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(54) Tubular rock bolt.

(57) Method of manufacturing a tubular rock bolt comprising the steps of forming an oversize, thick walled tube of substantially circular, annular section, cold drawing the thus formed tube by elongation thereof through dies to a section of reduced outer diameter having a pre-determined wall thickness, cutting a portion of the tube to a predetermined length to form a bolt, providing rock anchor attachment means to one end of the bolt, in use to receive rock anchor means in load transfer relation therewith, and, providing load transfer attachment means at the other end of the bolt for the attachment, in use, of load transfer means in secured load transfer relation with the rock bolt other end.

The tubular rock bolt may incorporate a visual ground movement indicator freely suspended as an unloaded rod element within the rock bolt, extending through and projecting outwardly beyond the rock bolt, to afford visual indication of any axial displacement or elongation of the rock bolt consequent upon loss of anchorage and/or settlement of the strata, or movement of the strata, inter alia, to cause significant extension of the rock bolt.

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TUBULAR ROCK BOLT

This invention is directed to a rock bolt system, and embraces the process of manufacture of the rock bolt, the improved rock bolt thus produced, including a Ground Movement Indicator embodiment and the method of use of the system.

Rock bolting is practiced in many areas of civil engineering ranging from excavating and tunnelling, to the attachment by anchoring back of fabricated structures to rock masses, and to the use of rock bolts in mining.

A wide range of rock bolts are known. In particular, hollow rock bolts are known, such as:

Canadian Patent	999 762	Williams	Nov. 16, 1976
Swiss Patent	631 782	Belloli	Aug. 31, 1982
WO	86/02/25	Velikov	April 10, 1986

In the case of the familiar Williams bolt, this hollow rock bolt is manufactured by the pierce-billet method, being a thick walled structure, and initial cost is up to about ten times that of a plain, mechanical rock bolt. The Williams rock bolt is used for specialty bolting, such as anchoring a machine to a cement floor or to rock.

One of the dominant factors in selecting rock bolts is that of cost. One of the most commonly used underground bolts are mechanical rock bolts, made from solid bar and used in conjunction with an anchoring shell.

In mining, the protection and safety of men and of equipment depends upon the integrity of the strata. Rock bolts having expansible shell anchors set into the remote end of a rock bore are anchored within the extended bores, at the back, the wall or the rock face, and a bearing plate and tensioning nut applied the outer end of the bolt for the purpose of compressing an adjacent strata of the rock so as to enhance its strength and stability and to collectively create a virtual rock beam. Rock bolts also are used for the attachment of mine screening mesh in area covering relation primarily with the rock back, for safety purposes, by containment of loose rock.

At certain locations in a mine, under circumstances where greater security is required, such as permanent passages or ways and in certain types of strata, rock bolts are grouted into their respective bores. Grouting is costly, but enhances the security of the rock bolt, and diminishes movement in the strata by filling the residual bore space or a selected portion, with cement or epoxy cement, thus also providing direct load transfer between the full length of the rock bolt and the adjoined strata, so as to more completely stabilize the strata.

Grouting is not generally carried out in the working area of a normal stope. However, in areas where acid ground water is encountered, so that rapid bolt deterioration can ensue grouting also affords significant corrosion protection to the rock bolts, to prolong their working life.

For a given length of rock bolt at a known unit cost, including hole drilling and bolt setting costs, the apparent cost of purchasing and setting rock bolts to secure a given area can be readily calculated on a theoretical basis, based on the area to be secured, the recommended density of bolting, and hence, the number of bores to be drilled and the number of bolts and shells to be procured and set. However, this does not present a true picture of the situation, nor of the costs involved.

Due to a number of factors such as poor initial installation, loss of anchorage due to slippage movement of the shell, including the local effects of blasting and other ground tremors and displacement, experience over many years in the field has revealed a "loss", in terms of effective load bearing, generally of about 40% of all ungrouted rock bolts, as initially placed.

This situation can be largely remedied by grouting of the installed bolts, with consequently increased costs. However, with the solid mechanical bolts in general use, effective grouting requires to be undertaken at the outset, owing to the need to provide a vent tube along the length of the rock bolt, and extending through the bearing plate at the rock surface, as well as the need to provide a grout injection access through the bearing plate. Thus, retroactive grouting cannot be effectively undertaken, being virtually impossible, on a practical basis while the cost of grouting on a routine basis greatly increases rock bolting costs.

One characteristic of all known prior use rock bolts is a total inability for an observer to ascertain from the stope floor what is taking place in terms of loading and displacements behind the rock face.

The present invention provides a tubular rock bolt that is particularly suited for grouting installations either at the time of installation, or subsequently. The presently disclosed tubular rock bolt construction lends itself to a family of tubular rock bolts most of which have a nominal load rating closely approximating the load ratings of existing mechanical rock bolts.

Furthermore, the subject tubular rock bolt incorporates standard rolled threads to enable use thereof with standard sizes of nuts and more particularly, with substantially standard shells.

In reviewing the contribution afforded by the present invention over the prior art, in terms both of cost and of load bearing capability performance the subject tubular rock bolt most closely approximates in its ultimate load characteristics to the common mechanical rock bolt of solid bar, and accordingly the latter is herein adopted as the valid basis for prior art comparison. The subject tubular rock bolt (TRB) makes possible the adoption of a visible projecting rod-like ground movement indicator (GMI) for installation with the TRB when in a non-grouted condition, to provide a readily seen visual indicator for indicating relative condition changes having taken place between the TRB and its associated strata subsequent to the placement of the TRB.

Such changes in the relative condition of a rock bolt arises as a consequence of a loss in tension in the rock bolt due to non-gripping of the shell within its bore in the rock, or to significant extension of the rock bolt as a consequence of load increase due to strata displacement, which conditions, in the case of prior art rock bolts, were visually undetectable.

These condition changes, taken singly or in combination in the case of the subject TRB tend to cause a relative retraction, inwardly of the GMI visible, projecting outer end towards or into the interior of the TRB.

It has been found that a TRB incorporating the foregoing enumerated advantages can be manufactured at an acceptable increase in cost over that of existing mechanical rock bolts, using fabricated cold drawn mechanical steel tube.

It has further been found that the fabricated tube can be cold drawn, within very close tolerances, to an outside diameter (O.D.) particularly suited to the formation of rolled threads thereon, for use with existing standard nuts and shells presently used in rock bolting.

In carrying out the process, a range of sizes of tubular bolts having a range of wall thicknesses has been achieved, so as to provide bolts having a significant range of load capabilities. In view of established rock bolting practice, wherein 19mm and 15.9mm (3/4" and 5/8") solid mechanical rock bolts are used, the subject tubular rock bolts have a selected tube O.D. to facilitate the rolling of a predetermined standard thread thereon, and a selected wall thickness, as a function of the tensile strength of the fabricated steel tube, to provide an as-installed load bearing capacity equivalent to that of a respective one of the existing equivalent standard mechanical rock bolts. However, it has been found, due to the material selected, and possibly influenced by the tubular form adopted, the subject tubular rock bolt demonstrates great axial resilience and a capacity for extension under cold working, such that effective longitudinal bolt extensions under working tensile loads are readily achieved. The strength and ductility of the TRB are significant in maintaining the compression load in the rock strata in the event of strata disturbance, such as blasting in the vicinity of the installed bolt, thereby providing acceptable performance, in use.

In addition to the foregoing recited characteristics, the subject tubular rock bolt (TRB), by virtue of its larger diameter, presents a larger peripheral "wetted area", to which grouting can bond itself, while the volume of grouting required is significantly diminished.

Also, the required volume of grout, on the basis of a standard bored rock hole, is significantly less for grouting a subject 23.4mm (.920") diameter tubular rock bolt than for grouting a 19mm (3/4") diameter, equivalent strength plain rock bolt; and is much less for grouting a subject tubular rock bolt than for grouting 15.9mm (5/8") diameter plain rock bolt. These material reductions represent significant cost savings to off-set the higher initial tubular rock bolt costs.

In addition to making available significant savings in grouting quantities, the subject TRB no longer requires the provision of an air vent tube, being self venting through its centre, thereby assuring more reliable grouting, by avoidance of the air locks frequently experienced with vent tubes, in the prior art. It also makes it possible to retroactively grout a bolt zone, subsequent to bolt installation.

In the case of 32mm (1 5/8") diameter rock bore, a subject TRB effects a worthwhile savings in grout quantity, compared with the corresponding standard 19mm (3/4") diameter bolt. The present invention thus provides a tubular rock bolt having a Predetermined outside tubular diameter to accept a predetermined rolled thread form. The subject tubular rock bolt has a wall of predetermined thickness, to afford an initial tensile load capacity substantially equal to that of an existing solid section mechanical rock bolt, wherein the subject tubular rock bolt has a comparable extensibility to that of the referenced solid section mechanical rock bolt, and provides a similar ability of maintaining an effective load and reliability, in use..

Manufacture of the subject cold drawn tube bolt is effected by first manufacturing a larger diameter steel tube.

Three processes are available, the tube being fabricated by: electric resistance welding the edges of a roll formed steel strip; by welding the strip edges by airjet or oxyjet heating, or by forming a seamless tube by the pierce billet and cold draw methods.

In the electric resistance welding method a strip of steel is prepared having its width equal to the perimeter of the tube to be formed. The strip is roll formed to the required circular section and the abutting edges welded, using low or high frequency power through electrode wheels, or sliding contacts or by way of an induction coil.

In the other continuous weld strip welding process a steel ribbon is roll formed at high temperature into a tube formation, and the closure edges thereof compressed together, generally under airjet or oxyjet heating, to form a continuous butt welded tube wall, to provide a high quality continuous butt jointed seamed tube, at comparatively low cost.

In the case of the seamless tube, a heated cylindrical billet is subjected to being pierced axially, and subsequently rolled to produce an intermediate thick walled tube.

The tubes thus formed by the respective processes are then cold mandrel-drawn through sizing dies until the required outer diameter (O.D.) and wall thickness are achieved, by cold working.

In order to achieve the subject tube bolt, optimized O.D.'s have been adopted, wherein, working within the constraints of standard rock bolt practice, threads can be rolled thereon for use with standard sized nuts and shells as used with prior art mechanical rock bolts.

Selection of the initial tube forming process is based primarily upon the cost factors involved, which also are influenced by the scale of the operation.

In accordance with the present invention a family of six different tubular rock bolts, TRB 1, 2, 3, 4, 5 and 6 have been evolved to-date and are in course of development:

Product Designation	TRB 1	TRB 2	TRB 3	TRB 4	TRB 5	TRB 6
Dimensions (OD x wall thickness)	17.5mm x 3.8mm (.690"x.150")	17.5mm x 4.3mm (.690"x.170")	23.4mm x 4.95mm (.920"x.195")	23.4mm x 4.95mm (.920"x.195") swaged	23.4mm x 6.6mm (.920"x.260")	23.4mm x 6.6mm (.920"x.260") swaged
Rock bore size	32mm (1-1/4")	32mm (1-1/4")	41mm (1-5/8")	32mm (1-1/4")	41mm (1-5/8")	32mm (1-1/4")
Replaces		15.9mm (5/8")bolt	15.9mm (5/8")bolt	15.9mm (5/8")bolt	19mm (3/4")bolt	19mm (3/4")bolt

Adoption of a 6.6mm (.26") wall thickness with the large 23.4mm (.92") diameter tube provides a high initial load capacity tubular bolt having substantially the same initial load bearing capacity as a 19mm (3/4") solid bar mechanical rock bolt, while accommodating standard rolled threads to receive a standard 25.4mm (1") threaded rock bolt shell, for anchoring purposes.

A further embodiment of the 23.4mm (.920") diameter tubular bolt having a thinner wall, namely of 5mm (0.195") thickness, provides an initial applied load bearing capacity approaching that of a 15.9mm (5/8") diameter solid rock bolt. This tube size also accepts a nominal 25.4mm (1") rolled thread, and exhibits characteristic extensibility under load.

In a further embodiment, it has been established that an end of a tubular rock bolt, such as the 23.4mm (0.92") tube, may be swaged, pointed or otherwise reduced to a smaller O.D., to accept a 19mm (3/4") rolled thread thereon, for use with 19mm (3/4") nuts and 19mm (3/4") standard shells.

It will be understood that the subject invention is not limited to the foregoing family of tubular rock bolts, and that different diameters and wall thicknesses may be adopted to meet the needs of the industry.

A further aspect of the present invention is the incorporation, with a tubular rock bolt, of a low cost, effective Ground Movement Indicator (GMI). Thus, an elongated rod-like GMI having the rod portion thereof freely suspended within the bore of the tubular rock bolt has the remote distal end thereof independently secured within the distal end of the strata bore, and the free proximal end of the rod portion initially extending outwardly from the bolt proximal end, as the visible GMI. Upon initial loading, by tensioning the bolt, in applying a predetermined working load thereto, a viewable portion of the GMI rod can be left projecting at the proximal end. Upon significant subsequent extension of the subject bolt under load, the projecting length of the GMI rod becomes sensibly and substantially proportionately diminished, to provide visual indication of significant change in the condition of the rock bolt relative to its strata, in its position at the rock back, wall or face, with a corresponding indication of a possible significant change having taken place in the related rock strata. Thus, the extent or degree of disappearance of the GMI rods in a given area of a stope could indicate to some extent the probable degree of danger of a rock fall occurring.

Generally, low cost wires or plastic rods are adopted in the role of GMI indicator rods.

In the preferred embodiment the GMI includes an indicator rod having its own anchor located above the shell to optimize its integrity, by enabling the rod to be independently anchored in the strata. The bridge portion of the bail of the shell is recessed to accommodate the distal bolt end of the TRB, and has a central aperture therein through which the GMI rod extends, when installed. The apertured bail bridge serves a valuable purpose in facilitating rupture of the bail in the event that the TRB tube is accidentally screwed upwardly through the shell, so as to rupture the bridge.

Rock bolts are provided in a range of lengths and sizes, and 1.5m (5ft) and 1.8m (6ft) rock bolts are generally considered standard production bolts. The subject GMI rods can be provided as a standard item, having a rod size, diametrically compatible with a range of tube bolt ID's and, being readily shortenable by a simple clipping operation, can be provided in a standard length, such as a 2.7m (9ft) or longer GMI rod, suitable for use with a 1.8m (6ft) or longer bolt, and then shortened, if required to be used with 1.5m (5ft) or shorter bolts. Generally the GMI rods is 0.9m (3ft) or 1.2m (4ft) longer than the tube bolt with which it is used.

When it is recognized that stope roof heights in the range of 3.65m to 6m (12-20ft) are commonplace, it will be understood that to be effective the protruding rod end of a GMI rod must be clearly visible, and a significant relative displacement thereof must be plainly evident, preferably when viewed from stope floor level, by suitable colouration, such as fluorescent paint.

In the preferred GMI embodiment, having the rod portion thereof supported independently of the TRB shell, the distal end of the GMI rod can be threadedly disengaged by unscrewing it from its anchor portion, to permit withdrawal of the GMI rod from an installed TRB, so that grouting of the TRB can then proceed without any impedence.

By way of example of the invention,
certain embodiments of the invention are now described, reference being made to the accompanying drawings, wherein:

Figure 1 is a side view of a section of rock face, showing an embodiment of the subject tubular rock bolt (TRB) installed in tensioned, anchored relation therein;

Figure 2 is a like view, showing a tubular rock bolt embodiment incorporating a ground movement indicator (GMI) therewith;

Figure 3 is an end view, from below, showing a TRB installation having a grouting tube inserted upwardly through the plate washer of the installation;

Figure 4 is a plan view of the GMI rod anchor arrangement; and

Figure 5 is a side view showing a GMI rod and associated shell anchor, together with bail and leaves portion of the shell, and a portion of the tubular rock bolt.

Referring to Figures 1, 2 and 5, the rock bolt assembly 10 comprises a cold drawn tube portion 12 having threaded end portions 14, 16 with rolled threads 18 thereon, and an axial through passage 19. A standard type of shell 20 has leaves portions 22, having serrated gripping surfaces 24 on the exterior thereof. Shell wedge body portion 26 is threadedly mounted at the distal end, on the rolled threads 18 of the tube end 16.

Referring more particularly to Figures 1, 2 and 3, with the bolt assembly 10 inserted into the rock bore 30, the leaves portions 22 of the shell 20 bear against the rock bore, and upon downward retraction of the tube portion 12, the wedge body 26 is drawn downwards axially into expanding relation with the leaves 22 of shell 20, causing them to engage the gripping serrations 24 thereof with the inner surface of rock bore 30.

The bottom tensioning nut 32 bears against the hardened round washer 34 and bearing plate 36, to draw the tube portion 12 axially outwardly in anchor loading relation. Thus, the tube portion 12 is tensioned, while the associated surrounding rock portion is compressed, and thereby stabilized.

In some instances, grout may be injected upwardly through the bore 19 of tube 12, and the GMI 40 is not present.

It is preferred to grout, using an offset passage $35'$ through the bearing plate 36 for upward insertion of a grouting tube 35 therethrough, with displaced air exiting downwardly through the centre passage 19 of tube 12. In such an arrangement, only a short length of grouting tube 35 requires to be inserted.

Referring to Figures 4 and 5, showing particulars of a first GMI embodiment, the threaded upper (distal) end portion 16 of a subject rock bolt 12 is shown.

The elements of the shell 20 are referred to above.

The rod 40 of GMI 54, having a cruciform anchor portion 60 secured to the rod 40 by threads 58 is inserted downwardly into passage 19 of bolt 12. The bail portion 28 of shell 20 has a central aperture 29 therein, for passage of rod 40 therethrough. The surface $40'$ of bail portion 28 is recessed to received the distal end 16 of tubular bolt 12, in the event of misadvertant rotation of bolt 12 causing the bolt 12 to advance axially through wedge body 26 of shell 20. Upon such an occurrence, with the leaves 22 being set in the rock bore 30, the bail portion $40'$ ruptures readily, adjacent to aperture 29, to save dislodgement of the leaves 22.

The GMI rod retaining thread 58, being formed in GMI anchor portion 60, is secured against rotation, and it is possible to unscrew and withdraw the GMI rod portion 40 from out of an installed TRB, so that initial non-grouted installation of a TRB incorporating a GMI can be followed by removal of the GMI rod 40, and carrying out of normal grouting procedures.

The proximal ends of the GMI rods 40 can be clipped off at a standard exposed length, on initial installation, subsequent to the tubular rock bolt 12 being tensioned by application of a predetermined torque on nut 32 to the desired initial value of working load.

In figures 2 and 5, the GMI rod 40 has the inner end portion 42 thereof supported independently above the distal end 16 of tube portion 12 by way of cruciform spring clip 60 which engages the rock bore 30. This has the benefit of optimizing the independence of GMI 54.

Claims

1. The method of manufacturing a tubular rock bolt comprising the steps of forming an oversize, thick walled tube of substantially circular, annular section; cold drawing the thus formed tube by elongation thereof through dies to a section of reduced outer diameter having a pre-determined wall thickness; cutting a portion of the tube to a predetermined length to form a bolt; providing rock anchor attachment means to one end of the bolt, in use to receive rock anchor means in load transfer relation therewith; and, providing load transfer attachment means at the other end of the bolt for the attachment, in use, of load transfer means in secured load transfer relation with the rock bolt other end.

2. The method as set forth in claim 1 wherein said tube forming step comprises forming a steel strip of predetermined gauge and width, into a laterally curved form; abutting the edges of the strip, and joining the abutted edges together.

3. The method as set forth in claim 2 said edges being joined by electric resistance welding.

4. The method as set forth in claim 1, said thick walled tube being formed from a solid, pierced billet.

5. The method as set forth in claim 1, said rock anchor means being secured to said rock bolt by thread means formed on a surface portion of the rock bolt.

6. The method as set forth in claim 1, said load transfer means comprising a predetermined thread form rolled on said rock bolt other end, nut means secured in threaded adjustable relation therewith, and load transfer washer means encompassing said thread form, in thrust transfer relation with said nut means.

7. The method as set forth in claim 1, including the steps of operating on an end portion of said bolt to reduce the outer diameter thereof, and threading said end portion.

8. A hollow, thin walled tubular rock bolt having an axial working load capacity substantially equal to a standard solid mechanical rock bolt of predetermined smaller diameter, said tubular rock bolt comprising a cold drawn steel tube (12) and providing an axial through passage (19), in use to facilitate the optional use of a ground movement indicator rod (40) in cooperation with the rock bolt.

9. The hollow rock bolt as set forth in claim 8, said cold drawn steel tube (12) being fabricated by welding the edges of a formed steel strip.

10. The hollow rock bolt is set forth in claim 8, said cold drawn steel tube (12) being seamless and formed from a pierced billet.

11. The combination as set forth in claim 8, said axial through passage (19) permitting, in use, the passage of air and grout therethrough.

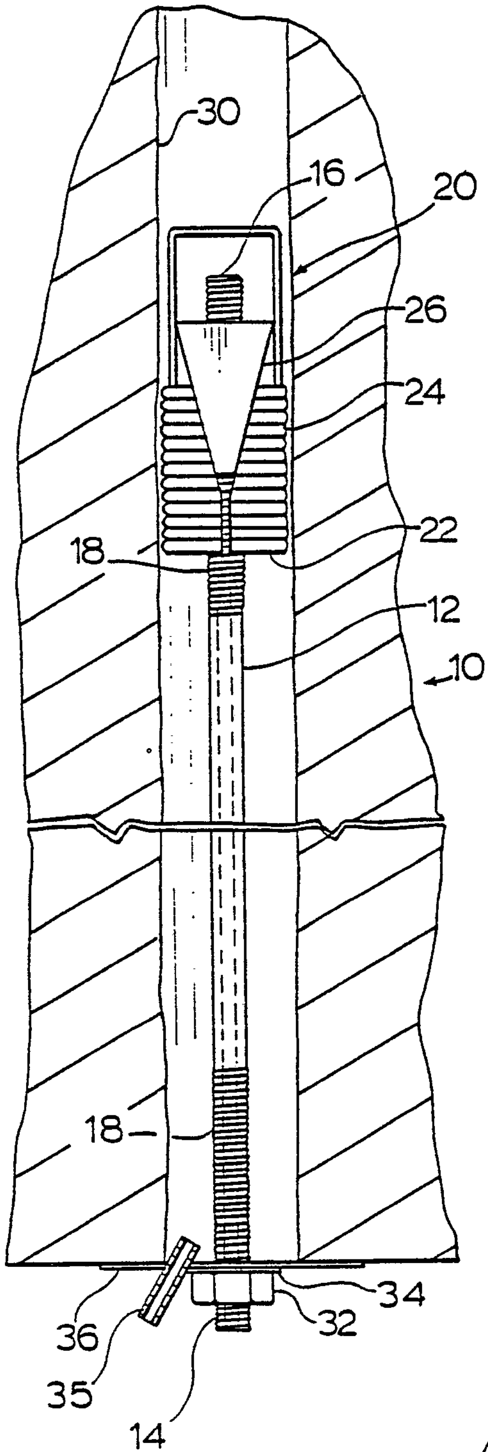

FIG.1.

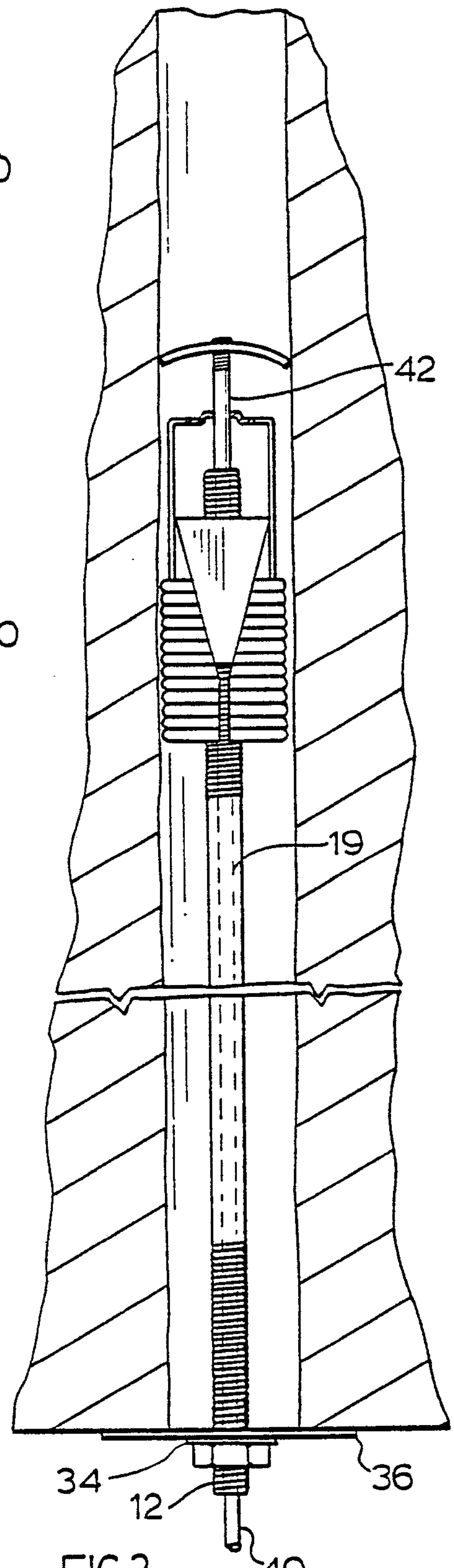

FIG.2.

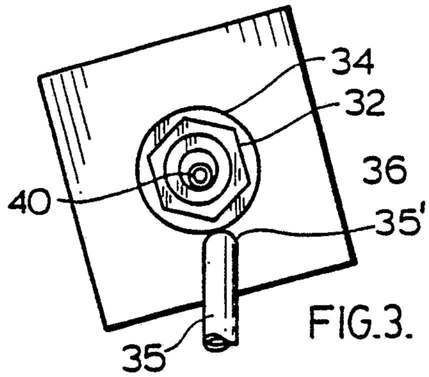

FIG.3.

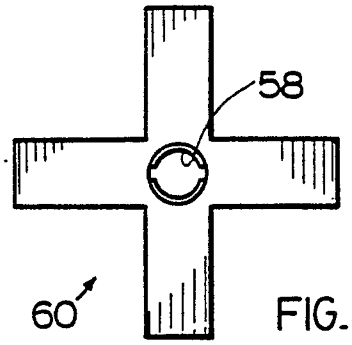

FIG.4.

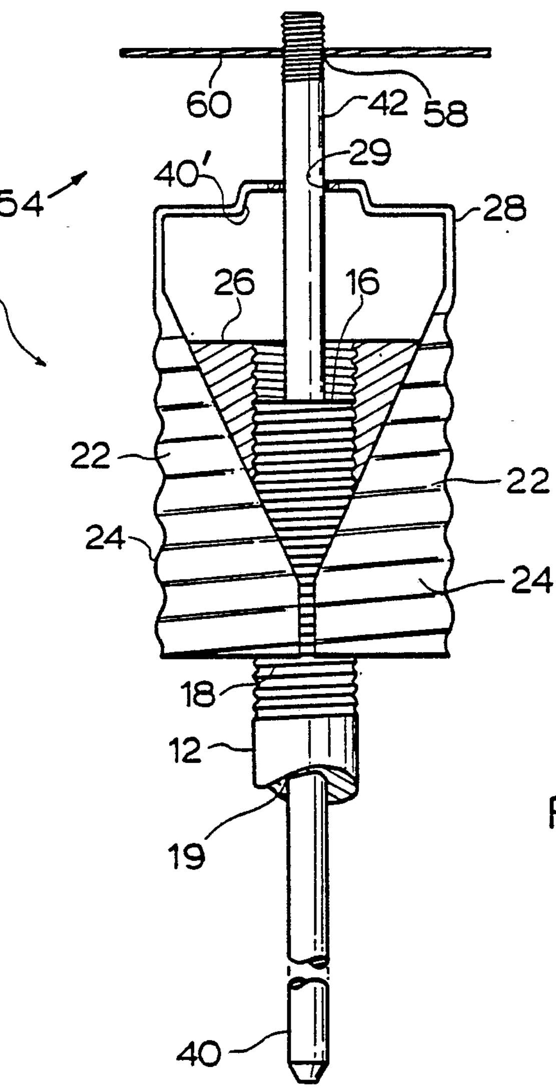

FIG.5.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 31 0689

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	US-A-2 696 137 (THOMAS et al) * Column 2, line 76 - column 3, line 12; figures * ---	1,8	E 21 D 21/00 E 21 D 21/02
A	US-A-2 804 797 (SEELY) * Column 7, lines 19-45; figures * ---	1,8	
A	GB-A-2 199 952 (COAL INDUSTRY) * Abstract; figure 1 * ---	8	
A	GB-A-1 025 729 (WILLIAMS) * Page 2, lines 29-45 * ---	8	
A	GB-A-1 164 007 (WORLEY) -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			E 21 D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29-01-1990	RAMPELMANN J.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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E : earlier patent document, but published on, or after the filing date
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