

US00RE47035E

(19) **United States**  
(12) **Reissued Patent**  
**Ericson et al.**

(10) **Patent Number: US RE47,035 E**  
(45) **Date of Reissued Patent: Sep. 11, 2018**

(54) **WEDGE CLAMP TYPE TERMINATION FOR ELEVATOR TENSION MEMBER**

(56) **References Cited**

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(21) Appl. No.: **10/805,490**

(22) Filed: **Mar. 19, 2004**

**Related U.S. Patent Documents**

Reissue of:

(64) Patent No.: **6,357,085**  
Issued: **Mar. 19, 2002**  
Appl. No.: **09/845,866**  
Filed: **Apr. 30, 2001**

U.S. Applications:

(62) Division of application No. 09/224,045, filed on Dec. 31, 1998, now Pat. No. 6,256,841.

(51) **Int. Cl.**  
**F16G 11/04** (2006.01)  
**B66B 7/08** (2006.01)  
**B66B 7/06** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **B66B 7/085** (2013.01); **F16G 11/04** (2013.01); **Y10T 24/3969** (2015.01)

(58) **Field of Classification Search**  
CPC ..... B66B 7/085; F16G 11/04; Y10T 24/3969  
USPC .... 24/136 R, 115 M, 136 L, 136 K, 25, 194, 24/196, 171; 187/411, 412, 349, 414, 187/251, 254, 266, 264, 404, 350, 373; 188/188; 403/211, 314, 374.1; 29/505, 29/525.01, 252.08, 525.08

See application file for complete search history.

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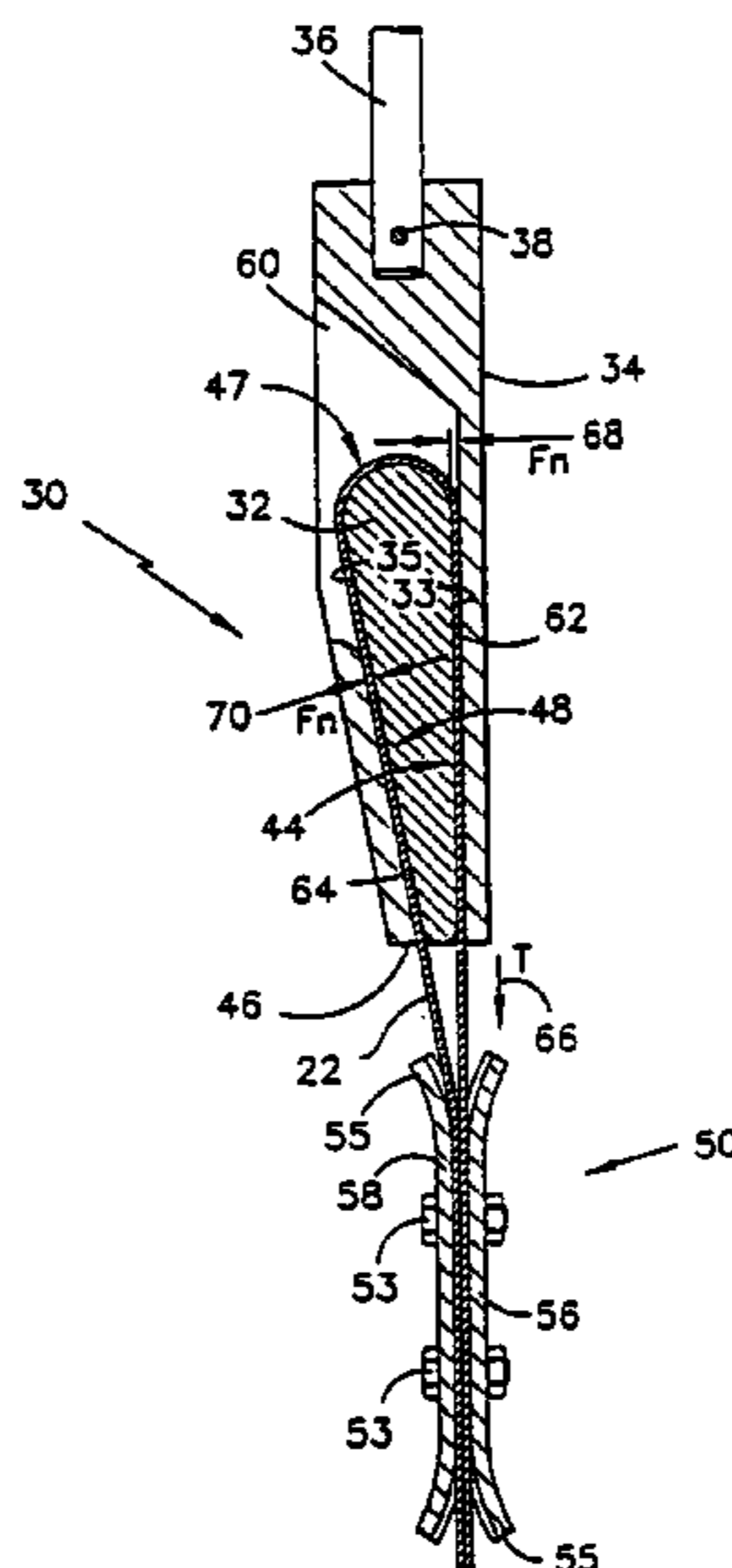
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(57) **ABSTRACT**

A tension member termination device optimized for terminating flat tension members having compressible outer coatings, the device including a wedge and a socket each having cooperating surfaces positioned at a predetermined angle for clamping the tension member therebetween. The angle reliably secures the tension member while avoiding deleterious pressure and stress upon the tension member. The invention also provides a safety clamp for optional use with the tension member termination device.

**7 Claims, 4 Drawing Sheets**



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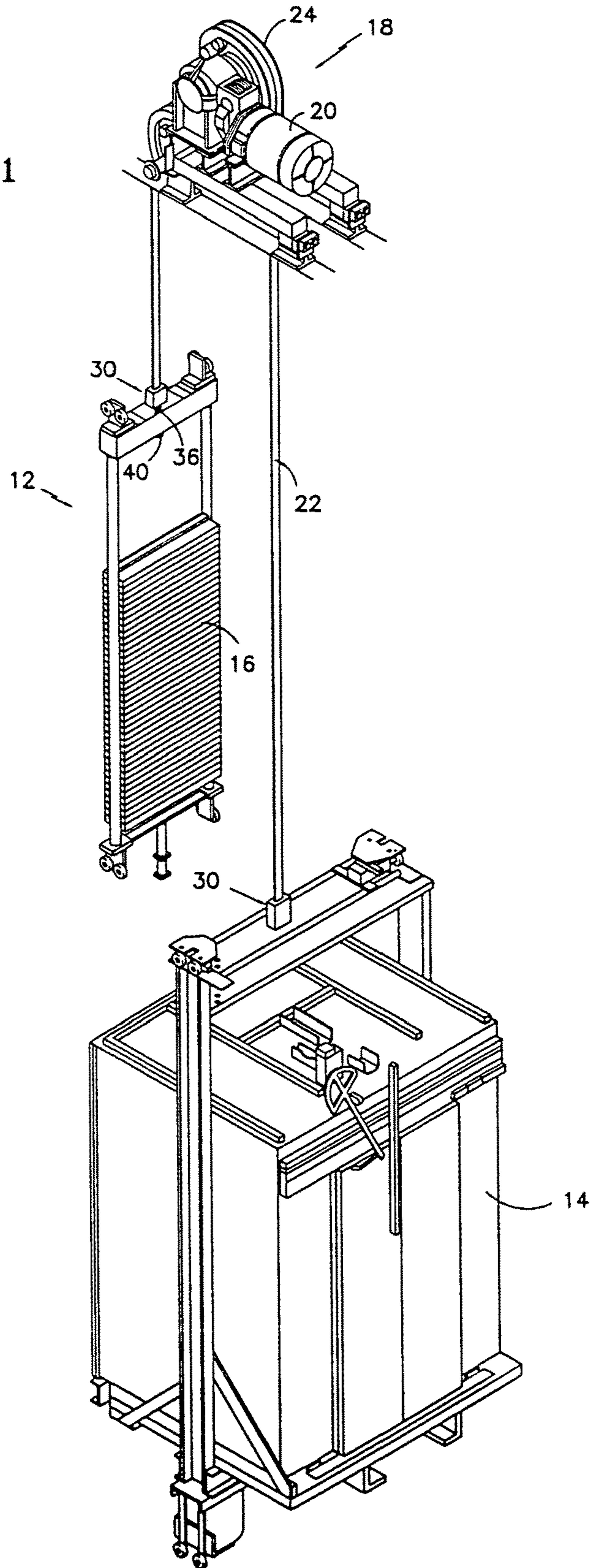
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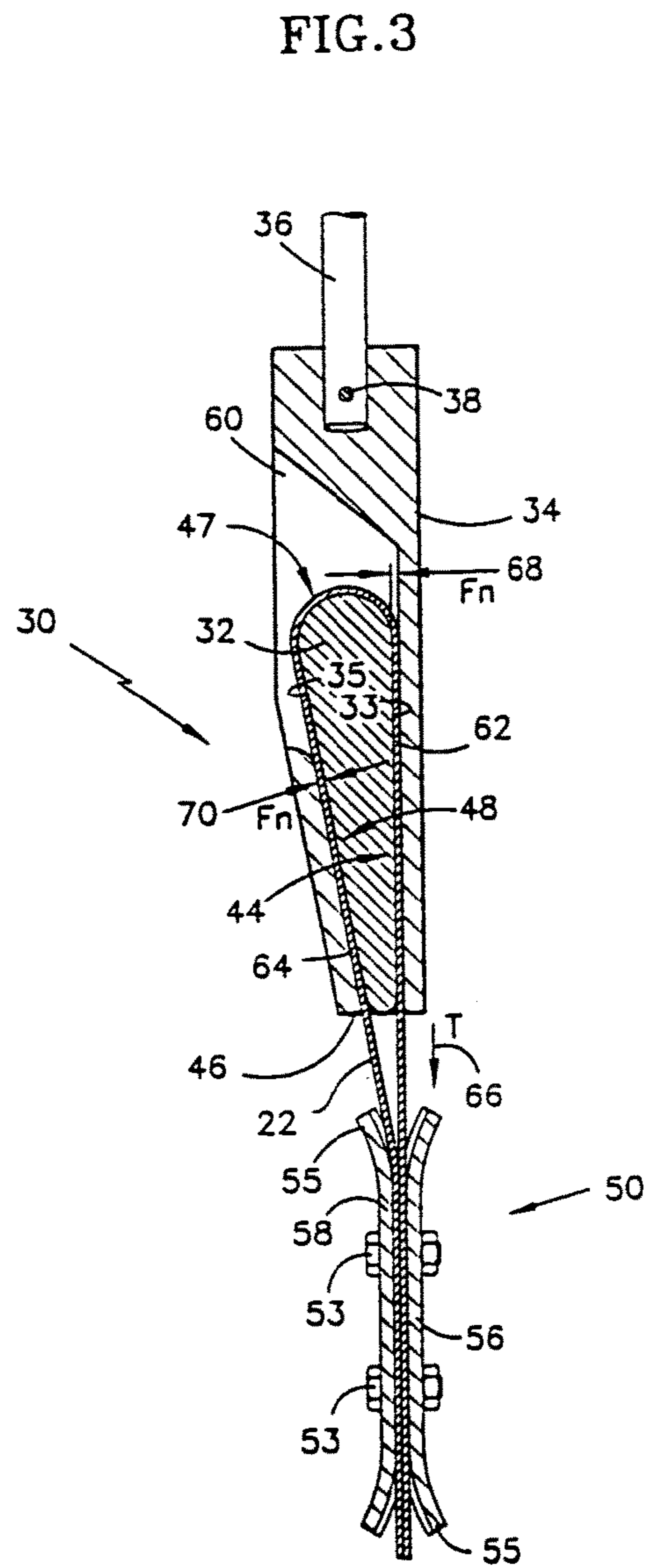
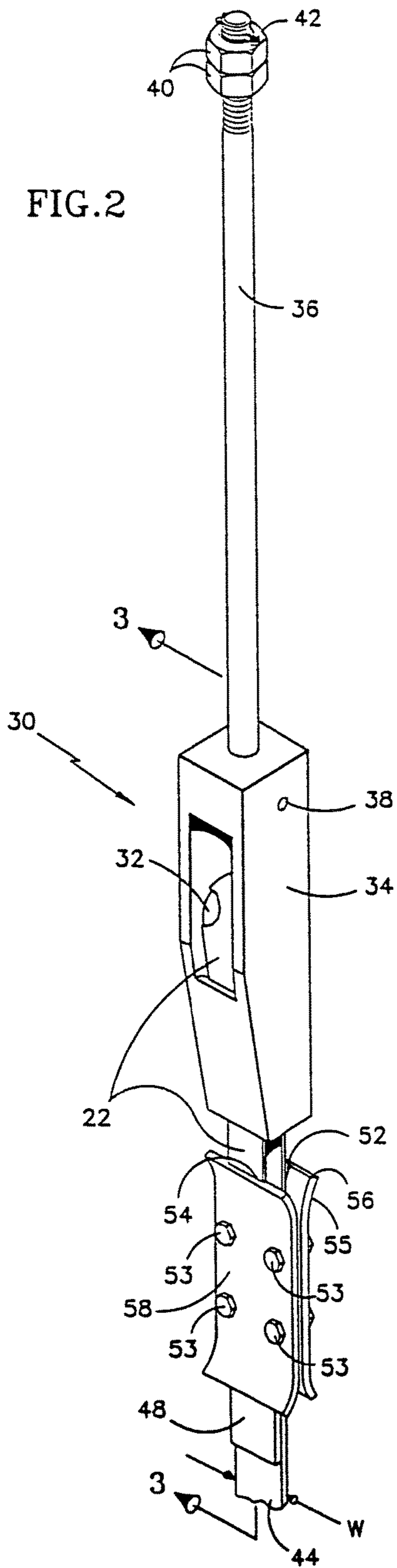
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FIG. 1





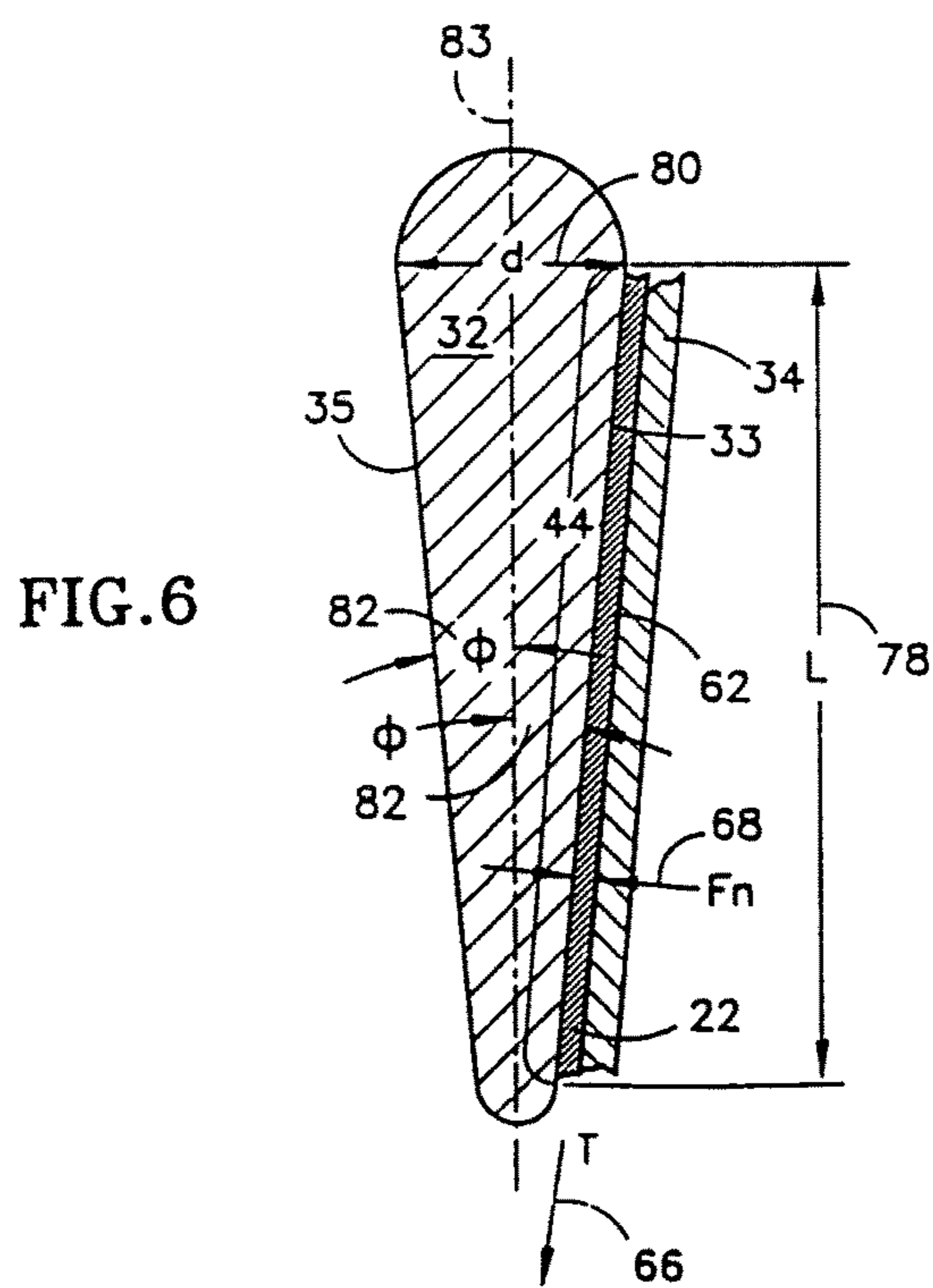
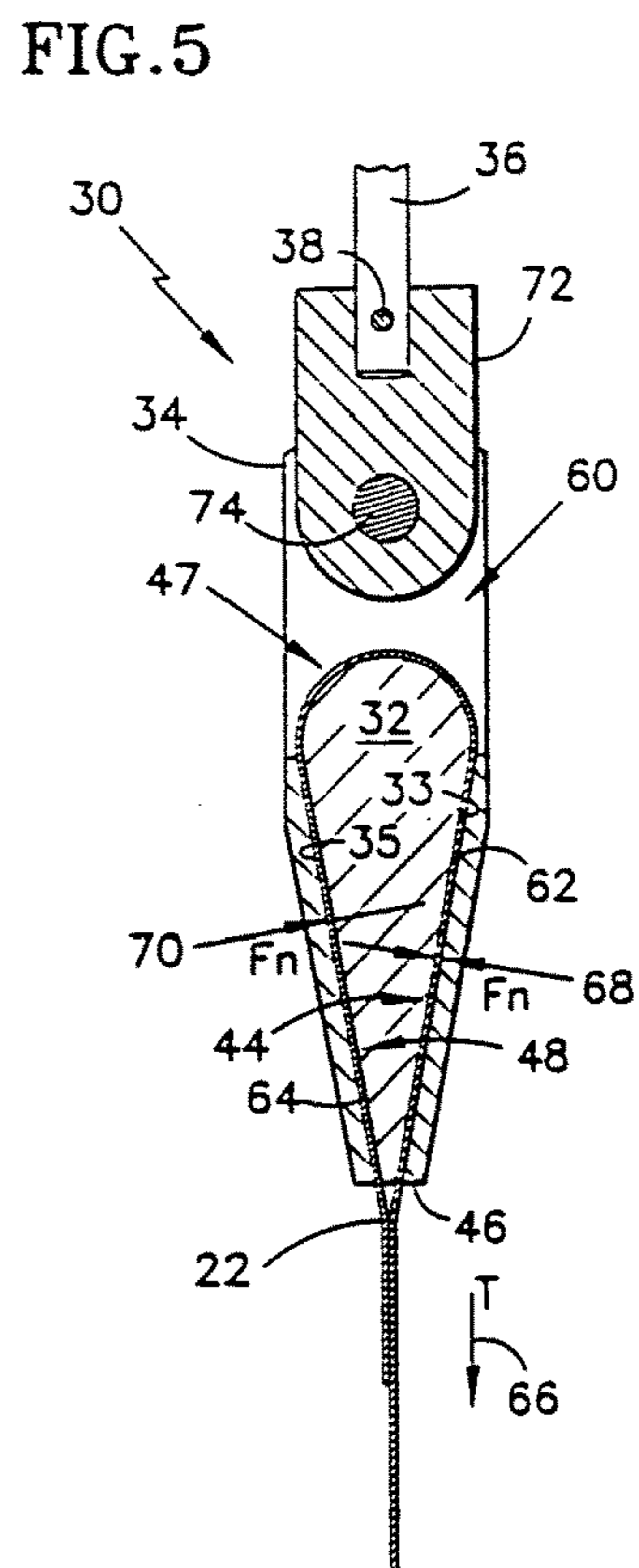
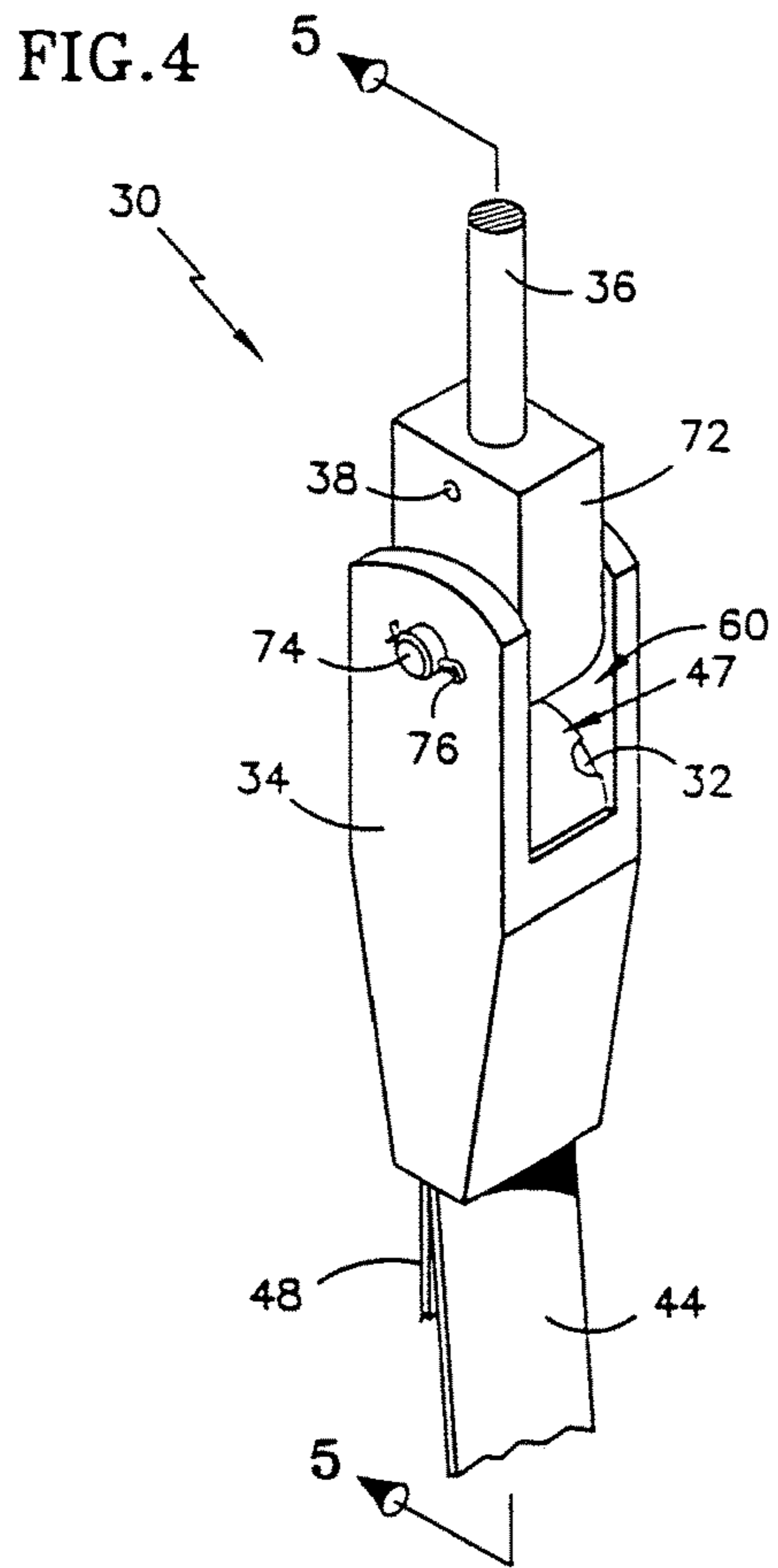


FIG. 7

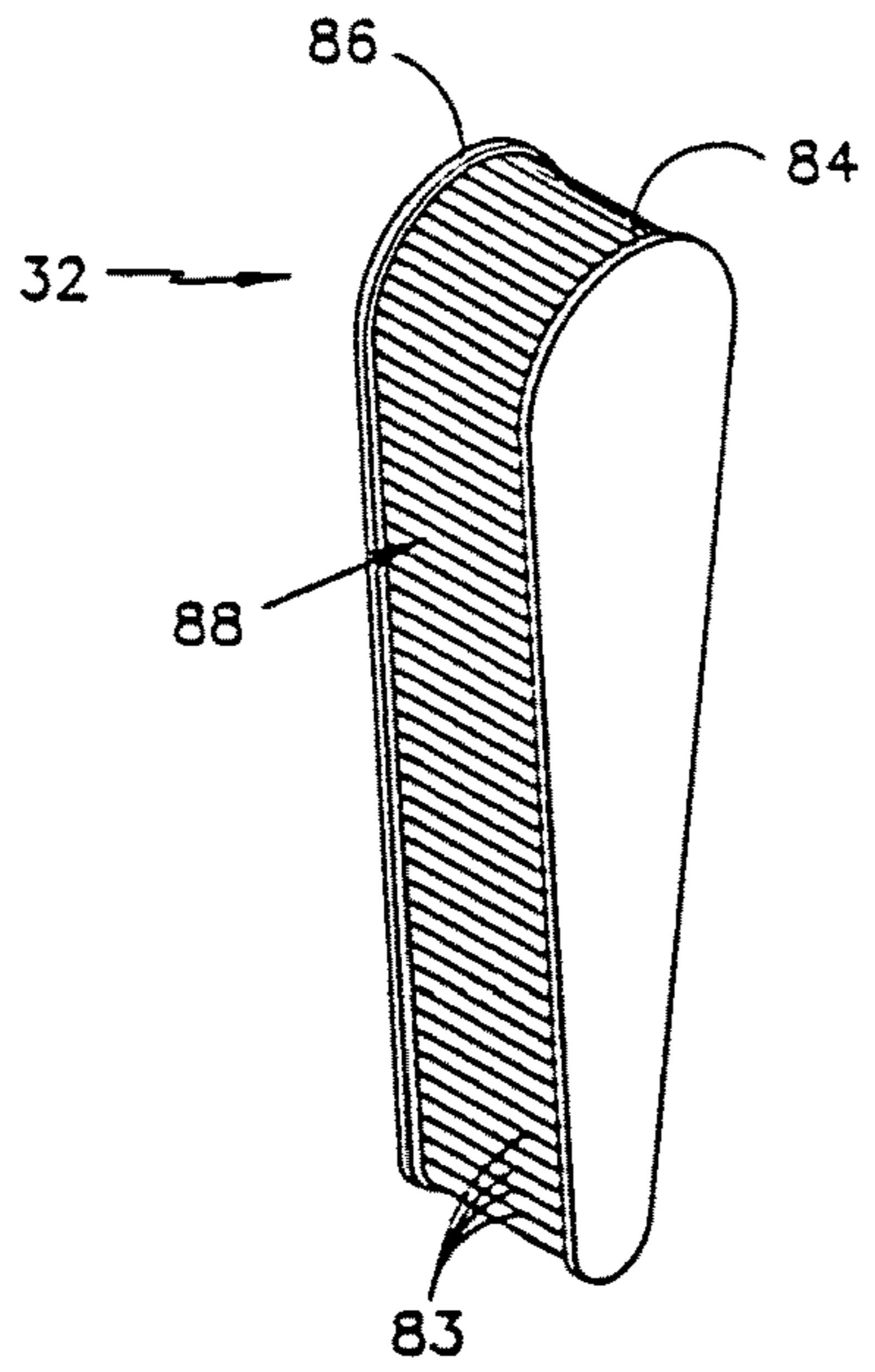


FIG. 8

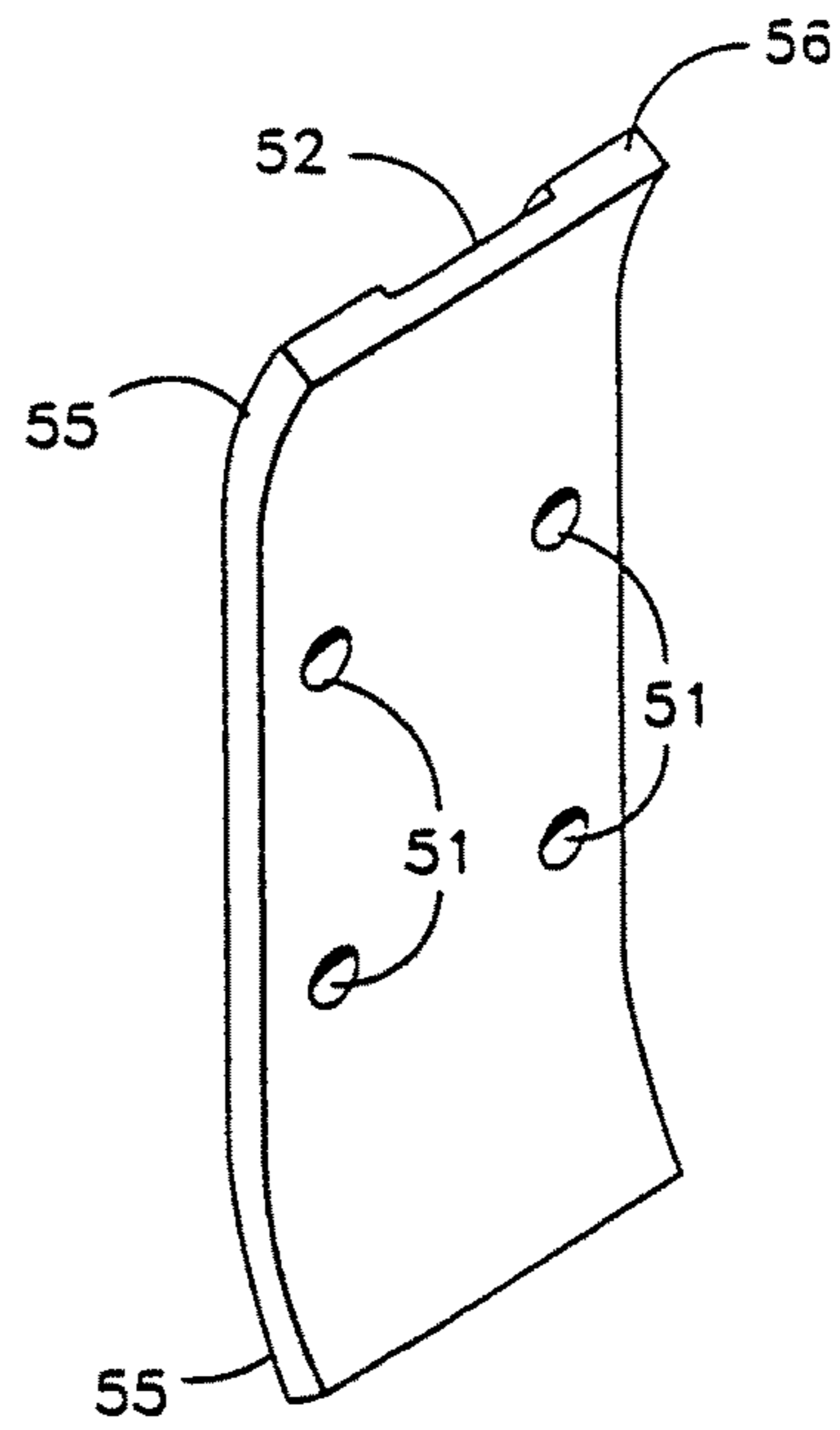
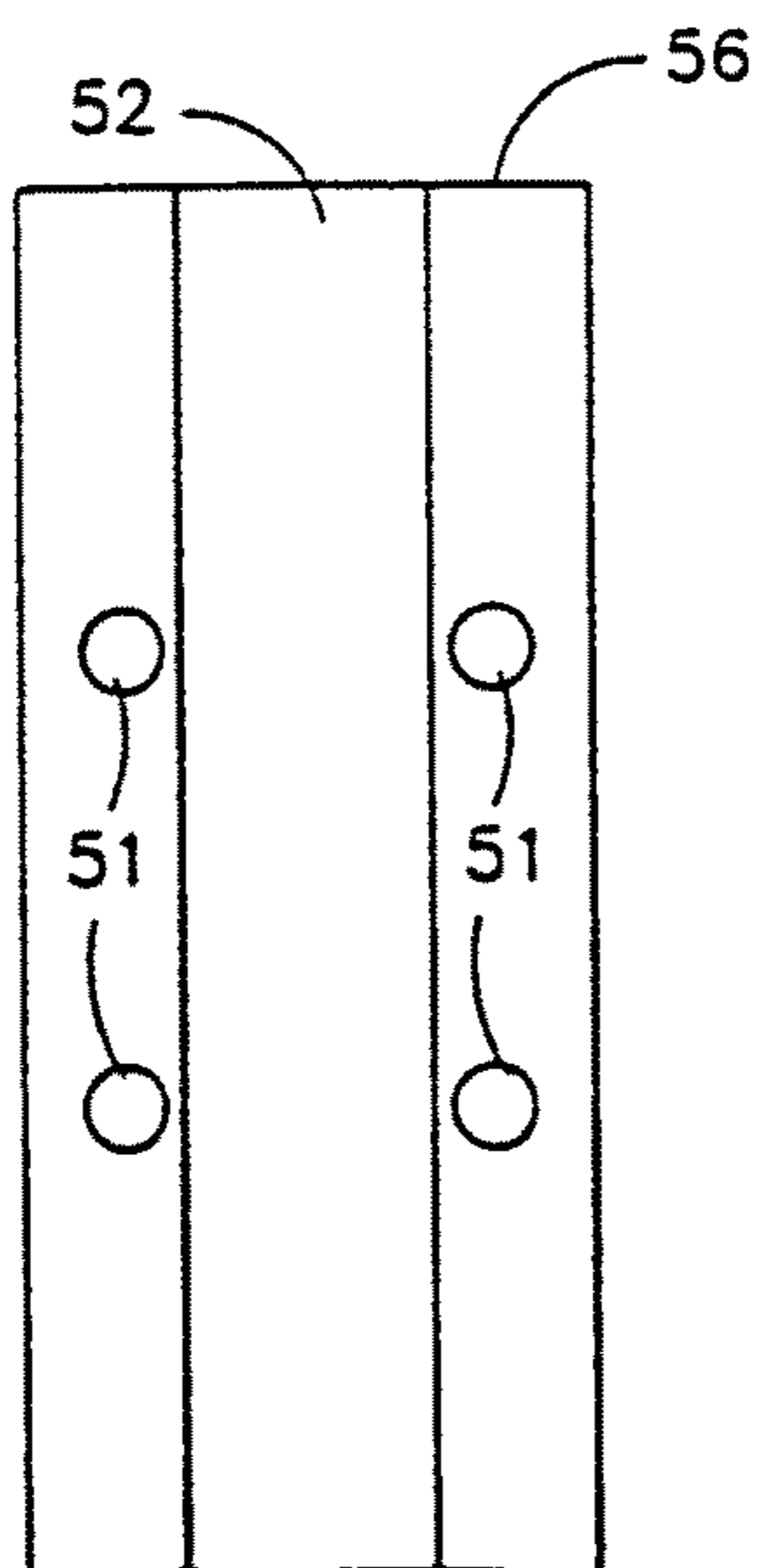


FIG. 9



## WEDGE CLAMP TYPE TERMINATION FOR ELEVATOR TENSION MEMBER

**Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.**

This application is a divisional of application Ser. No. 09/224,045, filed Dec. 31, 1998, now U.S. Pat. No. 6,256,841.

### TECHNICAL FIELD

The present invention relates to elevator systems, and more particularly to tension members for such elevator systems.

### BACKGROUND OF THE INVENTION

A conventional traction elevator system includes a car, a counterweight, two or more ropes interconnecting the car and counterweight, a traction sheave to move the ropes, and a machine to rotate the traction sheave. The ropes are formed from laid or twisted steel wire and the sheave is formed from cast iron.

Although conventional steel ropes and cast iron sheaves have proven very reliable and cost effective, there are limitations on their use. One such limitation is the traction forces between the ropes and the sheave. Typical techniques to increase the traction forces between the ropes and sheave result in reducing the durability of the ropes, increasing wear or the increasing rope pressure.

Another limitation on the use of steel ropes is the flexibility and fatigue characteristics of steel wire ropes. The minimum diameter of a steel rope is dictated mostly by fatigue requirements and results in a relatively thick rope. The relatively thick cross section of a steel rope reduces its inherent flexibility necessitating a sheave having a relatively large diameter. The larger the sheave diameter, the greater torque required from the machine to drive the elevator system thereby increasing the size and cost of the elevator system.

Another drawback of conventional round ropes is that smaller sheave diameters increase rope pressure shortening the life of the rope. Rope pressure is generated as the rope travels over the sheave and is directly proportional to the tension in the rope and inversely proportional to the sheave diameter  $D$  and the rope diameter. In addition, the shape of the sheave grooves, including such traction enhancing techniques as undercutting the sheave grooves, further increases the maximum rope pressure to which the rope is subjected.

In a typical rope driven elevator installation rope wedge clamps are used for termination purposes. Wedge clamps operate by securing the elevator rope between opposed angled walls of the wedge clamps and a tear drop shaped wedge around which the cable is wound. The wedge acts to cam the rope against the walls of the wedge clamp during tensioning of the ropes. A benefit of this design is that the wedge may have a relatively sharp angle producing a large clamping force. Because the steel ropes have a high compressive strength the large clamping force has no deleterious effects on the rope such as crush or creep.

In attempts to overcome the deficiencies and drawbacks of conventional round steel ropes for use in elevator systems coated tension members, including a relatively flat tension member, has been developed. The flat tension member includes a plurality of individual load carrying cords encased within a common layer of coating. An exemplary tension member of the type contemplated in this application is discussed in further detail in U.S. Ser. No. 09/031,108 filed Feb. 26, 1998 Entitled Tension Member For An Elevator and Continuation-In-Part Application Entitled Tension Member For An Elevator filed Dec. 22, 1998, both of which are entirely incorporated herein by reference.

The coating layer surrounds and/or separates the individual cords and defines an engagement surface for engaging a traction sheave. As a result of the configuration of the tension member, the rope pressure may be distributed more uniformly throughout the tension member, traction is increased and smaller sheave diameters are possible.

A method of terminating and securing flat tension members involves looping the members over a bar and clamping the end with a pair of plates. The plates are secured by a plurality of fasteners that pass through holes provided in the plates. Another method of terminating flat tension members includes a wedged end fastener wherein a wedge of material is positioned at the end of the tension member and clamped by a pair of plates. In such a configuration one of the plates comprises a wedge shaped cross section cooperating with the wedge of material and the second plate comprises a cross section of uniform thickness. The plates are similarly secured by a plurality of fasteners that pass through holes provided in the plates. A drawback to these types of termination methods is that the tension carrying capability of the termination relies solely on the clamping forces provided by the fasteners. In addition, the wedge type fastener limits the termination point of the member and hampers adjustability.

The above art notwithstanding, scientists and engineers under the direction of Applicants' Assignee are working to develop more efficient and durable methods and apparatus to drive elevator systems.

### DISCLOSURE OF THE INVENTION

According to the present invention, a termination device for a tension member having a compressible outer coating has a wedge disposed in a socket having cooperating jaw surfaces. The rope is wrapped around the wedge and inserted with the socket and clamped therein by forces generated by the tension in the member and the cooperation of the wedge and jaw surfaces.

A principal feature of the present invention is the geometry of the wedge, particularly the angle of the wedge, including its length and width. The wedge is sized and the angle is selected to provide sufficient clamping force to resist slippage of the rope without exceeding the compressive stress capability of the tension member. In addition, the wedge comprises a domed top portion to efficiently distribute the tension of the rope across the wedge.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is perspective view of an elevator system having a tension member termination device according to the present invention;

FIG. 2 is a perspective view of an embodiment of a termination clamp, showing an optional tension clamp device;



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FIG. 3 is a cross sectional view of the embodiment shown in FIG. 2 taken substantially along lines 3-3;

FIG. 4 is perspective view of an alternate embodiment showing a pivot block;

FIG. 5 is a cross sectional view of the embodiment shown in FIG. 4 taken substantially along lines 5-5;

FIG. 6 is diagrammatic cross sectional view of a wedge, tension member and jaw surface showing the relevant geometries and forces;

FIG. 7 is a perspective view of an embodiment of a wedge showing ridges and locking features;

FIG. 8 is a perspective view of a plate of the tension clamp of FIG. 2; and

FIG. 9 is a front plan view of a plate of the tension clamp of FIG. 8.

### BEST MODE FOR CARRYING OUT THE INVENTION

Illustrated in FIG. 1 is a traction elevator system 12. The elevator system 12 includes a car 14, a counterweight 16, a traction drive 18, and a machine 20. The traction drive 18 includes a tension member 22, interconnecting the car 14 and counterweight 16, and a traction sheave 24. The tension member 22 is engaged with the sheave 24 such that rotation of the sheave 24 moves the tension member 22, and thereby the car 14 and counterweight 16. Tension member 22 is coupled to counterweight 16 and car 14 by terminal clamp 30. Although shown as a geared machine 20, it should be noted that this configuration is for illustrative purposes only, and the present invention may be used with geared or gearless machines. In addition, although shown as a relatively flat tension member 22, it should be noted that this too is by way of example and the present invention may be used with other types of tension members including round coated tension members.

An embodiment of terminal clamp 30 is illustrated in more detail in FIG. 2. Tension member 22 is wrapped around wedge 32 and disposed within socket 34. Terminal clamp 30 is attached to car 14 and counterweight 16 via attachment rod 36 attached to socket 34 by pin 38. Attachment rod 36 is coupled to counterweight 16 and car 14 by threaded nuts 40 secured in place by cotter pin 42. Also shown in FIG. 2 is an optional gripping jaw clamp 50 wherein tension member 22 is clamped within grooves 52, 54 of plates 56, 58 in a double overlap arrangement.

Referring to FIG. 3 clamp 30 operates to provide a secure termination of tension member 22. In use, lead portion 44 of tension member 22 is inserted within aperture 46 in the bottom portion of socket 34, as viewed in the figure, wrap portion 47 of the tension member is then wrapped around wedge 32 and then tail portion 48 passed back out through aperture 46. Wedge 32 is then inserted within opening 60 of socket 34 to the clamp position shown in FIG. 2 wherein lead portion 44 and tail portion 48 are clamped between jaw surfaces 62, 64 respectively, of socket 34. Termination clamp 30 is designed such that tension member 22 and attachment rod 36 are substantially axially aligned to allow for efficient load transfer and prevents undesirable rotation of termination clamp.

Still referring to FIG. 3, in normal operation of the elevator system 12 (FIG. 1), the tension (T) in lead portion 44 of tension member 22 is in the direction indicated by arrow 66 which reacts in wrap portion 47 to force wedge 32 farther into socket 34 in the direction of aperture 46. With the load in tension member 22 forcing wedge 32 into socket 34, a clamping force represented by arrow 68 clamps lead

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portion 44 against jaw surface 62 and a clamping force represented by arrow 70 clamps tail portion 48 against jaw surface 64. Clamping forces 68, 70 are normal to jaws 62, 64 respectively, and to the respective portions of wedge 32 and are expressed as normal forces ( $F_n$ ). The clamping forces generated by jaws 62, 64, together with the friction forces acting on wrap portion 47, react out the total tension (T) in tension member 22 thereby retaining the member in clamp 30.

An alternative embodiment of termination clamp 30 is shown in FIGS. 4 and 5 wherein attachment rod 36 is attached to pivot block 72 by pin 38 and in turn pivotally attached to socket 34 by pivot pin 74 and secured by cotter pin 76. In this particular embodiment, lead portion 44 of tension member 22 is inserted within aperture 46 in the bottom portion of socket 34, as viewed in the figure, wrap portion 47 of the tension member is then wrapped around wedge 32 and then tail portion 48 passed back out through aperture 44. Wedge 32 is then inserted within opening 60 of socket 34 to the clamp position shown in FIG. 5 wherein lead portion 44 and tail portion 48 are clamped between jaw surfaces 62, 64 respectively, of socket 34. It is an important feature of this embodiment that once wedge 32 and tension member 22 are installed within socket 34 pivot block 72 is then installed to prevent the wedge from being inadvertently dislodged from the socket if tension is lost in the member, as will be more fully described hereinbelow. In addition, this particular embodiment maintains tension member 22 and attachment rod 36 substantially axially aligned to allow for efficient load transfer. Pivot block 72 also permits angular displacement of tension member 22 relative to the car 14 or counterweight 16 without imparting large stresses within attachment rod 36 or socket 34. Another advantage of this particular embodiment over that shown in FIGS. 2 and 3 is that the overall height the socket is reduced because the wedge 32 is inserted through the top of socket 34. Pivot block 72 is then inserted within close proximity of the wedge thus reducing the overall height of termination clamp 30.

The geometry of wedge 32 is an important factor in producing normal forces 68, 70 and properly retaining tension member 22. The relevant parameters of wedge 32 controlling the normal force  $F_n$  are shown with reference to FIG. 6 and include the length (L) designated by 78, depth (d) represented by 80, angle  $\phi$  represented by 82 and measured from centerline 83 to clamping surface 33, 35 and the width (W) of tension member 22 (FIG. 2). The other factor relevant to controlling the normal forces 68, 70 is the tension (T) in tension member 22 represented by 66. The parameters L and d are somewhat dependant on  $\phi$  and are typically limited by available space in the hoistway (not shown). Given a nominal tension T, normal forces  $F_n$  68, 70 (FIGS. 3 and 5) are inversely related to  $\phi$ . That is to say, if  $\phi$  is too small,  $F_n$  will be too great and tension member 22 will experience compressive creep. This is particularly important in an embodiment where tension member 22 is comprised of a urethane outer coating, or where the coating is another flexible elastomer, as they have a maximum compressive stress ( $\sigma_c$ ) capability of about 5 MPa before non-recoverable deformation, or creep, occurs. On the other hand if  $\phi$  is too large the normal forces will be too small the tension member will slip within termination clamp 30. It is particularly advantageous to reduce the compressive stress on tension member 22. One way to reduce the compressive stress is to increase the length L over which the clamping forces are applied, however hoistway consideration are generally limiting in this regard. Taking the above referenced physical

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parameters in to consideration, in order to preclude exceeding  $\sigma_c$  the minimum  $\phi$  can be predetermined in accordance with the formula:

$$\phi = \tan^{-1}[T/(\sigma_c * L * W)]$$

In a typical application of the present invention for a tension member having a T of about 2500 N, d ranges from about 60 mm to about 70 mm, L is about 140 mm,  $\phi$  ranges from about 9 degrees to about 10 degrees.

The present invention will now be described with respect to a specific example of the termination clamp **30** shown in FIGS. **4** and **5** by referring to FIG. **6**. A typical tension member **22**, as described in the above related applications, is comprised of a 30 mm wide flat flexible rope having a urethane outer coating and has a maximum tension capability of 30,000 N. As is known in the art, a safety factor of about 12 is applied to elevator ropes and provides a maximum tension in member **22** of about 2500 N. Wedge **32** has length L of 140 mm and angle  $\phi$  of 10 degrees geometrically yielding diameter d as follows:

$$d = 2(L \tan \phi) = 2(140 \tan 20/2) = 49.37 \text{ mm}$$

The determination of  $F_n$  with T equal to 2500 N is as follows:

$$F_n = T / \sin \phi = 2500 / \sin (20/2) = 14,397 \text{ N}$$

Since  $F_n$  is distributed over the entire area of lead portion **44** the compressive stress  $\sigma$  on the tension member **22** is a function of the area of lead portion, A, clamped between wedge **32** and jaw surface **62**, and is calculated as follows:

$$A = L * W = 140 * 30 = 4,200 \text{ mm}^2$$

The compressive stress in tension member **22** is then determined as follows:

$$\sigma = F_n / A = 14,397 / 4,200 = 3.43 \text{ MPa}$$

In this particular example, the compressive stress limit of the material is not exceeded and therefore no creep will occur.

The ability of termination clamp **30** to react out T in lead section **44** is important and is a function of  $F_n$  and the coefficient of friction ( $\mu$ ) between the tension member **22** and jaw surface **62** and the surface of wedge **32**. In the example given, tension member **22** is comprised of a urethane coating and jaw surface **62**, as well as wedge **32**, is smooth steel and a conservative number for the coefficient of friction between the surfaces is about  $\mu = 0.25$ . To properly maintain wedge **32** within socket **34** T must be preferably substantially reacted out within lead section **44** although a remainder may be transferred into wrap section **47**. The following relation, from clamping theory, provides the maximum reaction force  $F_r$ , or the amount of tension that can be reacted, in the example given for  $\mu = 0.25$ :

$$F_r = \mu * F_n = 0.25 * 14,397 = 3,599 \text{ N}$$

Therefore, recalling that the maximum T in the example given is 2500 N, all of the tension T will be reacted out of tension member **22** in the lead portion **44** and the member will not slip within termination clamp **30**.

An alternative embodiment of the present invention aimed at increasing the coefficient of friction between the tension member **22** and the jaw surface **62**, **64** and wedge **32** comprises a roughened surface on the jaws and the wedge. In one particular embodiment the surface is roughened by a sandblasting procedure. Sandblasting of the surfaces raises the coefficient of friction to 0.35 or greater. Other methods of increasing the surface friction include etching, machining, knurling and other suitable equivalents. In addition to raising the coefficient of friction the roughened surfaces would

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form small ridges and valleys. A characteristic of the urethane coating is its tendency to exhibit cold flow under high loading conditions. Under the loading conditions described above the urethane coating cold flows into and around the ridges and valleys, also referred to as locking features, in the wedge and socket and provides for a small but effective mechanical lock. The locking features increase the ability of the termination clamp to resist slippage of tension member **22**. It is within the scope of the present invention that the locking features may comprise grooves, striations **83** (FIG. **7**), cuts, diamond pattern, or other suitable equivalents. It is important to note that the locking features reduce the required normal force as described hereinabove. The use of locking features as describes allows a reduction in the length L, or an increase in angle  $\phi$  to further minimize the risk of creep.

An alternative embodiment for wedge **32** is shown in FIG. **7** and includes ridges **84**, **86** forming a channel **88** therebetween. Ridges **84**, **86** are approximately the height of a cord within the coating of tension member **22**. For example, a particular embodiment of tension member **22** is 3 mm thick having a cord with a 1.4 mm cord disposed therein. Ridges **84**, **86** for this particular embodiment would define a channel **88** having a depth of approximately 1 mm. Tension member **22** is disposed within channel **88** and wedge **32** is installed within socket **34** as described herein above. The benefit of ridges **84**, **86** are that they contain tension member **22** within channel **88** given the anticipated cold flow characteristics of the coating material. In addition, ridges **84**, **86** are sized to prevent compressive stress failure of tension member **22** by limiting the displacement of wedge **32** within socket **34**. In the event that a higher than anticipated normal force  $F_n$  is transferred to the member ridges **84**, **86** will contact jaw surfaces **62**, **64** and arrest the travel of wedge **32** within socket **34**.

Referring now to FIGS. **2**, **8** and **9**, the above mentioned optional tension clamp **50** for use with the termination clamp **30** is illustrated. The purpose of tension clamp **50** is to aid in terminating and reacting tension in member **22** and to equalize the tension between lead portion **44** and tail portion **48** as they enter socket **34**. Tension clamp **50** also assists termination clamp **30** in the unlikely event of that tension member **22** loses tension, such as for instance, during an abrupt stop of elevator car **14**. Tension clamp **50** is clamped onto the tail portion **48** and lead portion **44** prior to entering socket **34**. When engaged with the tension member **22**, tension clamp **50** cannot move thereon. Plates **56**, **58** as shown and described are identical, however it is within the scope of the present invention that the plates are different wherein one plate has a tension member groove and one plate has no groove.

As described hereinabove tension clamp **50** comprises a pair of plates **56**, **58** each having a tension member groove **52**, **54** approximately the thickness of the tension member **22**. Bore holes **51** are provided for through passage of fasteners **53**. Plates **56**, **58** further include leading edges **55** comprising a generous radius to facilitate a smooth transition of lead portion **44** and tail portion **48** from socket **34** into tension clamp **50**.

In use, the lead portion **44** is inserted into groove **52** of plate **56** and tail portion **48** into groove **54** of plate **58** and the plates are assembled together with fasteners **53**. When the bolts **53** are tightened tension member **22** is clamped within the grooves **52**, **54** and are held resistant to slippage by plates **56**, **58**. In this way the tension member is prevented from moving relative to tension clamp **50**.

When optional tension clamp 50 is used in conjunction with termination clamp 30, leading portion 44 and tail portion 48 load share the full tension created by car 14. In this regard, the analysis for determining the clamping performance established herein above is modified to reflect a load sharing in the tension in each of the cables.

While preferred embodiments have been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustration and not limitation.

What is claimed is:

1. A termination device for a tension member, the tension member having a width  $W$  and an elastomer coating that has a maximum compressive stress capability  $\sigma_c$ , the tension member being subjected to a tensile force  $T$ , the termination device comprising:

a socket; and

a wedge that fits within the socket with the tension member wrapped around the wedge, the wedge having a clamping surface that includes a length  $L$  and is disposed at an angle  $\phi$ , which is measured from a centerline of the wedge to the clamping surface and which relates to the length  $L$  in accordance with the formula defining a minimum of the angle  $\phi$ :

$$[\phi \geq \tan^{-1}] \phi = \tan^{-1}(T/(\sigma_c * L * W)).$$

2. A method for terminating a tension member having a width  $W$  and an elastomer coating that has a maximum compressive stress capability  $\sigma_c$ , comprising:

feeding the tension member into an aperture of a socket; wrapping the tension member around a wedge having a clamping surface that includes a length  $L$  and is disposed at an angle  $\phi$ , which is measured from a centerline of the wedge to the clamping surface;

feeding the tension member back through the aperture; and

applying a tensile force  $T$  in the tension member so that the tension member is compressed between the wedge and the socket, wherein the tensile force  $T$  is applied in accordance with the formula defining a minimum of the angle  $\phi$ :

$$[\phi \geq \tan^{-1}] \phi = \tan^{-1}(T/(\sigma_c * L * W)).$$

3. A method according to claim 2 further comprising: positioning the tension member in a back-to-back arrangement;

placing a pair of plates on either side of the tension member;

inserting a plurality of fasteners through the plates;

tightening the fasteners; and

clamping the tension member between the plates in a double overlap arrangement.

4. A termination device for a tension member, the tension member having a width  $W$  and a compressible coating that has a predetermined maximum compressive stress capability  $\sigma_c$ , the compressible coating being subject to compressive creep, the tension member being subjected to a tensile force  $T$ , the termination device comprising:

a socket; and

a wedge that fits within the socket with the tension member wrapped around the wedge, the wedge having a clamping surface that includes a length  $L$  and is disposed at an angle  $\phi$ , which is measured from a

centerline of the wedge to the clamping surface and which relates to the length  $L$  in accordance with the formula defining a minimum of the angle  $\phi$ :

$$\phi = \tan^{-1}(T/(\sigma_c * L * W)).$$

5. A method for terminating a tension member having a width  $W$  and a compressible coating that has a predetermined maximum compressive stress capability  $\sigma_c$ , the compressible coating being subject to compressive creep, the method comprising:

feeding the tension member into an aperture of a socket; wrapping the tension member around a wedge having a clamping surface that includes a length  $L$  and is disposed at an angle  $\phi$ , which is measured between a centerline of the wedge and the clamping surface;

feeding the tension member back through the aperture; and

applying a tensile force  $T$  in the tension member so that the tension member is compressed between the wedge and the socket, wherein the tensile force  $T$  is applied in accordance with the formula defining a minimum of the angle  $\phi$ :

$$\phi = \tan^{-1}(T/(\sigma_c * L * W)).$$

6. A termination device for a tension member, the tension member having a width  $W$  and comprised of a plurality of inner load carrying cords and a compressible coating, wherein the compressible coating defines a traction surface for the tension member and the compressible coating has a predetermined maximum compressive stress capability  $\sigma_c$ , the compressible coating being subject to compressive creep if the maximum compressive stress capability is exceeded, the tension member being subjected to a tensile force  $T$ , the termination device comprising:

a socket; and

a wedge that fits within the socket with the tension member wrapped around the wedge, the wedge having a clamping surface that includes a length  $L$  and is disposed at an angle  $\phi$ , which is measured between a centerline of the wedge and the clamping surface and which relates to the length  $L$  in accordance with the formula that defines a minimum of the angle  $\phi$ :

$$\phi = \tan^{-1}(T/(\sigma_c * L * W)).$$

7. A method for terminating a tension member having a width  $W$  and comprised of a plurality of inner load carrying cords and a compressible coating, wherein the compressible coating defines a traction surface for the tension member and has a predetermined maximum compressive stress capability  $\sigma_c$ , the compressible coating being subject to compressive creep if the predetermined maximum compressive stress capability is exceeded, the method comprising:

feeding the tension member into an aperture of a socket; wrapping the tension member around a wedge having a clamping surface that includes a length  $L$  and is disposed at an angle  $\phi$ , which is measured between a centerline of the wedge and the clamping surface;

feeding the tension member back through the aperture; and applying a tensile force  $T$  in the tension member so that the tension member is compressed between the wedge and the socket, wherein the tensile force  $T$  is applied in accordance with the formula that defines a minimum of the angle  $\phi$ :

$$\phi = \tan^{-1}(T/(\sigma_c * L * W)).$$