**TITLE OF THE INVENTION:**

# TERMINATION INSTALLATION METHOD FOR LONG CABLES

Patent Application of
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## CROSS-REFERENCES TO RELATED APPLICATIONS

This non-provisional patent application claims the benefit of an earlier-filed provisional application. The first provisional application was assigned serial number 61/934,170. It listed the same inventor.

## STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable.

## MICROFICHE APPENDIX

Not Applicable

DESCRIPTION

Title of the Invention: Termination Installation Method for Long Cables

1. Technical Field.

This invention relates to the field of tensile strength members. More specifically, the invention comprises a method for creating a long cable with a high-performance termination or terminations that can be pre-tested using equipment that is limited to testing shorter cables.

2. Background Art.

Tensile strength members must generally be connected to other components in order to be useful. A flexible cable provides a good example. The cable must generally include some type of end-fitting so that it can be transmit a load. For example, a cable used in a hoist generally includes a lifting hook on its free end. This lifting hook may be rigged to a load. The assembly of an end-fitting and the portion of the cable to which it is attached is generally called a "termination."

A tough steel lifting hook is commonly attached to a wire rope to create a termination. A "spelter socket" is often used to create the termination. The "spelter socket" involves an expanding cavity within the end-fitting. A length of the wire rope is slipped into this cavity and the individual wires are splayed apart. A liquid potting compound is then introduced into the expanding cavity with the wires in place. The liquid potting compound transitions to a solid over time and thereby locks the wire rope into the cavity.

The potting compound used in a spelter socket is traditionally molten lead and – more recently – is more likely a high-strength epoxy. However, the term "potting compound" as used in this description means any substance which transitions from a liquid to a solid over time. Examples include molten lead, thermoplastics, UV-cure or thermoset resins (such as two-part polyesters or epoxies). Other examples include plasters, ceramics, and cements. The term "solid" is by no means limited to an ordered crystalline structure such as found in most metals. In the context of this invention, the term "solid" means a state in which the material does not flow significantly under the influence of gravity. Thus, a soft but stable wax is yet another example of such a solid.

The prior art approaches to adding a termination are explained in detail in commonly-owned U.S. Patent No. 7,237,336, which is hereby incorporated by reference. An exemplary termination is shown in FIGs. 1-4. FIG. 1 shows a cable 10 made from advanced high-

strength synthetic filaments. Many different materials are used for these filaments. These include KEVLAR, VECTRAN, PBO, DYNEEMA, SPECTRA, TECHNORA, ZYLON, glass fiber, and carbon fiber (among many others). In general the individual filaments have a thickness that is less than that of human hair. The filaments are very string in tension, but they are not very rigid. They also tend to have low surface friction.

In order to gain a strong and repeatable result, the addition of an end fitting to a cable made of high-strength synthetic filaments must generally be done under controlled conditions such as found in a factory. This is particularly true of medium to large end fittings configured for a cable having an overall diameter of greater than 20 mm and sometimes being considerably larger.

An end-fitting is most commonly attached to a larger synthetic filament cable by potting. Liquid potting compound (such as an epoxy or a polyester) is added to a cavity in the fitting after a length of filaments has been placed within the fitting. It is preferable to hold the components in a stable configuration while the potting compound cures – which may take 12 hours or more. Temperature and other variables are preferably controlled during this process, as are the properties of the potting compound itself.

A properly attached end-fitting creates a very strong termination. However, in many applications the strength of the termination must be tested. Exemplary applications include hoisting cables and mooring cables where a known and predictable strength is very important. This requirement creates challenges in the field of synthetic-filament cables since conventional testing equipment designed for wire rope and other conventional filaments does not work well. Specialized testing equipment for synthetic cables does exist, but it tends to have a limited length capability.

It is desirable to use synthetic filament cables to replace steel and other conventional cables, but in order to do so the synthetic filament cables must have an equivalent useful length. Steel cables may have a length of 1,000 meters or more, and the testing equipment designed for synthetic cables is simply not long enough to test such a cable.

Some prior art techniques open a path for a solution to these and other problems. It is known to join multi-stranded cables using weaving methods. In these methods, connections are made by interweaving strands of one section of cable with strands of another section of cable (sometimes the sections lie in the same cable and sometimes they do not).

FIG. 1 shows an exemplary prior art operation. Cable 10 includes eight individual strands of synthetic filaments. Each strand may contain a million or more individual filaments, but the prior art weaving operations do not break the cable down beyond the strand level. The depiction of cable 10 is representative rather than entirely accurate. The example shown has 8 separate strands. The strands would typically be interwoven with 2 pairs of strands in a left-hand helix and two pairs in a right-hand helix.

The objective of the example shown in FIGs. 1 and 2 is to weave a length of the cable back on itself to form an “eye” on the cable’s end. Considerable mechanical skill and dexterity is required to form an eye on the end of a cable and in other instances to join lengths of cable together. However, persons having these skills are commonly found in industries where large cables are used. Further, the strength and reliability of cable splices made by such persons are well understood and accepted.

In FIG. 1, a length of strands proximate the cable ends is unwoven to create separated strands 14. The end of the cable is bent into a loop or bight, sometimes around a reinforcing element such as thimble 12. FIG. 2 shows the continuation of the operation. The weave of the strands within the cable is loosened so that separated strands can be threaded back into the cable in a prescribed pattern. Interwoven section 24 is thereby created. The loose ends of separated strands 14 are eventually cut off (after a sufficiently log interwoven section 24 has been created) and taped or otherwise secured.

The result is eye splice 16 on one end of cable 10. The eye splice does work. However, it is not a particularly efficient termination. In this context the term efficiency means the ratio of the breaking stress of the complete cable with the termination attached versus the breaking stress for one individual synthetic filament. A perfectly efficient cable would have an efficiency of 100%. Obviously, this is not achievable. An eye splice such as shown in FIG. 2 will typically have an efficiency below 70%.

On the other hand, high-performance terminations may be created which have efficiencies greater than 90%. FIG. 3 – a sectional view - shows an example of a high-performance termination. Anchor 18 includes an internal cavity 20. A length of strands from cable 10 is placed within this cavity. Preferably the strands are splayed apart in some form of expanding cavity (though other techniques may be used). A liquid potting compound is placed within the cavity (either before, during, or after the strands are added).

The liquid potting compound transitions to a solid over time to create potted region 22. Once solidified as shown, the strands within potted region 22 are locked in place and anchor 18 is secured to the end of the cable. Some feature for transmitting a load to the cable is typically included. In this example loading feature 21 assumes the form of a loop.

Other classes of high-performance terminations can be made without using a potting compound to secure the cable strands to the anchor. FIG. 10 shows an assembly that is commonly referred to as a "spike and cone" termination. A length of strands is splayed apart in cavity 20 as for the potting example. However, rather than using potting compound, they are mechanically secured. Cone 62 is introduced into the center of the strands. Compression plug 64 is then screwed into the open end of anchor 18 via threaded engagement 66. The strands are then mechanically clamped in place.

It is possible to combine the prior art approaches – such as by using potting compound in the spike-and-cone configuration of FIG. 10. However the high-performance termination is created, the result is quite efficient. Termination efficiencies exceeding 90% are possible. In addition, anchor 18 can be made quite tough. As an example, the anchor may be made of stainless steel so that it can endure an abusive environment. Such a termination is advantageous in many instances where a synthetic cable might be used to replace wire rope or other more traditional materials.

## SUMMARY OF INVENTION

The present invention comprises a method for creating a composite cable having at least one high-performance termination on at least one end. A high-performance termination is added to an end of a short synthetic tensile strength member. The strength of the tensile strength member and termination is then tested. Once tested satisfactorily, the short cable is spiced onto a long cable of the same type using prior art splicing techniques. The union of the short cable and the long cable creates a "composite" cable having a high-performance termination on at least one end. In most applications it is preferable to set the length of the short cable so that the interwoven splice will exist at a desired location.

## BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a perspective view, showing the creation of a prior art eye splice.

FIG. 2 is a perspective view, showing the continuation of the operation of FIG. 1.

FIG. 3 is a sectional elevation view, showing the addition of a high-performance termination to one end of a synthetic cable.

FIG. 4 is a perspective view, showing a terminated short cable made according to the present inventive process.

FIG. 5 is a perspective view, showing a composite cable made according to the present invention.

FIG. 6 is an elevation view, showing an exemplary test rig used to test a short cable made according to the present invention.

FIG. 7 is an elevation view, showing an inventive cable in use on an oil platform.

FIG. 8 is an elevation view, showing an inventive cable being used to hoist a load out of the water.

FIG. 9 is an elevation view, showing an inventive cable being used on a dragline crane.

FIG. 10 is a sectional elevation view, showing another type of high-performance termination.

REFERENCE NUMERALS IN THE DRAWINGS

| | |
|---|---|
| 10 | cable |
| 12 | thimble |
| 14 | separated strands |
| 16 | eye splice |
| 18 | anchor |
| 20 | cavity |
| 21 | loading feature |
| 22 | potted region |
| 24 | interwoven section |
| 26 | short cable |
| 28 | drum |
| 30 | test loading device |
| 32 | oil platform |

34 crane
35 boom
36 composite cable
38 sea surface
40 sea floor
42 payload
44 max hook height
46 lower splash boundary
48 drum
50 top sheave
52 dragline crane
54 boom
56 lifting crane
58 dragging cable
60 bucket
62 cone
64 compression plug
66 threaded engagement

## DESCRIPTION OF EMBODIMENTS

The present invention applies to virtually any type of tensile strength member. Cables are used as examples of elastic strength members in the embodiments described. However, the reader should keep in mind that the invention is by no means limited to cables.

The main concept of the invention is to create a “short” tensile strength member with one or more high-performance terminations attached. The “short” assembly is tested so that its useful working load is known for certain. The “short” assembly is then joined to a “long” tensile strength member using prior art interweaving techniques. The result is a composite cable whose overall performance is known by (1) the results of the testing done on the “short” assembly, and (2) years of accumulated practical understanding of the performance of interwoven splices. The terms “short” and “long” are of course vague and they will be defined in the context of the invention.

FIG. 4 shows two components of a composite cable before they are joined together. Short cable 26 includes a high-performance termination that has been attached to one end as described previously. Cable 10 in this example is a “long cable” with no attached hardware. In this example both cables are made of braided strands. The drawing does not depict the braided construction completely accurately, since it is quite complex, but the lines show that some of the braid components are twisted in one direction and some are twisted in the opposite direction.

It is possible using prior art techniques to create an interwoven splice between these two pieces of cable. FIG. 5 shows the two cable segments joined together by an interwoven splice. Short cable 26 and long cable 10 are joined together by interwoven section 24. The result is a much longer “composite” cable.

The terms “short” and “long” are relative to each other. A “short” cable might range from as short as 5 meters to as long as 100 meters. A “long” cable might range from 100 meters up to several km in length. When the terms “short” and “long” are used in this description, the reader should understand that the “long” cable is 5 or more times longer than the short cable. The determination of the length of each component is often dictated by the application, as will be explained subsequently.

A detailed explanation of the prior art interweaving techniques used in cable splices is beyond the scope of this disclosure, but the reader may benefit from some general explanation. An interwoven splice is applicable to any tensile strength member made of multiple strands, so long as the strands are arranged in some ordered fashion. Cable strands are generally braided or twisted, with braiding being most common. A permanent joint can be created between two cables (or two parts of a single cable) by partly untwisting the strands and then interweaving them. Interwoven splices can be used to form a loop or eye on and end of a cable. They may also be used for joining the ends of two cables together.

In general, a section of completely unwoven strands are created on the end of one cable and a section of loosened (yet not unwoven) strands are created on the end of a second cable. The completely unwoven strands on the first cable are then woven into the voids between the loosened strands on the second cable in a prescribed and repetitive fashion. A specified number of weaves are created. Any excess material from the unwoven strands of

the first cable is then removed and the free ends are secured by any suitable method, such as taping or whipping.

The creation of a proper interwoven splice is a skilled job that is customarily carried out by a trained rigging specialist. Fortunately, such specialists are common within the industries needing high-strength cabling. When properly done, an interwoven splice is capable of maintaining the cable's full breaking strength.

The interweaving techniques are very old, as most were developed in the age of sailing ships. The performance of such interwoven splices is well understood and – perhaps as importantly – very well trusted within the industries where they are used. Readers wishing to know more of the details of accepted interwoven splicing techniques are referred to The Splicing Handbook, 2nd Edition, published by International Marine (ISBN 0-07-135438-7).

Terminations such as shown in FIGs. 3 and 10 are preferably created under controlled conditions. This will typically be a factory production facility, though a smaller scale facility could be set up to handle it as well. In the case of a potted termination, cable and anchor alignment is preferably maintained over the cure time of the potting compound. This may take a day or even longer. In addition, the strand alignment within the cable also dictates the creation of a constrained length of cable extending out of the anchor.

Potting compound mix ratios are important, as are other factors such as the ambient temperature. Preferably many conditions are controlled in order to create a strong and repeatable result. Even with the best process controls, however, some critical applications simply demand that the completed cable/anchor assembly be tested.

FIG. 6 schematically depicts a testing rig for a short cable 26 with an attached anchor 18. Cables made of synthetic filaments tend to have low surface friction and are not easy to grip. It is often important to apply very high tensile loads in the test. In many cases this will be a significant fraction of the calculated breaking strength of the cable. Thus, it is often not possible to apply this amount of tension through a fixture that simply grips the cable's exterior. Likewise, it is not desirable to knot a portion of the cable around a loading fixture since the knot will drastically reduce the cable's strength.

FIG. 6 shows one end of short cable 26 being wrapped around drum 28. It is possible to wrap several turns of the cable around a drum of suitable diameter and thereby secure the

cable's free end without over-stressing it. Test loading device 30 is attached to anchor 18 using a hook or similar feature. Tension may then be applied through test loading device 30 while drum 28 is held in position. In another version, test loading device 30 could be held in a fixed position while torque is applied to the drum. Other testing fixtures are obviously possible.

The result of the test is that the cable can be certified as having been loaded to a specified amount with no problem resulting. Any defect in the manufacturing of the components or the assembly process may thereby be reliably detected.

Returning now to FIG. 5, the reader will recall that short cable 26 is joined to long cable 10 using known interweaving ("splicing") techniques. When properly executed, interwoven section 24 will have a break strength equal to or greater than the break strength of the cable itself. As explained previously, the break strength of the high-performance termination (created by attaching anchor 18) will typically be somewhat less than the break strength of the cable (though possibly quite close).

Thus, in the assembly of FIG. 5 the "weak link" is the termination. However, the termination has been tested (such as by the rig of FIG. 6) and certified to exceed a specified break strength. Thus, the assembly as a whole in FIG. 5 (a "composite cable") may be certified as having a break strength in excess of the tested amount.

At this point it may be natural to wonder why a composite cable is needed and ask instead why one would not simply attach the anchor to one end of long cable 10 and dispense with the need for the interweaving process. There are several reasons why such an approach would be undesirable. First, long cable 10 is often extraordinarily long. It is not unusual for such a cable to be 5,000 meters or more in length. Such a cable is often rolled onto a large and heavy drum. It is not a simple matter to move such a large cable and bring it into a controlled facility for the addition of an anchor.

Second, it is generally true that a test such as shown in FIG. 6 must be carried out by a device on one end of the cable that engages the anchor and a device on the other end that engages the free end of the cable. Thus, the length of the cable being tested determines the length of the apparatus required to test it. For example, it is not preferable to engage a synthetic cable at some mid-point and then apply considerable tension. The test of FIG. 6 shows the free end of the cable being wrapped around a drum and secured. Five or ten turns

may be needed to adequately secure the cable to the drum. Applying the drum-wrap at the mid-point of the cable would likely produce slippage between the cable strands and a degradation of the cable's performance. Thus, the cable must be tested it by holding it at its ends and applying tension.

Therefore, the distance between the drum and the test loading device 30 will determine the length of the cable that can be tested. A large facility might have a test fixture that is 50 meters in length, but a longer fixture is rare. It is also not generally feasible to have a "mobile" end point such as a moving vehicle. Static testing of such cables often requires huge tensile forces – such as 250,000 pounds. No vehicle remains stationary during the application of such a force. Even static structures must be carefully designed to withstand such forces.

Since one of the significant features of the present invention is the actual testing of the high-performance termination, it is important for short cable 26 to have only a moderate length. Preferably it is less than 100 meters in length and may in fact be much shorter. The length selected for short cable 26 will of course determine the location of the interwoven section.

Returning now to FIG. 5, the reader will note that interwoven section 24 is thicker than the other portions of the composite cable. This added thickness can cause problems when running the interwoven section over pulleys or other devices. Thus, the location of the interwoven section is preferably considered when creating a composite cable. The pulleys and other feeding devices can be designed to accommodate the added thickness of interwoven section 24. However, it is generally undesirable to have interwoven section 24 pass around a pulley or other bend while it is heavily loaded.

FIG. 7 shows one representative application for a composite cable made according to the present invention. Crane 34 is mounted on oil platform 32, well above sea surface 38. Composite cable 36 extends down into the water where it is connected to payload 42 resting on sea floor 40. In this simple example, sea floor 40 might lie at a depth of 3,000 meters below sea surface 38. It is apparent from this diagram that the interwoven section of composite cable 36 lies well underwater at this point and in fact will be quite close to sea floor 40.

However, when the crane reels in composite cable 36 the interwoven section will be pulled up toward the surface. FIG. 8 shows a closer view of crane 34. Crane 34 includes drum 48 which is used to pay off and reel in composite cable 36. Boom 35 mounts tip sheave 50, over which the cable passes. Max hook height 44 represents the maximum height to which the crane can lift the payload.

As those skilled in the art will know, the load imposed on the cable by payload 42 varies substantially depending upon whether the payload is immersed in the sea or lifted clear into the air. The weight of an object immersed in water is reduced by the weight of the volume of water displaced by the object. This concept is generally referred to as Archimedes Principle. For a typical solid structure, its weight in water is less than ½ its weight in air.

Crane designers working in offshore applications carefully consider Archimedes Principle. The water's surface is not stationary in offshore applications but rather moves with each passing swell. Thus, there is often not a clearly defined surface level. Instead, the engineers refer to a "splash zone" having a lower boundary and an upper boundary. They consider that the payload could be lifted free of the water anywhere within this "splash zone."

It is the lower extreme of the splash zone that is often most important. Lower splash boundary 46 is shown in FIG. 8. At any time that payload 42 is lifted above this height it might in fact be free of the water and the composite cable would then be subjected to the full weight of the payload in air.

Designers in this off-shore application might decide that the interwoven section of the composite cable needs to be on drum 48 before payload 42 is lifted above lower splash boundary 46. They may further conclude that the interwoven section needs to have five turns on the drum between itself and the paid off portion of the cable when payload 42 is lifted above lower splash boundary 46. These criteria represent examples of design constrains that determine the length of short cable 26 in a particular application.

FIG. 9 shows a different application with different selection criteria. Dragline crane 52 has a large boom 54 with an attached top sheave 50. Lifting cable 56 passes through top sheave 50 and down to bucket 60. Dragging cable 58 pulls bucket 60 toward the crane's cab during the digging cycle.

In this example interwoven section 24 is located far enough above anchor 18 to prevent its falling into the very hostile environment existing around the bucket and its

associated rigging. However, interwoven section 24 is also located low enough so that it is never pulled over top sheave 50 during the normal operation of the dragline crane.

The reader will thereby perceive the advantages offered by a composite cable constructed of a short cable with an attached high-performance termination that is connected to a long cable. Additional optional features and combinations include:

1. Attaching a short cable with a high-performance termination to both ends of a long cable;

2. Attaching a short cable to a long cable using interlocking eye splices as shown in FIG. 2; and

3. Attaching a short cable to a long cable using other known and trusted techniques.

Although the preceding description contains significant detail, it should not be construed as limiting the scope of the invention but rather as providing illustrations of the preferred embodiments of the invention. Those skilled in the art will be able to devise many other embodiments that carry out the present invention. Thus, the language used in the claims shall define the invention rather than the specific embodiments provided.