

(12) UK Patent Application (19) GB (11) 2 139 659 A

(43) Application published 14 Nov 1984

(21) Application No 8411121
(22) Date of filing 1 May 1984
(30) Priority data
(31) 495066 (32) 13 May 1983 (33) US

(51) INT CL³
F16G 11/02
(52) Domestic classification
D1T 3B2
(56) Documents cited
None
(58) Field of search
D1T

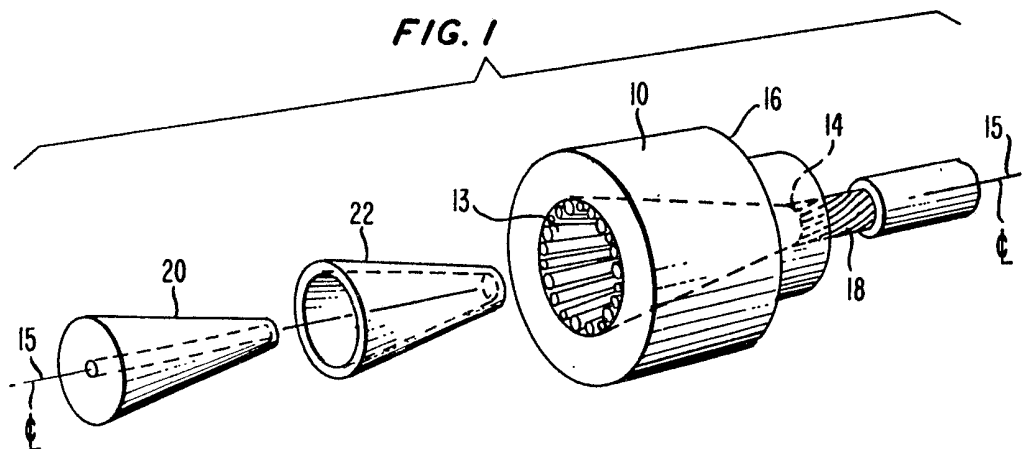
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(54) Stranded cable termination arrangement

(57) A cable termination arrangement includes a tapered socket body (10) and a mating plug (20) covered with a sleeve of malleable material (22). Cable strands are inserted and spread out inside of the socket. The plug and sleeve are pushed into the socket for forcing the strands into the sleeve. When a tensile force is applied to the cable, slippage between the cable and the socket is zero.



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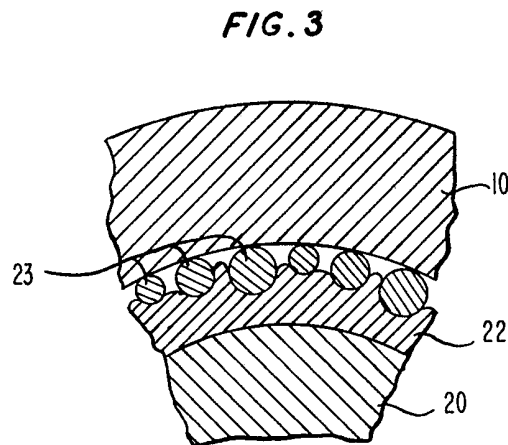
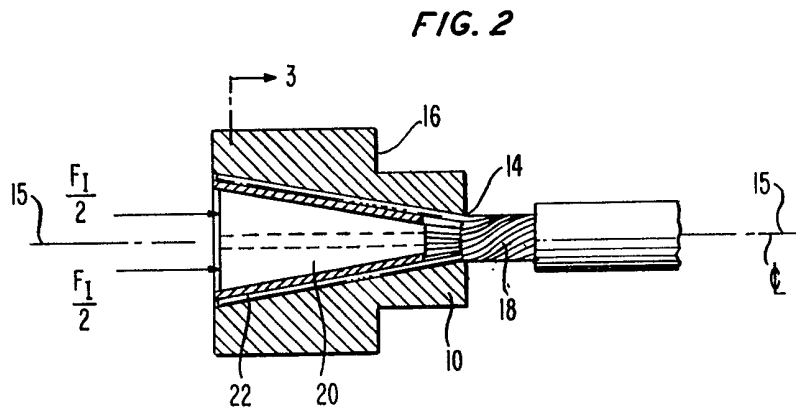
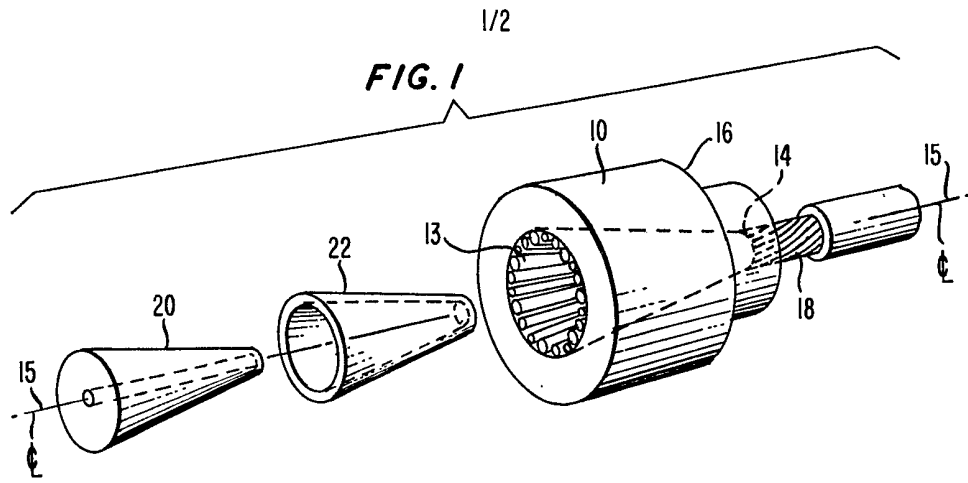


FIG. 4

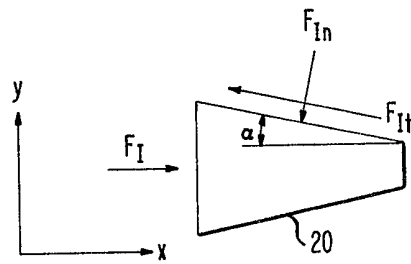


FIG. 5

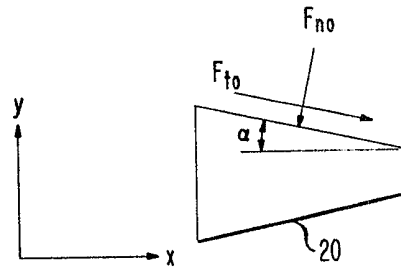
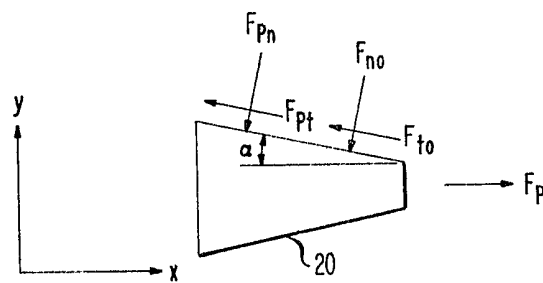


FIG. 6



SPECIFICATION

Stranded cable termination arrangement

- 5 *Background of the Invention* 5
 This invention relates to a stranded cable termination arrangement e.g. for high strength applications.
 In the prior art, stranded cables with high tensile strength have been terminated in assemblies which use a clamp or a high strength epoxy to hold the cable end in the termination. Although
 10 these prior terminations have been used in various applications for years, there are associated problems. 10
 Problems with the clamped arrangement include slippage between the cable end and the termination hardware when high tensile forces are applied.
 Problems with the epoxy arrangement include the just mentioned slippage and a necessity to
 15 provide a path through the termination structure for injecting the epoxy, for bleeding out any trapped air and for curing the epoxy to gain maximum strength. 15
- Summary of the Invention*
 These problems are solved by a cable termination arrangement including a tapered socket
 20 body and a mating plug covered with a sleeve of malleable material. Cable strands are inserted into and are spread out inside of the socket. The plug and sleeve are pushed into the socket, thereby forcing the sleeve around the strands. When a tensile force is applied to the cable, slippage between the cable and the socket body is zero. 20
- 25 *Brief Description of the Drawing* 25
 An embodiment of the invention, given by way of example, will now be described with reference to the appended drawings, wherein:
Figure 1 is an exploded isometric view of a stranded cable termination arrangement embodying the invention;
 30 *Figure 2* is a fragmentary cross-sectional view of a cable termination arrangement in place on an end of a cable; 30
Figure 3 is a partial cross-sectional end view of the cable termination shown in Fig. 2; and
Figures 4, 5 and 6 are force diagrams relating to a cable termination embodying the invention.
 35 35
- Detailed Description
 Referring now to Fig. 1, a socket body 10 for a high strength cable termination is fabricated out of a high strength, material such as beryllium copper or steel. Other high strength materials may be suitable for some high strength cable terminations. Other lower strength materials may
 40 be useful in low strength cable terminations. 40
 In Fig. 1, the socket body 10 has a frustum shaped hollow cavity 12 opening out to a relatively wide base 13 of the frustum. The cavity is shaped like a truncated cone, which is cut off at the top to provide a narrow top opening 14. The sides of the cone intersect at an angle α with a center axis 15 which intersects the planes of the base and the openings at their center
 45 points. 45
 The outside of the socket body 10 is shown as a cylindrical shape having a flange, or collar, area 16. This flange area 16 is designed to provide a surface for supporting a force greater than the maximum tensile force F_M which can be applied to the cable being terminated.
 A stranded cable 18 is shown with an end inserted through the top opening 14 of the socket
 50 body. The several strands of the cable are flared out inside of the socket body and are spread out so that the strands are laid side-by-side near the top opening and slightly separated at the base opening 13 of the socket. These strands are laid down on the surface of the socket without crossovers and in a single layer at the base opening. The cable 18 is designed to withstand the maximum tensile load F_M without failure. 50
 55 Once the cable strands are flared out inside of the socket body 10, a plug 20 covered with a sleeve 22, is inserted over the strands inside of the socket body. 55
 The plug 20 and the sleeve 22 are shown as conically shaped frustums designed to fit snugly into the socket. Their sides intersect the center axis at the angle α .
 A high strength material such as steel or beryllium copper is used for fabricating the conically
 60 shaped plug 20. A center axis hole in the plug 20 allows a center member or a core of the cable to be passed through the termination hardware without interfering with the strength of the termination. 60
 Sleeve 22 is fabricated out of a malleable material such as annealed copper which is relatively soft and workable, or pliable, before the termination arrangement is put together. A
 65 metal, such as aluminum, having an internal lubricant is not useable. 65

When the sleeve 22 is positioned to cover the plug 20, as shown in Fig. 1, at the base opening of the socket body 10 while the strands are flared out therein, the termination arrangement is ready for insertion into the socket.

As shown in Fig. 2, this combination of the plug 20 and the sleeve 22 is pressed into the socket body 10 with an insertion force F_i that is higher than the expected tensile force to be applied to the cable. Such expected tensile force may be near the maximum tensile force F_M for the cable design. 5

By so pressing the plug 20 and sleeve 22 into the socket body, the cable strands are trapped between the wall of the socket body and the sleeve. Resulting compressive and shear forces cause the copper of the sleeve 22 to cold flow around the separate strands of the cable. The copper partially fills the gaps, or interstices, between the strands of the cable. As a result of the cold working of the copper, it is work-hardened to a higher shear strength that increases the strength of the resulting termination. 10

As shown in Fig. 3, the cold flow of the copper sleeve increases the contact between the surface of the copper sleeve 22 and the surfaces of the strands 23. Instead of a line contact with each strand 23, as occurred before the forced insertion step, there now is an area of contact between the sleeve 22 and each strand 23 of the cable. Friction forces along each of these areas increase the strength of the termination arrangement. 15

It is noted that the separate strands 23 may have the same diameter as one another or may have different diameters from one another. The mentioned increase of strength in the resulting termination arrangement occurs regardless of whether the strand diameters are uniform or of various sizes. 20

As shown in Fig. 4, the injection force F_i is broken into two force components. One force component is the normal component F_{in} which is perpendicular to the surface of the plug 20 and creates two friction forces. One of these friction forces is between the copper sleeve 22 and the strands 23 of Fig. 1. The other friction force is between the strands 23 and the socket 10. The other force component in Fig. 4 is the tangent component F_{it} which is parallel to the surface of the plug 20. Balancing forces in the x-direction: 25

$$30 \quad F_i = F_{in} \sin \alpha + F_{it} + F_{it} \cos \alpha. \quad (1) \quad 30$$

Using known friction formulas,

$$35 \quad F_{it} = \alpha F_{in}. \quad (2) \quad 35$$

By substituting equation (2) into equation (1),
 $F_i = F_{in} \sin \alpha + \mu F_{in} \cos \alpha = F_{in} (\sin \alpha + \mu \cos \alpha)$.

$$40 \quad \text{Then } F_{in} = \frac{F_i}{(\sin \alpha + \mu \cos \alpha)}. \quad (3) \quad 40$$

For small values of α , $\cos \alpha \approx 1$, $\sin \alpha \ll \cos \alpha$, and

$$45 \quad F_{in} \approx \frac{F_i}{\mu}. \quad (4) \quad 45$$

Because $\mu < 1$, a small angle α produces a large injection normal component F_{in} .

Referring now to Fig. 5, there is shown a force diagram with the injection force F_i removed. Without the injection force, the normal force component F_{no} is slightly decreased from the value of the force component F_{in} , but it remains significant due to energy stored in the system. 50

$$55 \quad \text{Then } F_{no} \approx F_{in}, \text{ and} \quad (5) \quad 55$$

the tangential component F_{to} reverses direction and decreases in magnitude.

Balancing forces in the x-direction:

$$60 \quad F_{no} \sin \alpha = F_{to} \cos \alpha, \text{ or } F_{to} = F_{no} \tan \alpha. \quad (6) \quad 60$$

$$\text{In the limit } F_{to} = \mu F_{no}. \quad (7)$$

The required condition for the plug to stay in the socket body is

$$65 \quad F_{no} \sin \alpha \leq F_{to} \cos \alpha. \quad (8) \quad 65$$

Using equation (7) in equation (8), in the limit:

$$F_{no} \sin \alpha \leq F_{no} \cos \alpha, \text{ or } \sin \alpha \leq \mu \cos \alpha. \quad (9)$$

5

Thus the acceptable range of values for the angle α is limited by an expression

$$\tan \alpha \leq \mu. \quad (10)$$

10 Referring now to Fig. 6, there is shown a force diagram with tension applied to the cable. The existing tangential force from the no external load condition opposes movement resulting from the tensile force. The cable is under tension and the strands are trying to pull out of the termination. As long as the tensile force F_p is less than the friction force between the strands 23 and the socket 10 of Fig. 1 plus the friction force between the stands 23 and the plug-copper sleeve combination, the strands will not move. As the pulling force increases, the strands try to move out of the termination, but at this stage the strands 23 are pulling the plug 20 and sleeve 22 combination with them due to friction. In effect the plug is jammed more solidly into the socket 10, producing additional surface loads F_{pn} and F_{pt} . The harder the strands 23 pull on the plug and sleeve combination, the higher F_{pn} becomes. Therefore, the friction force increases with cable tension and prevents the steel wires from pulling out. This system is thus self-energizing. Balancing forces in the x-direction:

$$F_p = F_{no} \sin \alpha + F_{to} \cos \alpha + F_{pn} \sin \alpha + F_{pt} \cos \alpha. \quad (11)$$

25 The total normal force on the plug = $F_{no} + F_{pn}$ and the total tangent force on the plug = $F_{to} + F_{pt}$. 25

$$\text{In the limit, } F_{to} = \mu F_{no}, \text{ and} \quad (12)$$

30 $F_{pt} = \mu F_{pn}$. (13) 30

Also in the limit,

$$F_p = F_{no} \sin \alpha + \mu F_{no} \cos \alpha + F_{pn} \sin \alpha + \mu F_{pn} \cos \alpha, \text{ or } F_p = (F_{no} + F_{pn})(\mu \cos \alpha + \sin \alpha). \quad (14)$$

35 For small angles, $F_p \approx \mu(F_{no} + F_{pn})$. 35

Using equations (4) and (5),

40 $F_{no} \approx \frac{F_i}{\mu}$, and (15) 40

$$F_p \approx F_i + \mu F_{pn}. \quad (16)$$

45 Thus it is shown that the pulling force F_p , which will pull the strands 23 out of the socket 10, is greater than the injection force F_i . 45

Although the plug 20 and the sleeve 22 have been shown and described as having surfaces inclined at the angle α from the center axis, that is an exemplary angle for simplifying computations. Plugs and sleeves, having surfaces inclined at angles different from the angle α , also are useful in high strength cable terminations.

50 From the foregoing mathematical analysis, it is clear that for some purposes the termination arrangement is strong enough without the sleeve. 50

From the foregoing mathematical analysis, it is clear that for some purposes the termination arrangement is strong enough without the sleeve.

CLAIMS

55 1. A stranded cable termination 55

CHARACTERIZED BY

a socket (10) having a frustum shaped interior tapering from a base opening (13) to a top opening (16);

a group of cable strands (18) inserted into the top opening (16) with individual strands spread out forming a single layer of strands at the base opening, (13);

a malleable sleeve (22) shaped to fit inside of the socket (10); and

means (20) for reforming the sleeve (22) to produce areas of contact between the sleeve and the strands (18) within the interior of the socket (10).

2. A stranded cable termination, in accordance with claim 1,

65 CHARACTERIZED IN THAT 65

the socket (10) and the reforming means (20) each comprise a high strength material; and the sleeve (22) is fabricated out of annealed copper.

3. A stranded cable termination, in accordance with claim 1,
CHARACTERIZED IN THAT

5 the socket and the reforming means, each comprises a high strength material; and 5
the sleeve (22) is fabricated of a metal without an internal lubricant.

4. A stranded cable termination, in accordance with claim 1,
CHARACTERIZED IN THAT

10 the group of strands (18) is comprised of individual strands (23) having different diameters 10
from one another.

5. A stranded cable termination, in accordance with claim 1,
CHARACTERIZED IN THAT

the reforming means (20) is forced into the sleeve (22) and socket (10) by a force exceeding a maximum tensile force determined by the design of the stranded cable (18).

15 6. A stranded cable termination, in accordance with claim 1, 15
CHARACTERIZED IN THAT

the reforming means (20) work-hardens the sleeve for increasing the shear strength of the sleeve.

7. A stranded cable termination, in accordance with claim 1,

20 CHARACTERIZED IN THAT 20

the reforming means comprises a conically shaped plug (20) of high strength material such as steel or beryllium copper.