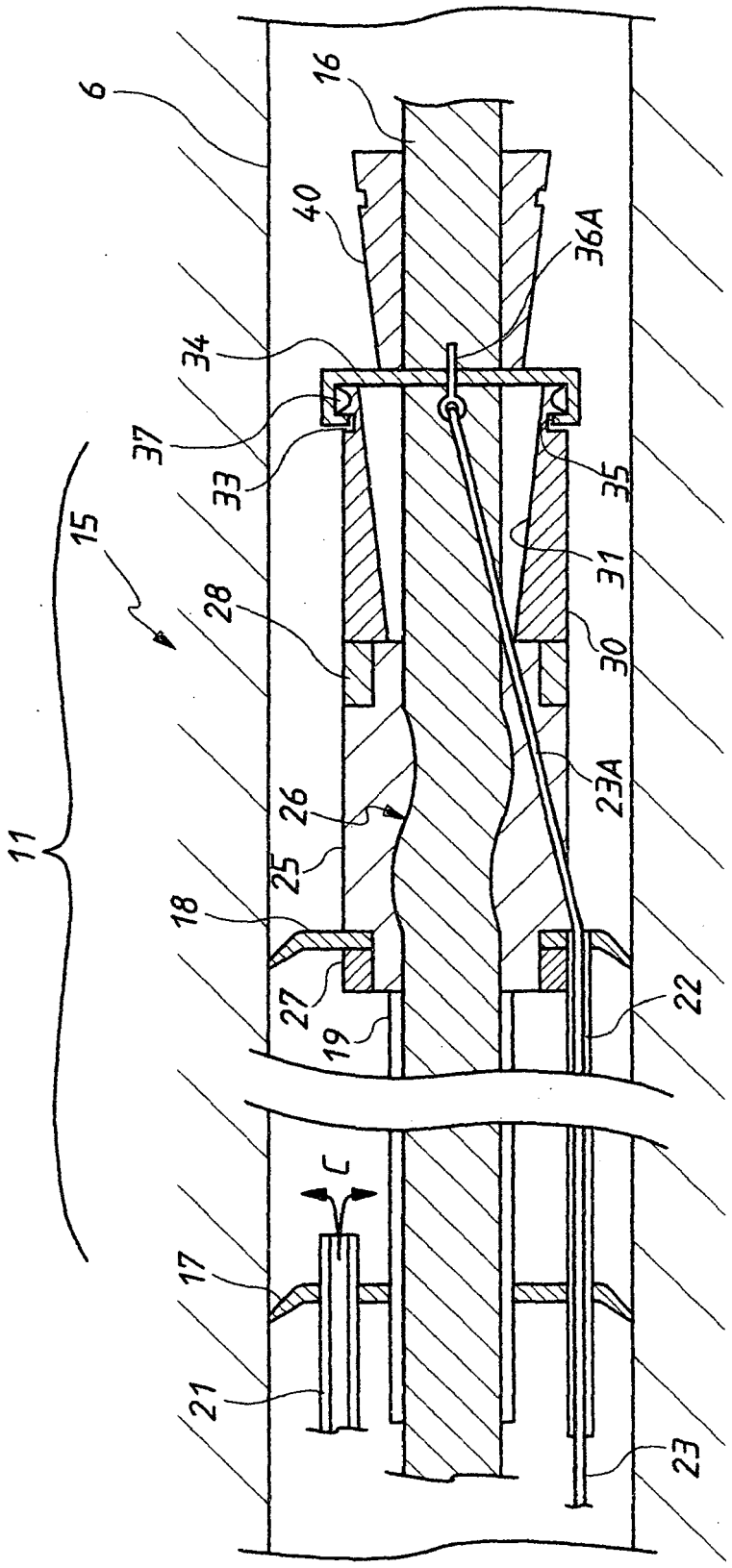

FIG.3

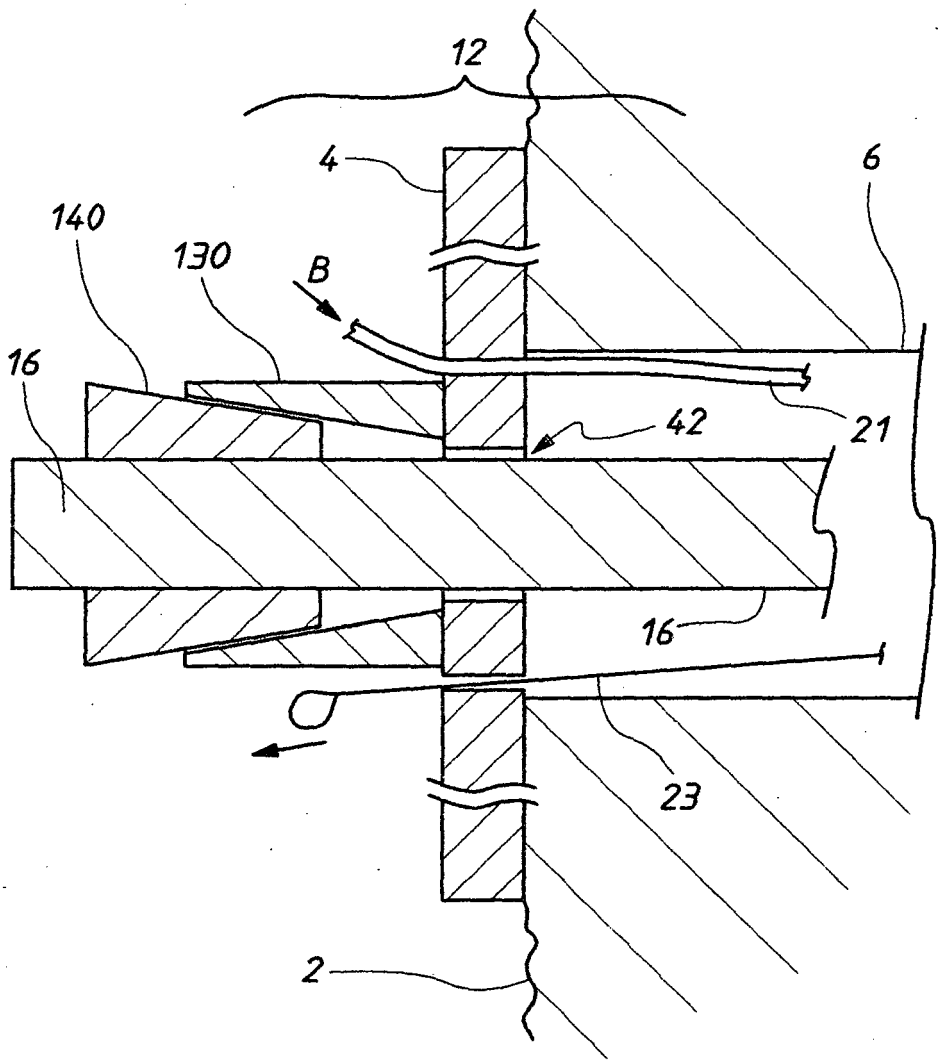

FIG.4

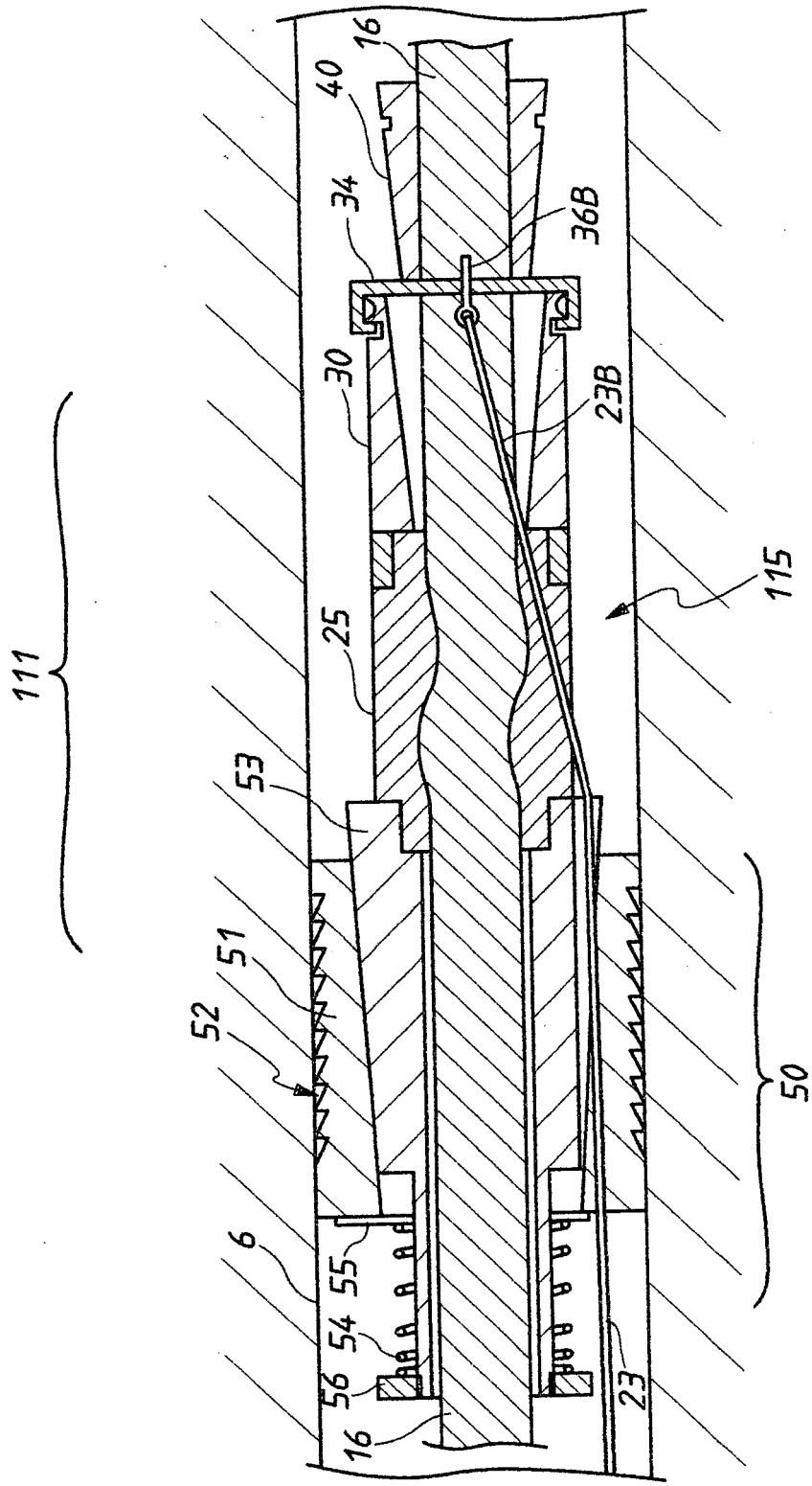

FIG.5

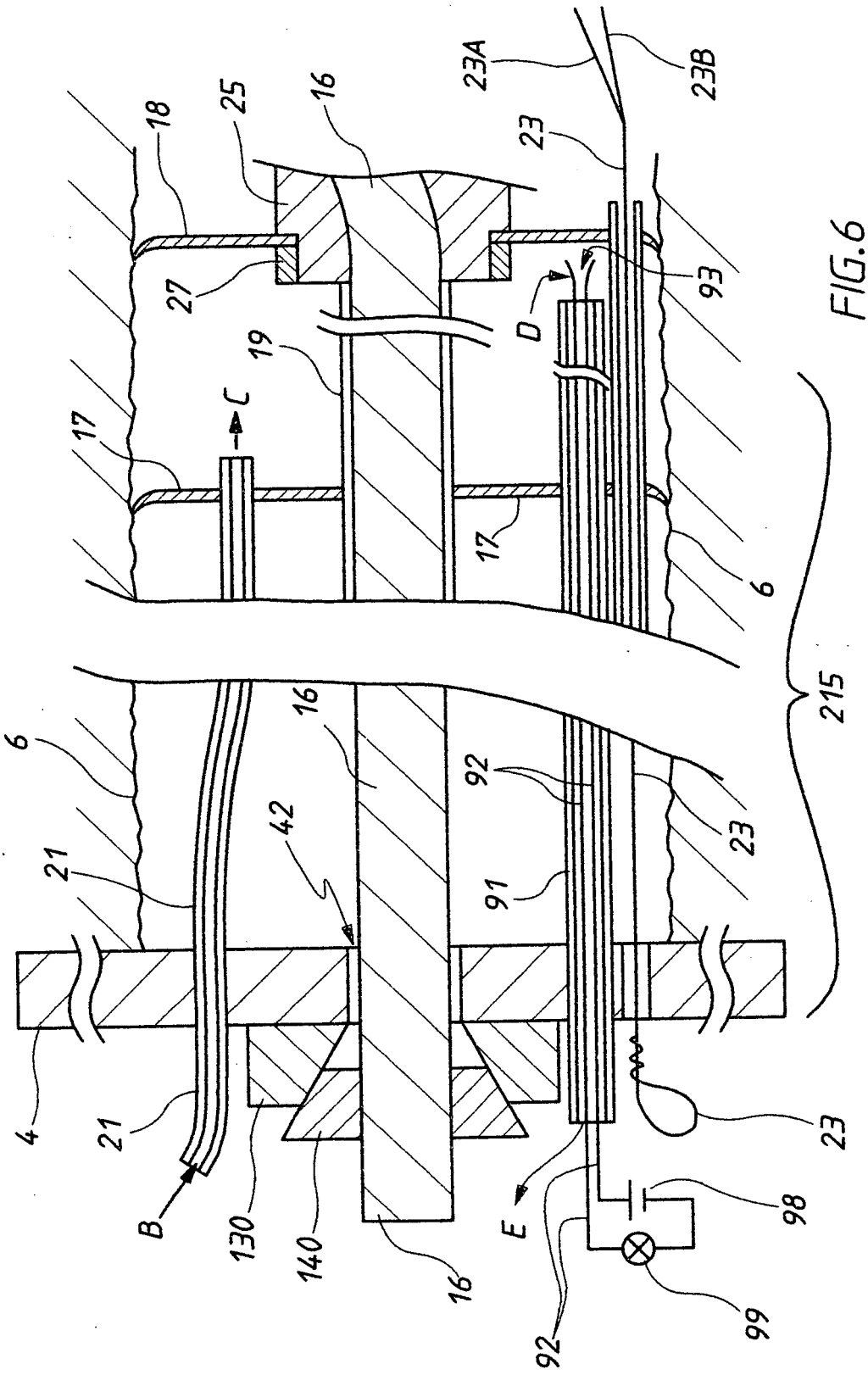
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FIG.6

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EUROPEAN SEARCH REPORT

Application Number
EP 09 01 0175

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 6 270 290 B1 (STANKUS JOHN C [US] ET AL) 7 August 2001 (2001-08-07) * column 7, line 26 - line 60; figures 1-3 * -----	18-21	INV. E21D21/00
A	US 2004/136789 A1 (FERGUSSON JEFFREY ROBERT [AU]) 15 July 2004 (2004-07-15) * paragraph [0035] - paragraph [0037]; figures 4,5,9 * -----	1-18	
A	US 4 611 954 A (CASSIDY BRUCE A [US]) 16 September 1986 (1986-09-16) * column 2, line 3 - line 15 * * column 3, line 61 - column 4, line 55 * * figures 5,6 * -----	1-18	

TECHNICAL FIELDS SEARCHED (IPC)

E21D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	11 September 2009	Strømmen, Henrik

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 09 01 0175

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11-09-2009

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6270290 B1	07-08-2001	NONE	
US 2004136789 A1	15-07-2004	CA 2432835 A1	21-12-2003
		ZA 200304823 A	13-02-2004
US 4611954 A	16-09-1986	NONE	

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 7037046 A **[0015]**