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(71) Applicant: **Spencer Clark Metal Industries Limited, Greasbrough Street, Rotherham, S60 1RJ (GB)**

(72) Inventor: **Howarth, David Michael, Newbold Fields House Dunston Road, Chesterfield Derbyshire (GB)**

(74) Representative: **Votier, Sidney David et al, CARPMAELS & RANSFORD 43, Bloomsbury Square, London WC1A 2RA (GB)**

(54) **Steel corrosion protected members.**

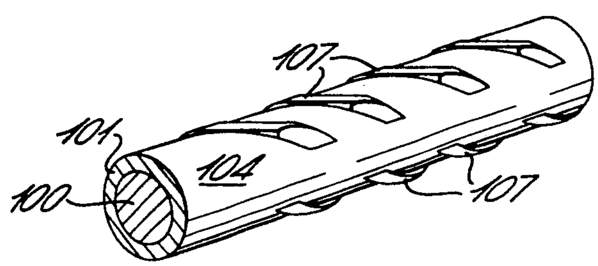
(57) A steel corrosion-protected member such as a reinforcing bar, a rock anchor, tie bar or prestressing tendon comprises a core of carbon or alloy steel with a cladding of stainless steel or copper.

A number of methods of applying the cladding are described including inserting a mild steel rod or bar into a stainless steel tube and hot rolling the rod and tube together to reduce diameter and apply the usual rib pattern.

Alternatively a composite billet may be extruded and then rolled down to size.

The resulting reinforcing bar shows a carbon steel core (100) to which is welded by pressure a stainless steel cladding (101) with ribs (107).

A rock anchor is also described which has a core of carbon or alloy steel clad with stainless steel and includes a threaded end formed on the stainless steel.



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Steel corrosion-protected members

This invention relates to steel corrosion-protected members such as reinforcement members and tension members for ground anchors, tie bars, reinforcing bars, rock anchors and the like.

Reinforcing bars are normally made of mild steel and are used in construction of buildings, bridges, highways, piers, etc., very often in corrosive environments such as salt water environments.

Corrosion of reinforcement is recognised as the principal cause of premature deterioration of concrete structures. The corrosion has been associated with a number of conditions such as use of poor quality concrete (contaminated aggregates), low concrete cover, concrete subjected to chloride in penetration (marine environment, de-icing salts) or chloride set accelerators. The products of corrosion result in a volume change and at best cause rust staining and spalling of the structure and at worst cause structural weakening.

To overcome this problem it is known to use stainless steel reinforcing bars but these are extremely expensive both in terms of material cost and manufacturing cost.

It is one object of this invention to provide a viable and much less expensive alternative to stainless steel reinforcing bars.

In accordance with one aspect of the invention a corrosion-protected steel reinforcement member or tension member comprises a mild steel core with a cladding of stainless steel or other corrosion resistant metal or alloy such as mickel/copper alloy. A preferred stainless steel is type 316 which is nominally 18% chromium, 11% nickel and 2% molybdenum but other grades such as types 304 and 321 may be used. A preferred nickel/copper alloy is Morel 400 (70% nickel, 30% copper).

The core material may be, for example, a mild steel with up to 0.25% carbon but minor additions of Niobium or Vanadium or both may be employed. If creep resistance is a particular requirement the core may include up to 2% of the chromium and molybdenum.

From another aspect the invention comprises a method of manufacturing a corrosion-protected steel reinforcement member or tension member comprising the steps of:-

inserting a mild steel rod or bar into a stainless steel tube; and

hot rolling the rod and tube together so as to weld the tube onto the rod.

Preferably, before the hot rolling is done the stainless steel tube and mild steel rod are joined at one end or both by welding. Alternatively, a clad billet may be made by casting stainless on a mild steel base material.

The hot rolling is preferably carried out at a temperature in the range 700°C to 1250°C and within this a narrower range of say 800°C to 1000°C is preferred depending on the hot workability characteristics of the disimilar metals employed and the final mechanical properties demanded.

Alternatively a two-stage process may be used in which hot rolling is followed by warm working.

The rolling temperature affects final mechanical properties of the clad bar. Conventional hot working of a clad bar would normally result in a finish rolling temperature in excess of 1000°C i.e. the properties would be those levels obtainable from a straight air cool from 1000°C. This order of finish rolling temperature is satisfactory to obtain specified strength properties in rolling solid high yield reinforcing bar. Unfortunately in using an austenitic stainless steel as cladding material the strength in any standard section is diluted i.e. austenitic stainless is of lower strength than high yield bar to say B.S. 4449. There is of course no way of hardening the stainless in ribbed form (smooth bar could be cold drawn) so we resort to warm working. Warm working in the present bar route consists of rolling the billet to a bar conventionally up to the last three passes. At this stage the hot bar is held on the mill floor until the temperature drops to about 750°C. On reaching this lower temperature the bar then goes through the final passes. This results in a significant improvement in the yield strength of the stainless steel and brings it to the same order as high yield reinforcing bar. The warm working process has little or no effect on strength of the carbon steel insert material.

The cut ends of the reinforcing bar may be sealed by applying heat shrinkable plastic caps which may for example be of polythene or any other heat shrinkable plastic.

Alternatively, or in addition, the cut ends of the bar may be sealed by means of a resin or plastic coating composition which may be applied by brushing or dipping the ends into the liquid composition.

Additionally the ends may be sealed by the application of a stainless cap using a resin adhesive or by using a friction welded cap. Alternatively the end seal may be provided by incorporating a short length of stainless insert in the tube prior to hot rolling.

Preferably before manufacturing the reinforcing bar the mild steel rod or bar and the stainless steel tube are very thoroughly cleaned and degreased so as to remove any dirt, grease and oxide film that may be on either. It is particularly important to remove oxide film from the internal surface of the stainless steel tube so as to ensure a good weld contact between that surface and the external surface of the mild steel rod or bar.

An alternative method of manufacture involves casting rather than hot rolling. Either a stainless steel cladding is cast onto a mild steel core or a stainless steel shell is cast first and then filled with mild steel.

The first method employs refractory cores or sleeves in an ingot mould. An ingot mould is made up containing a refractory core which is positioned down the central axis.

The first metal e.g. stainless steel, would then be teemed through the gap between the mould wall and the refractory core. After a relatively short period of initial solidification the refractory core or sleeve is pulled out of the mould and the space left is filled up with a molten second metal e.g. mild steel.

The second method is to replace the refractory core or sleeve in the ingot mould with the first of the two dissimilar metals e.g. suspend a mild steel core in the centre of an ingot mould and cast stainless between the mild steel and the ingot mould wall.

Alternatively a steel reinforcement member or a tension member may be manufactured from a solid extruded composite billet comprising a core of mild steel and an outer layer of stainless steel or copper, the extruded billet being rolled down to the size required for use as a reinforcement member or a tension member.

From another aspect, the invention relates to a ground anchor or tie bar which comprises a bar of high tensile steel which has a coating or cladding of stainless steel throughout its length except for a threaded portion of the bar at at least one end of the bar.

One of the problems in using ground anchors and tie bars is that they are often required to extend for a considerable distance into the ground, rock, or other sub-structure. It is often necessary to join successive lengths of bars together.

In accordance with one aspect of this invention a ground anchor or tie bar comprises a number of lengths of bar each with stainless steel cladding or coating and threaded ends, joined by means of internally threaded jointing members, or turnbuckles, the joints being made corrosion resistant.

By using a jointing member or turnbuckle to connect the two threaded cores of the high tensile steel bars the load may be entirely carried within the core, the coating or cladding playing no part in carrying longitudinal stresses.

The joints may be made corrosion resistant, for instance, by injecting a resin or other corrosion resistant material through a hole in the jointing member or turnbuckle after it has been tightened in place.

To assist in the corrosion protection the exposed threads at the ends of the tie bar may also be coated with stainless steel or chromium or cadmium plated or otherwise protected.

An optional method of providing further corrosion protection is to attach a heat shrunk plastic sleeve to the joint between adjacent bars so that the ends of the heat shrunk sleeves grip and overlap the adjacent ends of the stainless steel clad portions of the bars and create a damp proof and water tight seal. This heat shrink sleeve could also be filled with a resin which might for instance be a foam resin.

Another problem which arises, particularly when using ground anchors, is the protection of the inner end of the ground anchor. In accordance with this invention the inner end is protected either by welding a stainless steel bottom plate onto the bottom end of the bar so that the stainless steel bottom plate is in contact with the adjacent stainless steel cladding or by heat shrinking a plastic sleeve or cover onto the bottom end.

Preferably the top plate of the anchor or tie bar has attached to it a stainless steel tube or sleeve preferably welded to the under side of the top plate, thus protecting the high tensile or carbon steel material of the core of the bar up to or beyond the point of commencement of the stainless steel sleeve.

In the accompanying drawing is diagrammatically illustrated a method in accordance with this invention of manufacturing a mild steel reinforcing bar with a cladding of stainless steel, and a method in accordance with this invention of manufacturing a rock anchor, embodying the present invention.

In the accompanying drawings:-

Fig. 1 shows a typical length of mild steel reinforcing bar or rod;

Fig. 2 shows a stainless steel tube which may be used for cladding the mild steel bar or rod;

Fig. 3 shows the stainless steel tube welded at both ends to the mild steel bar or rod;

Fig. 4 shows diagrammatically the stainless steel tube and mild steel bar or rod being passed through a furnace and then hot rolled;

Fig. 5 shows a finished clad reinforcing bar with the appropriate end caps applied;

Fig. 6 shows a short length of ribbed bar made in accordance with this invention, part of it being shown in section to illustrate the relative thicknesses of stainless steel cladding and mild steel bar;

Fig. 7 is a vertical longitudinal section through a rock anchor embodying the present invention; and

Fig. 8 is a section through an alternative form of the rock anchor.

In manufacturing the clad reinforcing bar a length of mild steel reinforcement bar or rod 100 as illustrated in Fig. 1 is subject to pickling, degreasing and general cleaning so as to remove any layer of grease, dirt or oxide. The bar or rod 100 may be for example, 32mm in diameter and made of 0.25% carbon steel. A convenient length might be anything between 1m and 3m depending on the ultimate application of the reinforcement bar or rod which is being made.

A heavy gauge stainless steel tube 101 (Fig. 2) of wall thickness appropriate to the final envelope thickness and made, typically, of 18% chromium, 8% nickel steel is then degreased and cleaned so as to remove grease, dirt and oxide film. The diameter of the tube 101 is so chosen that it is a simple push fit onto the mild steel bar or rod 100 and of substantially the same length as the bar or rod.

One end 102 or both ends of the stainless steel tube is or are then welded to the mild steel bar or rod as illustrated in Fig. 3. The assembly 104 of mild steel bar or rod 100 and stainless steel tube 101 is then placed in a furnace 103 and heated to a temperature between 750°C and 1250°C and then promptly hot rolled by means of a conventional hot rolling mill 105 with ribbed rolls 106 which will apply the usual reinforcement ribs 107 to the reinforcement bar and at the same time will cause the stainless steel tube 101 to become firmly welded throughout its length to the mild steel bar or rod 100.

The mild steel bar with its cladding of tube is in effect used as a billet and rolled conventionally to form a clad bar in whatever diameter is required with whatever pattern of ribs is required.

When the reinforcing bar is used plastic end caps 108 may be heat shrunk onto the two ends of the bar as illustrated in Fig. 5. Alternatively the ends may be sealed by using resin or other suitable sealing compound as previously described. In some cases for additional security the ends may be sealed with a resin and then plastic end caps heat shrunk on.

Fig. 6 shows a portion of a typical ribbed reinforing bar produced in accordance with the invention.

The stainless steel is chosen for the particular application, but basically what is required is a standard austenitic stainless steel and a conventional mild steel for the rod or bar.

The corrosion resistant reinforcement bar will have similar mechanical properties to that of a conventional mild steel reinforcing bar but will be suitable for use in for example, concrete structures where corrosion resistance is necessary, such as sea walls, bridges harbour construction, chemical plants etc. The reinforcing bar produced in accordance with this invention may also be used to form rock anchors and other strengthening and reinforcing devices which are commonly used in concrete construction and ground stabilisation.

The production of reinforcing bars for building industry use is based on:- a) a core material of 0.25% carbon maximum with possibly minor additions of niobium and vanadium; and (b) an outer cladding of nominally 18% chromium, 8% nickel. This stainless grade may be specified to type 316, 304 or 321. These bars would be used where corrosion resistance is required.

The next stage is to use an envelope with greater corrosion resistance than say type 316 stainless, e.g. Monel 400 (70% Ni 30% Cu).

Another category is where a combination of high strength and corrosion resistance is demanded, where the insert is a high strength alloy steel and the envelope is again type 316. In this case the clad bar may have to be hardened and tempered to obtain the high strength levels.

If a combination of creep resistance and corrosion resistance is required the insert material could be say 2% Cr.Mo creep resistant material and the outside envelope type 316.

In Figure 7 the rock anchor, which might also be adapted for use as a tie bolt, or other form of ground anchor, consists basically of a high tensile steel core 10 on which is a stainless steel sheath 11, the sheath being smooth or ribbed as shown at 12. Both ends of the bar 10 are threaded as shown at 13 and 14 respectively. This is the basic component of the rock anchor. Two such rock anchors or lengths of tie bar may be connected together, as shown in Figure 1, by means of a connecting member, or turnbuckle 15, which is internally threaded with threads of opposite hand. These threads engage corresponding threads of opposite hand formed on the threaded extension 14 of the bar and on a similar threaded extension 14a of an adjacent length of the rock anchor. The turnbuckle 15 has an injector hole 16 by means of which resin or other sealant may be injected into the space 17 between the ends of the threaded portions 14 and 14a so that the sealant will flow into the threads and seal them. The turnbuckle may itself be made of stainless steel.

To assist further in creating a corrosion resistant joint between the two adjacent lengths of rock anchor a heat shrink plastic sleeve 18 is shrunk onto the adjacent ends of the two rock anchor lengths so as to form a complete seal enclosing the turnbuckle and the joint. This heat shrink sleeve may itself be filled with resin or other corrosion resistant material which may for example be a foamed resin or polystyrene so as to provide complete damp and water proof protection.

The lower end of the rock anchor may have a protective stainless steel end plate 19 welded to it, the end plate being welded to the stainless steel cladding at this point so as to ensure a complete seal.

In practice in forming the joint it is possible to machine away the stainless steel covering and expose the core of high tensile steel and then form appropriate threads on the cores. It may also be desirable to coat the exposed threads with stainless steel or to chromium plate the exposed threads

Threads can be formed on top of the cladding by roll threading, without exposing the core.

The shrink sleeve preferably overlaps the stainless steel cladding by not less than three diameters of the bar.

If a rock anchor is required with a resistance to over-turning a plate larger than the diameter of the bar may be attached to the bottom end either by conventional welding or by friction welding.

As a large length 13 of threaded bar is often required at the top end of the anchor and if this is not of stainless material, it requires adequate protection. One way of doing this as shown in Figure 1 is to employ a stainless steel tube 20 welded to a stainless steel top plate 21 and extending down so as to overlap stainless steel cladding of the core. This tube is made long enough to allow for anchor adjustment during pretensioning. Above the end plate 21 is located a stainless steel washer 22 and a load bearing nut 23 which is used for stressing the anchor. A further stainless steel cap nut 24 is applied above this to protect the exposed threads. This cap nut 24 is drilled and tapped with a small hole 25 to permit injection of sealant into the space within the nut and down the thread. The main support plate is also drilled and tapped at 26 to permit the injection of sealant into the space beneath the load carrying nut and into the space formed between the ground anchor/rock bolt and the tubular sleeve 20. Thus the carbon steel material of the core is protected up to or beyond point of commencement of the stainless steel sleeve.

In Figure 2 the lower end of the anchor is sealed by means of a heat shrink sleeve 27. The upper end of the threaded core 13a is plated with chromium or cadmium or other suitable plating. The remaining details of this embodiment are the same as described with reference to Figure 1.

Either of these ground anchors may be used in multiple form i.e. with two, three or more ground anchors passing through a single top plate or end plate. They may be used, for example, in hard rock or concrete and may be grouted into place in the hole in the rock, concrete or other formation in the normal way.

Where cladding is threaded without penetration no additional thread protection is necessary. Associated components, nuts, washers, plates and turnbuckle (23, 21, 26, 25 in Figure 7) remain unchanged.

The manufacture of the basic bars which form the rock anchors may be carried out as described above in relation to reinforcing bars.

Alternatively the bars which form the rock anchors may be formed from solid extruded composite billet i.e. a composite billet of stainless steel and high tensile steel. The extruded billet may be formed so as to give the correct proportions of stainless steel cladding to mild steel core and the extruded billet may be rolled down to the size required for a particular rock anchor or tie bolt.

By using a co-extruded tube consisting of an outer sleeve of stainless steel and an inner sleeve of high tensile steel, advantage is taken of the fact that the materials are extruded together so that metallurgical bond is formed at the interface of the two materials. This avoids problems of mechanical bonding of two different materials which can result in problems during thermal cycling conditions etc. due to interface separation.

The method of making these rock anchors and tie bolts starting with a solid extruded composite billet may equally be applied to the reinforcing bars and other reinforcing members described above in connection with Figs. 1 to 6.

To form an extruded composite billet, a sleeve of each of the component materials is prepared either from a pierced billet or solid bar. The two sleeves are machined to close tolerances and the inner sleeve of high tensile steel fitted to the outer sleeve of stainless steel to form a composite billet. The ends of the sleeves are welded to prevent contamination and the composite billet is heated to extrusion temperature. Glass lubricant is applied to the billet which is then transferred to a 3,000 tonne extrusion press.

A mandrel is pushed through the axis of the composite billet and then reduction and elongation are effected by squeezing the billet through the annular space between a die and a mandrel. The extruded billet may be then cold reduced or hot reduced employing conventional methods. The usual heat treatment and surface finishes may then be used. If desired the finished reduced billet, assuming it is of the size required for making a rock anchor, may then be passed through rolling dies which form conventional. patterns of ribs on the exterior surface of the stainless steel cladding. As seen in the drawings, the stainless steel cladding is a minor proportion of the corss section and obviously does not carry the tensile loads.

Claims:

1. A corrosion-protected steel reinforcement member or a tension member comprises a carbon steel core with a cladding of stainless steel or other corrosion resistent metal or alloy such as a nickel/copper alloy.

2. A member according to Claim 1 and in which the stainless steel is nominally 18% chromium and 8% nickel.

3. A member according to Claim 1 and in which the nickel/copper alloy is 70% nickel, 30% copper.

4. A member according to Claim 1, Claim 2 or Claim 3 and in which the mild steel has up to 0.25% carbon with minor additions of Niobium or Vanadium or both.

5. A member according to any preceding claim and in which the core includes up to 2% of the chromium and molybdenum.

6. A method of manufacturing corrosion-protected steel reinforcement member or a tension member comprising the steps of:-

inserting a carbon steel rod or bar into a stainless steel tube; and

hot rolling the rod and tube together so as to weld the tube onto the rod.

7. A method according to Claim 6 and in which, before the hot rolling is done, the stainless steel tube and mild steel rod are joined at one end or both by welding.

8. A method of making a corrosion protected steel reinforcement member or a tension member according to Claim 1 and in which a clad billet may be made by casting stainless on a mild steel base material.

9. A method according to any of Claims 6 to 8 in which the hot rolling is carried out at a temperature in the range 700°C to 1250°C.

10. A method according to Claim 9 and in which the temperature is in the range of 800°C to 1000°C. the temperature being chosen according to the hot workability

characteristics of the disimilar metals employed and the final mechanical properties demanded.

11. A method according to any of Claims 6 to 10 and in which a two-stage process is used in which hot rolling is followed by warm working.

12. A method according to Claim 11, using an austenitic stainless steel comprising hot rolling the billet to a bar at a temperature between 800°C and 1250°C up to the last three passes, holding the hot bar on the mill floor until the temperature drops to about 750°C, and rolling the final passes at this lower temperature.

13. A member according to any of Claims 1 to 6 and in which cut ends of the member are sealed by applying heat shrinkable plastic caps and/or by means of a resin or plastic coating composition, applied by brushing or dipping the ends into the liquid composition.

14. A member according to any of Claims 1 to 6 and in which the ends are sealed by the application of a stainless cap using a resin adhesive or by using a friction welded cap, or by incorporating a short length of stainless insert in the tube prior to hot rolling.

15. A ground anchor, tie bar, or prestressing tendon which comprises a bar of high tensile steel which has a coating or cladding or stainless steel through its length.

16. A ground anchor, tie bar or prestressing tendon comprises a number of lengths of bar, in accordance with Claim 15, each with stainless steel cladding or coating and threaded ends, joined by means of internally threaded jointing members, or turnbuckles.

17 A ground anchor, tie bar or prestressing tendon in accordance with Claim 16 in which the joints are made by mechanical methods other than threading.

18. A ground anchor or tie bar in accordance with Claim 17 in which the joints are made corrosion-resistant by injecting a resin or other corrosion-resistant material

through a hole in the jointing member or turnbuckle after it has been tightened or fixed in place.

19. A ground anchor, tie bar or prestressing tendon according to Claim 16 and in which, to assist in the corrosion protection the threads at the ends of the tie bar are coated with chromium or cadmuum plating.

20. A ground anchor or tie bar according to any of Claims 15 to 19 in which further corrosion protection is provided by attaching a heat shrunk plastic sleeve to the joint between adjacent bars so that the ends of the heat shrunk sleeves grip and overlap the adjacent ends of the stainless steel clad portions of the bars and create a damp proof and water tight seal.

21. A ground anchor or tie bar according to Claim 20 and in which the heat shrink sleeve is filled with a resin such as a foamed resin.

22. A ground anchor according to any of Claims 15 to 21, the inner end of which is protected either by welding a stainless steel bottom plate onto the bottom end of the bar so that stainless steel bottom plate is in contact with the adjacent stainless steel cladding or by heat shrinking a plastic sleeve or cover on to the bottom end.

23. A ground anchor according to any of Claims 15 to 22 in which the top plate of the anchor or tie bar has attached to its underside a stainless steel tube or sleeve which protects the high tensile or carbon steel material of the core of the bar up to or beyond the point of commencement of the stainless steel sleeve.

24. A method of manufacturing a clad steel corrosion protected reinforcement member or tension member comprising extruding a composite billet having a core of carbon steel and an outer edge layer of stainless steel or copper, the extruded composite billet then being rolled down to the size required for use as a reinforcement member or tension member.

25. A method according to claim 24 and in which to form the extruded composite billet, a sleeve of each of the component materials is prepared either from a pierced billet or solid bar, the two sleeves are machined to close tolerances and the inner sleeve of high tensile steel fitted to the outer sleeve of stainless steel to form a composite billet, the ends of the sleeves are welded to prevent contamination and the composite billet is heated to extrusion temperature, and lubricant is applied to the billet which is then transferred to an extrusion press.

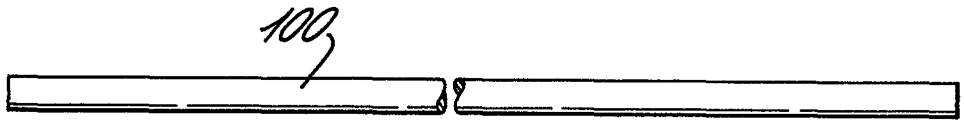


FIG. 1.

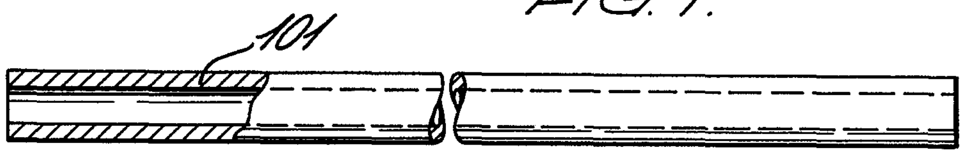


FIG. 2.

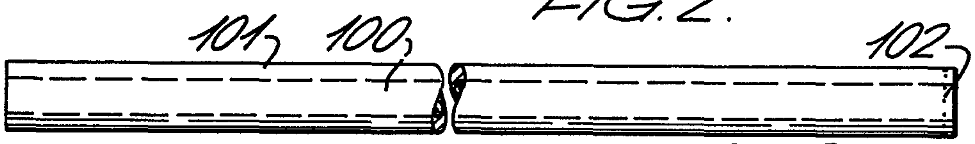


FIG. 3.

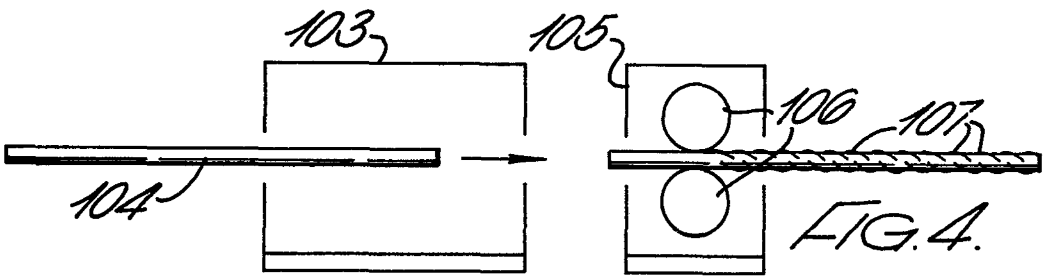


FIG. 4.

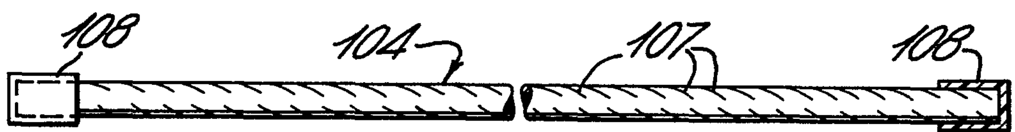
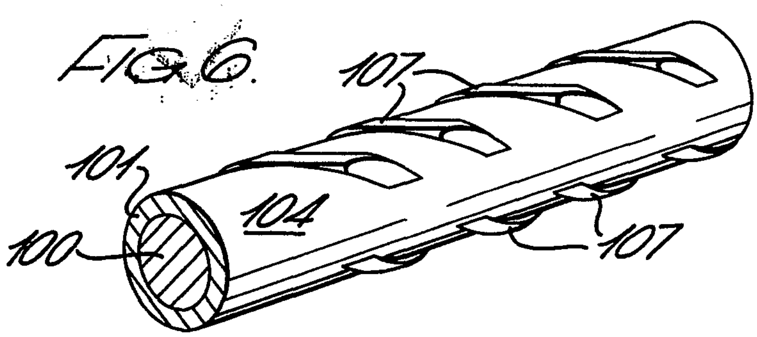


FIG. 5.

FIG. 6.



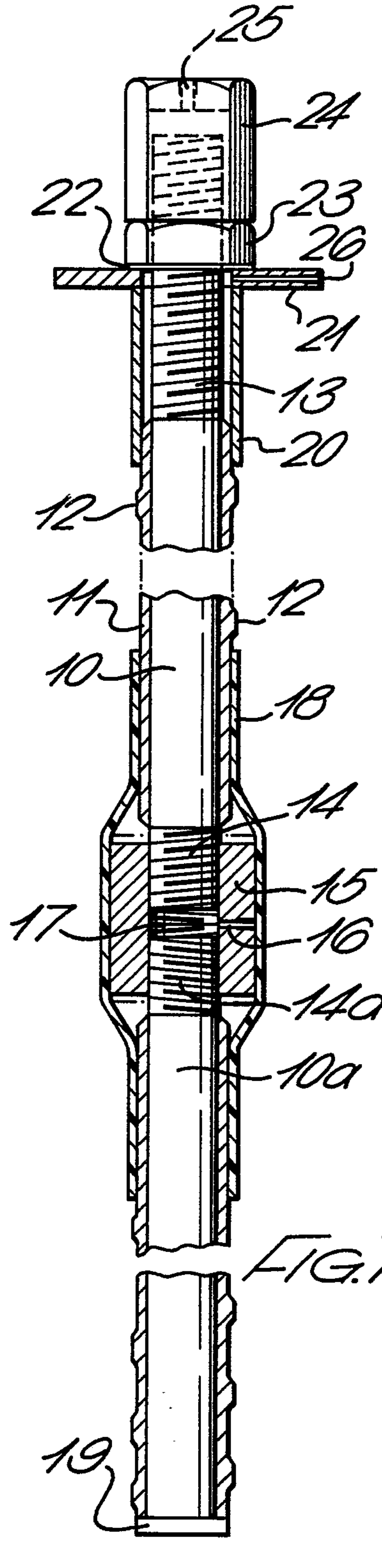

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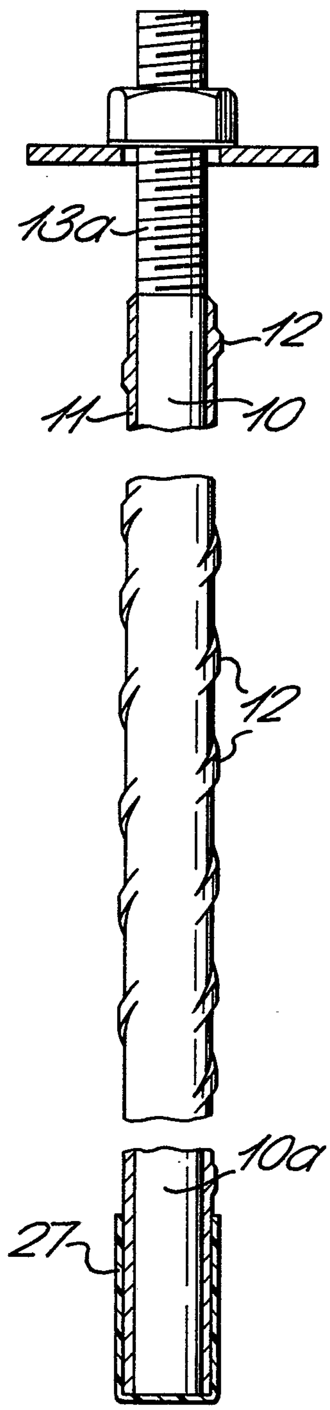
FIG.7.

FIG.8.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European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 82 30 0810.7

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
A	DE - B2 - 2 731 780 (ASAHI KASEI KOGYO K.K.) * whole document * --	
A	US - A - 4 242 150 (H.M. MAXWELL) * page 1 * --	
P,A	DE - A1 2 944 878 (DYCKERHOFF & WIDMANN AG) * claims 1, 5, 7 * ----	1

CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)

E 04 C 5/01
C 21 D 8/08

TECHNICAL FIELDS SEARCHED (Int.Cl. 3)

B 21 D 49/00
C 21 D 8/00
E 02 D 5/00
E 04 C 5/00

CATEGORY OF CITED DOCUMENTS

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&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	28-04-1982	v. WITTKEN

EPO Form 1503.1 06.78