

Nov. 14, 1967

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3,352,098

MULTI-ELEMENT WIRE LINE HAVING COMPACTED STRANDS

Filed Dec. 23, 1964

4 Sheets-Sheet 1

FIG. 1

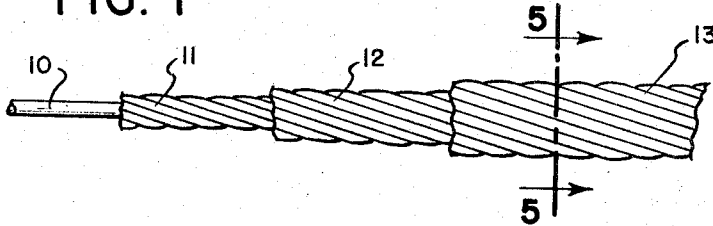


FIG. 2

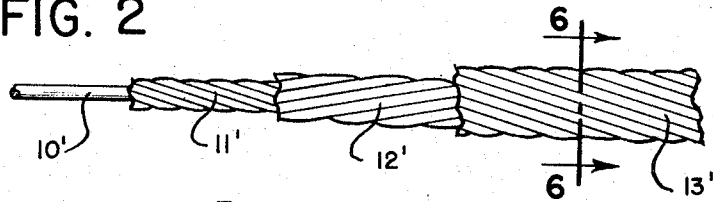


FIG. 3

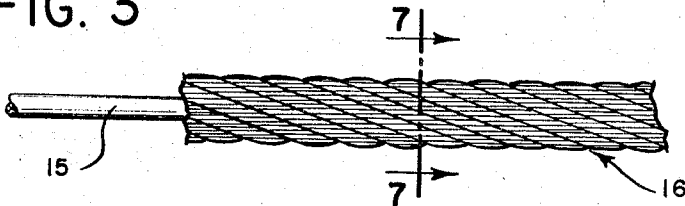


FIG. 4

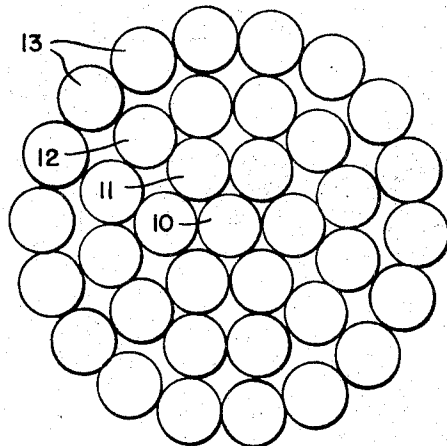
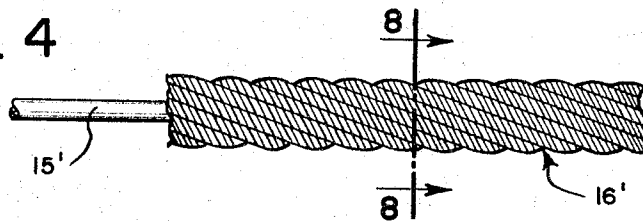


FIG. 5

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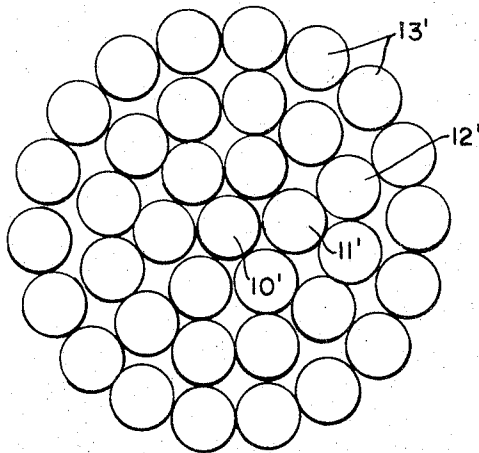


FIG. 6

FIG. 7

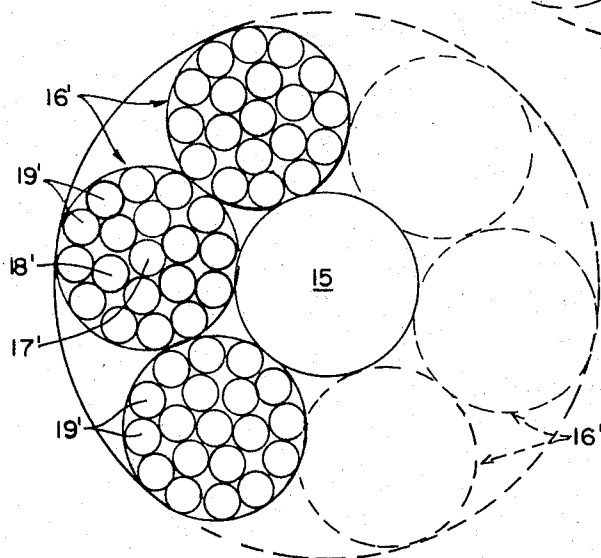
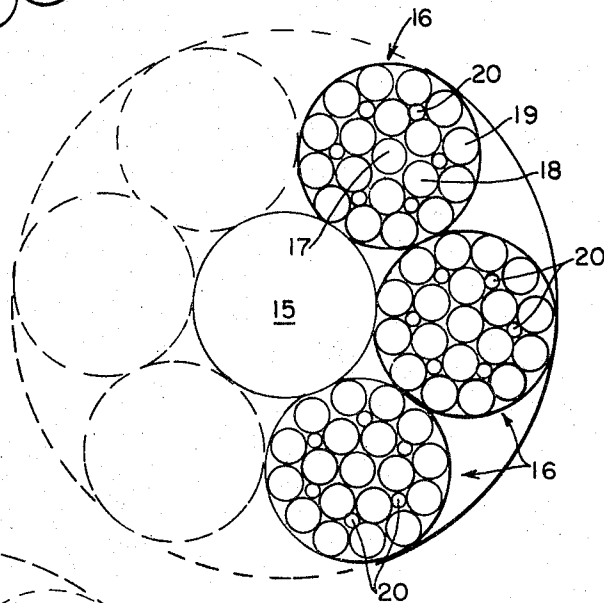


FIG. 8

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FIG. 9

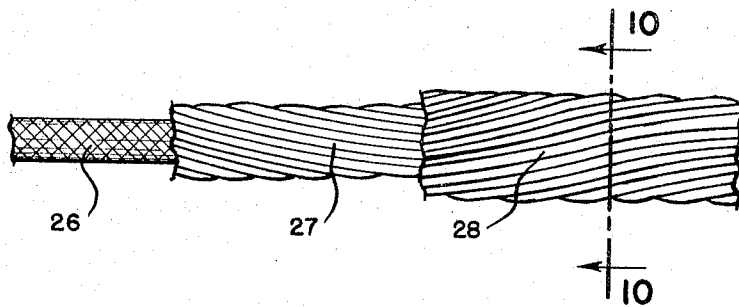
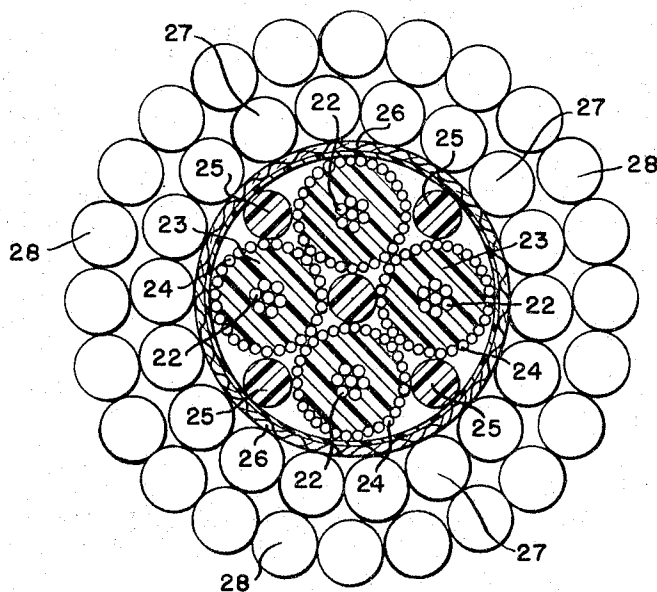


FIG. 10



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FIG. 11

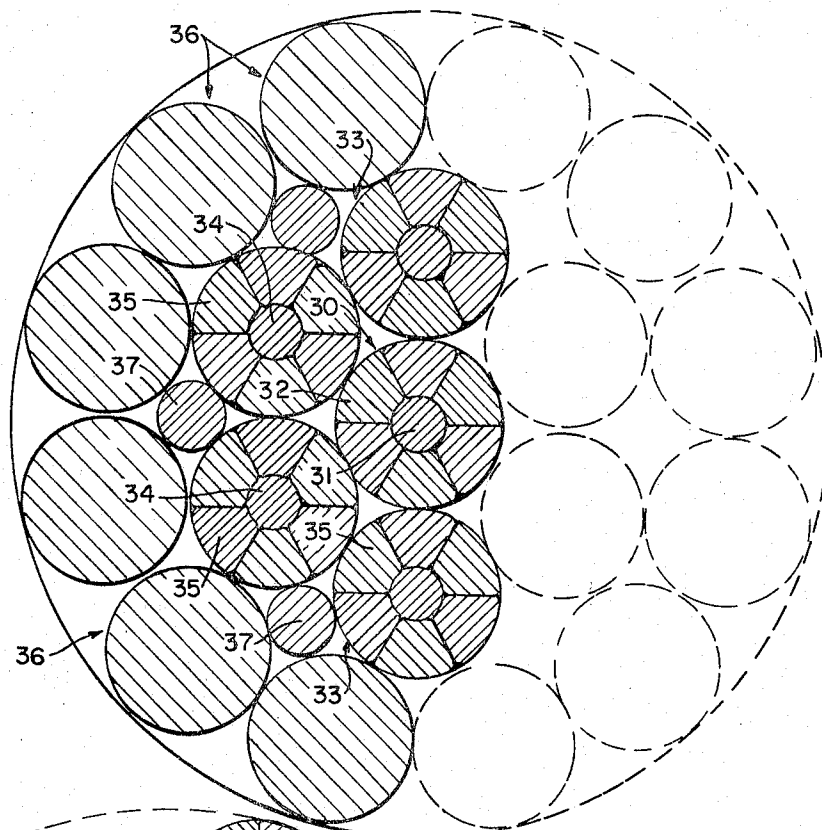
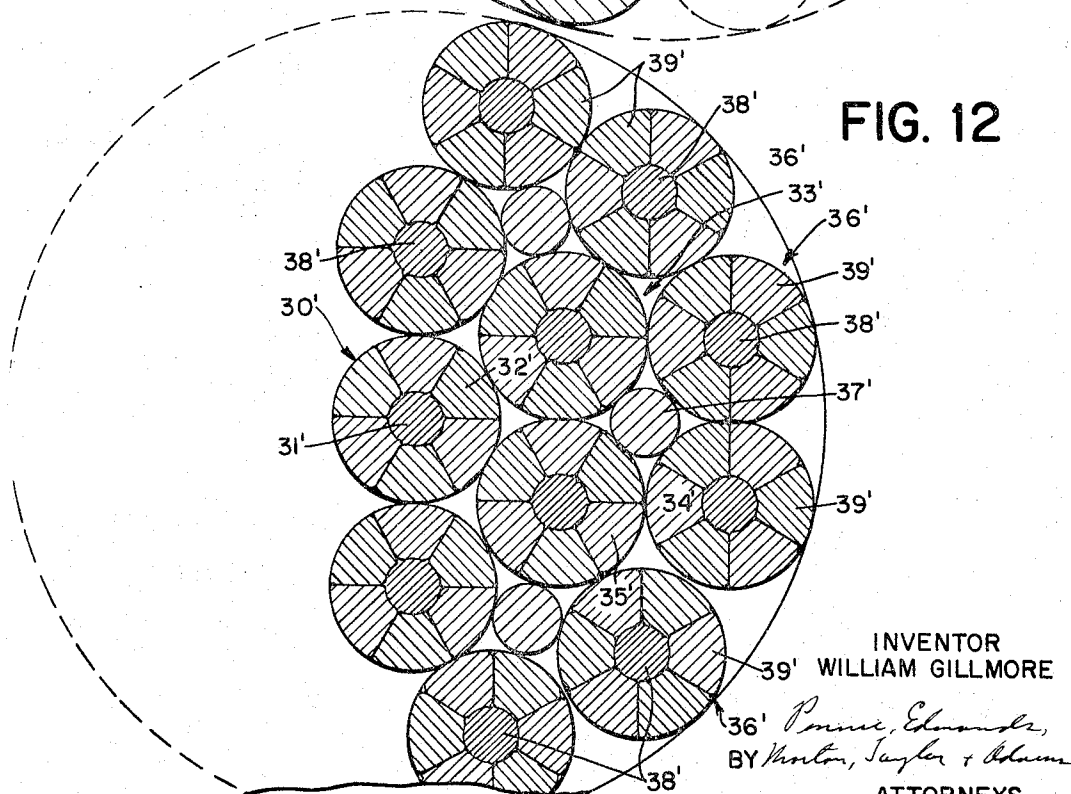


FIG. 12



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MULTI-ELEMENT WIRE LINE HAVING COMPACTED STRANDS

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23 Claims. (Cl. 57-147)

ABSTRACT OF THE DISCLOSURE

Wire strand, rope or cable made up of elongated elements arranged in groups which are disposed symmetrically about the center line of the structure, each of the elements being formed of a center sub-strand comprising a central wire and surrounding helical wires, and one or more layers of surrounding helical sub-strands each comprising its own central wire and surrounding helical wires, every one of the center and helical sub-strands being individually pre-reduced so that the wires thereof are compacted together and the exterior surface thereof is substantially smooth.

This invention relates to wire line which includes a multiplicity of helical elements divided into a plurality of groups disposed symmetrically about the longitudinal axis of the line. More particularly, it relates to wire line of this type wherein each of a plurality of these elements comprises a smooth reduced compacted strand.

Wire line generally includes two types, strand and rope. Strand consists of a core wire and one or more concentric layers of helical wires laid about the core wire. The layers of helical wires may have a lay of the same direction or every other layer may have a lay opposite in direction to those adjoining it. Wire rope, on the other hand, comprises a core of various materials, such as hemp, wire or strand, and a layer of multi-element wire strands laid helically about the core. The wires in each of the strands may have a lay which is the same as or opposite to the direction of the strands themselves. Wire line can also include tension-bearing electrical cable which may consist of one or more layers or strands of wire applied concentrically about an inner construction of electrical conductors; such line is referred to herein as "cable" for convenience.

There are certain current uses of wire strand, rope, and cable which require optimum flexibility, fatigue life, and tensile strength, and it is the general purpose of this invention to provide the most advantageous combination of these advantages. The invention is founded on the discovery that wire monofilaments of common rope, strand and cable may be substituted to great advantage by groups of fine sub-strands which are each individually pre-reduced into a smooth-surfaced compacted condition. There are many benefits to be gained from this advance in the art and they are particularly applicable to extremely demanding requirements such as those imposed upon wire lines used for aircraft arresting gear and catapults where the rope or strand must often be passed over sheaves rapidly under very high tension and impact loading.

Broadly stated, the wire line of the invention includes a multiplicity of helical elements divided into a plurality of groups, each of the groups being disposed symmetrically about the longitudinal axis of the line. Where each of these elements in the prior art has consisted of a wire monofilament at least some of them in the wire line of the invention are subject to a significant improvement in design. The improvement is that each of a plurality of these elements comprises a center sub-strand formed of a central wire and at least one layer of side-by-side helical

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wires surrounding the central wire. At least one layer of side-by-side helical sub-strands surround the center sub-strand, and each of these helical sub-strands comprises a central wire and at least one layer of side-by-side helical wires surrounding the central wire. Each of the center and helical sub-strands is in an individually pre-reduced condition with the wires thereof deformably compacted together and the outer surface thereof substantially smooth.

By mentioning above that the helical elements are divided into a plurality of groups, each of strand, rope and cable is contemplated. If a given group of the elements is in a concentric array disposed about the core element, it is a strand; if the group of elements is a multi-layer strand laid helically about the core, it is rope; and if the elements are laid about electrical conductors to lend them tensile strength, it is what is referred to here as cable. In any case, by substituting the fine sub-stranded elements of the invention for the wire monofilaments which previously have served as these elements, surprising advantages are produced in the performance of the line under severe operating conditions.

Greatly increased fatigue life results from this construction and therefore the line may be passed rapidly over sheaves without failure. This is because in a typical sheave system the bending stresses imposed upon the very fine wires of the sub-strands of the invention are far less than those imposed upon the larger wires of conventional line. Because compacted sub-strands are substituted for wires, there is a marked reduction of mass and lesser metallic area for identical sizes of line. This reduction is in the order of twelve percent and it greatly minimizes the inertial effects of strand, rope or cable subject to rapid acceleration or deceleration. Also, the tensile strength of the wire line of the invention is greater, even though there is less mass and metallic cross-sectional area as compared to wire strand, rope or cable of similar sizes which are of standard construction. It is possible to double the strength of a given size wire line made in accordance with the invention and still retain sufficient flexibility for acceptable fatigue life in a sheave system.

Preferred embodiments of the invention are described hereinbelow with reference to the accompanying drawings, wherein

FIG. 1 is a fragmentary elevation of a regular lay strand adapted to the invention;

FIG. 2 is a fragmentary elevation of a cross-lay strand adapted to the invention;

FIG. 3 is a fragmentary elevation, of a regular lay rope adapted to the invention;

FIG. 4 is a fragmentary elevation of a lang lay rope adapted to the invention;

FIG. 5 is an enlarged section taken along the line 5-5 of FIG. 1 showing how the elements of the FIG. 1 strand are grouped;

FIG. 6 is an enlarged section taken along the line 6-6 of FIG. 2 showing how the elements of the FIG. 2 strand are grouped;

FIG. 7 is an enlarged section taken along the line 7-7 of FIG. 3 showing how the elements of the FIG. 3 rope are grouped;

FIG. 8 is an enlarged section taken along the line 8-8 of FIG. 4 showing how the elements of the FIG. 4 rope are grouped;

FIG. 9 is a fragmentary elevation of a co-axial electrical cable adapted to the invention;

FIG. 10 is an enlarged section taken along the line 10-10 of FIG. 9 showing how the elements of the FIG. 9 cable are grouped;

FIG. 11 is an enlarged section showing the details of one form of at least some of the elements of FIGS. 1 to 10; and

FIG. 12 is an enlarged section showing the details of another form of at least some of the elements of FIGS. 1 to 10.

In the strand as shown in FIGS. 1 and 5, a core element 10 is surrounded by a first layer of six side-by-side helical elements 11, a second layer of twelve side-by-side helical elements 12, and a third or outer layer of eighteen side-by-side helical elements 13. All of these elements are of more or less the same nominal diameter and they are arranged concentrically about the axis of the strand. Proper dimensioning will cause them to nest together so that each element engages all those around it in substantially line contact therewith. The layers of elements 11, 12 and 13 in the FIG. 1 strand are all of the same lay direction so that each helical element is disposed parallel to those adjacent it without crossing them. This form can be referred to as regular lay strand.

The strand shown in FIGS. 2 and 6 is the same as that of FIGS. 1 and 5 except that it is of cross lay construction. Thus it has a core element 10', six first layer helical side-by-side elements 11', twelve second layer helical side-by-side elements 12' of a lay opposite in direction to the first layer elements 11', and eighteen third or outer layer helical side-by-side elements 13' of a lay direction opposite to that of the second layer elements 12' and the same as that of the first layer elements 11'. Again the layers are concentrically arranged and all the elements are of the same diameter. However, only in a given layer do the elements lie parallel to those alongside them in line contact therewith, while from one layer to the next the elements cross over each other because of their opposite lay. This cross lay form does not tend to untwist under tension as regular lay strand does.

In FIGS. 3 and 7, a wire rope construction is shown. It includes a core 15 which may be of hemp or other non-metallic material, a single wire monofilament, or a strand of several elements. Six helical side-by-side strands 16 surround the core 15 in line contact with one another. Each of the strands 16 is formed of a core element 17, a first layer of helical side-by-side elements 18, and a second or outer layer of helical side-by-side elements 19. The lay of the elements 18 and 19 in each strand is of a direction which is opposite to that of the strands 16 about the core 15, and therefore the outer layer elements 19 of the strands 16 appear substantially parallel to the longitudinal axis of the rope as viewed in FIG. 3. This can be referred to as regular lay rope. It should also be noted that six helical filler elements 20 are included in regular lay rope such as this between the second or intermediate layer of elements 18 and the third or outer layer of elements 19 in the interstices between those layers.

The wire rope of FIGS. 4 and 8 differs mainly from that of FIGS. 3 and 7 only in that it is of lang lay rather than regular lay construction. It includes a core 15' of one of the aforementioned materials and six helical side-by-side strands 16' surrounding the core 15' in line contact with one another. Each of the strands 16' is formed of a core element 17', a first layer of helical side-by-side elements 18' and a second or outer layer of helical side-by-side elements 19'. The lay of the elements 18' and 19' in each strand is of a direction which is the same as that of the strands 16' about the core 15', and therefore the outer layer elements 19' of the strands 16' appear substantially skewed with respect to the longitudinal axis of the rope as viewed in FIG. 4. It is this characteristic which is referred to as lang lay.

In FIGS. 9 and 10, a coaxial electrical cable is shown which is reinforced with tension-bearing elements. Four separate central conductors 22 are each surrounded first by a layer of dielectric material 23 and then by a braided outer conductor 24. Plastic monofilaments 25 serve as fillers. Around all these elements is a multi-layer covering, the exterior of which is defined by a fibrous braided sheath 26 impregnated with dielectric material. This completes the typical current-carrying coaxial cable part of the as-

sembly, but to lend it strength a first layer of eighteen elements 27 followed by a second layer of twenty-four elements 28 of opposite lay have been helically applied about the coaxial cable.

Each of these wire lines (i.e., the strand of FIGS. 1 and 2, the ropes of FIGS. 3 and 4), and the coaxial cable of FIGS. 9 and 10 includes a multiplicity of elements (i.e., the elements 10-13, 10'-13', 17-20, 17'-19', 27-28) which are divided into a plurality of groups (i.e., the core and three concentric layers in the strands of FIGS. 1 and 2, the six strands in the rope of FIGS. 3 and 4, and the two concentric layers in FIGS. 9 and 10), each of the groups being disposed symmetrically about the longitudinal axis of the line. In conventional strand, rope and cable available heretofore each of these elements 10-13, 10'-13', 17-20, 17'-19', and 27-28 has been a monofilament of wire. For certain demanding uses, the ability of such line to withstand abrasion, repeated bending, impact loading, and high tension has been less than satisfactory. It is the general purpose of this invention to correct these shortcomings by improving upon the elements of at least some of the aforementioned groups in the line. In place of wire monofilaments, the invention provides that each of several of the elements 10-13, 10'-13', 17-20, 17'-19', and 27-28 be of the form shown in FIGS. 11 or 12.

In the FIG. 11 element, a center sub-strand 30 comprises a central wire 31 and one layer of six side-by-side helical wires 32 surrounding the central wire 31. A layer of six side-by-side helical sub-strands 33 surrounds the center sub-strand 30 and each of the sub-strands 33 comprises a central wire 34 and one layer of side-by-side helical wires 35 surrounding the central wire 34. About the layer of sub-strands 33 is an outer layer of twelve side-by-side helical monofilament wires 36. All of the sub-strands 30 and 33 and the outer wires 36 are of more or less the same diameter so that they nest together in approximately line contact with one another. Six smaller filler wires 37 may be disposed in the interstices between the layers of sub-strands 33 and the outer wires 36.

In addition to substituting the elements of the FIGS. 1-10 strand, rope and cable with the structure of FIG. 11, the invention provides that each of the center and helical sub-strands 30 and 33 of that structure are in an individually pre-reduced condition with the wires 31, 32 and 34, 35 thereof deformably compacted together and the outer surface thereof substantially smooth. This is done by following the stranding operation of each of the sub-strands 30 and 33 with a reducing step, such as swaging, in which they are radially compressed before they are stranded together to form the element of FIG. 11.

In the alternate form of FIG. 12, the only departure is that the twelve outer monofilament wires 36 are replaced by sub-strands. Thus, in the form of FIG. 12 a center sub-strand 30' comprises a central wire 31' and one layer of six side-by-side helical wires 32'. A layer of six side-by-side sub-strands 33' surrounds the center sub-strand 30' and each of the sub-strands 33' comprises a central wire 34' and one layer of six side-by-side helical wires 35' surrounding the central wire 34'. About this first layer of sub-strands 33' is an outer layer of twelve side-by-side helical sub-strands 36', each of which comprises a central wire 38' surrounded by six side-by-side helical wires 39'. Again, all of the sub-strands 31', 33' and 36' are of approximately the same diameter to permit them to nest together in substantially line contact with one another. Six smaller filler wires 37' may also be disposed in the interstices between the layers of sub-strands 33' and 36'. As in the previous FIG. 11 element, the FIG. 12 form has each of its sub-strands 30', 33' and 36' pre-reduced into a smooth compacted state.

In accordance with the invention, either the FIG. 11 or FIG. 12, or evident variations thereof, may be used in place of some or all of the elements which heretofore have been wire monofilaments in the strand, rope and cable of FIGS. 1-10. One particularly advantageous application of

this concept to the strand of FIGS. 1 and 2 is to have all the elements 10-13 and 10'-13' thereof in one of the two forms represented by FIG. 11 or 12. In the regular and lang lay rope shown in FIGS. 3 and 4, either of the forms of elements may be used for all the elements thereof which had been monofilaments of wire, except for the core 15, and even that could be substituted by a strand of either of the FIG. 11 or 12 elements is desired. The multiplicity of combinations of elements embodying this concept should be evident.

In one preferred form of the invention a regular lay wire rope such as that shown in FIGS. 3 and 7 was fabricated. The core 15 was of hemp and each of the six strands 16 was applied about it to form what could otherwise be designated as 1 3/4 inches 6 x 19 filler-wire regular lay wire rope. However, each of the nineteen elements 17-20 of the six wire strands 16 was formed in accordance with the modification of FIG. 12. In each such element, the center sub-strand 30' was a 1 x 7 smooth reduced strand of .102 inch diameter, each of the first layer sub-strands 33' was a 1 x 7 smooth reduced strand of .095 inch diameter, and each of the outer or third layer sub-strands 34' was a 1 x 7 smooth reduced strand of .088 inch diameter. The filler wires 37' were each a wire monofilament of .041 inch diameter. Consequently, each of the FIG. 11 or 12 elements used in the rope was a 1 x 133 strand.

In a comparative test conducted on the coaxial cable assembly of FIGS. 9 and 10, two samples were identical in all respects except that one had 1 x 7 compacted strand such as that shown in FIG. 12 while the other had wire monofilaments for the elements 27 and 28. The former survived 167,157 reversals in a fatigue bending test which the latter failed after only 5,313 reversals.

The bending stresses imposed upon the very fine wires included in sub-strands formed into elements for strand, rope or cable in accordance with the invention are considerably less than the bending stresses imposed upon wire monofilaments previously used for those elements. As a result, the new line is especially suited for sheave systems where it is repeatedly flexed under tension. A given size line in which the FIG. 11 or 12 elements are included can have an ultimate tensile strength twice that of conventional strand, rope or cable, and with substantially less mass per unit length and metallic cross-sectional area. Not only does this conserve material, but it makes the line considerably lighter, and less subject to the inertial effects or rapid acceleration and deceleration. At the same time, the flexibility of the strand, rope or cable embodying the invention is markedly superior to that of its conventional counterparts.

I claim:

1. In a wire line which includes a multiplicity of elements divided into a plurality of groups, each of said groups being disposed symmetrically about the longitudinal axis of the line, said wire line being improved in that each of a plurality of said elements comprises

(a) a center sub-strand comprising a central wire and at least one layer of side-by-side helical wires surrounding the central wire, and

(b) at least one layer of side-by-side helical sub-strands surrounding the center sub-strand, each of said helical sub-strands comprising a central wire and at least one layer of side-by-side helical wires surrounding the central wire, and

(c) each of said center and helical sub-strands being in an individually pre-reduced condition with the wires thereof deformably compacted together and the outer surface thereof substantially smooth.

2. In a wire strand which includes a core element, at least one intermediate layer of side-by-side helical elements surrounding the core element and an outer layer of side-by-side helical elements surrounding the intermediate layer, said strand being improved in that each element of at least one of said intermediate and outer layers comprises

(a) a center sub-strand comprising a central wire and at least one layer of side-by-side helical wires surrounding the central wire, and

(b) at least one layer of side-by-side helical sub-strands surrounding the center sub-strand, each of said helical sub-strands comprising a central wire and at least one layer of side-by-side helical wires surrounding the central wire, and

(c) each of said center and helical sub-strands being in an individually pre-reduced condition with the wires thereof deformably compacted together and the outer surface thereof substantially smooth.

3. A wire strand according to claim 2 wherein the lay of the intermediate and outer layers of helical elements surrounding the core element is of opposite direction from one such layer to the next.

4. A wire strand according to claim 2 wherein the lay of the intermediate and outer layers of helical elements surrounding the core element is of the same direction in all such layers.

5. A wire strand according to claim 2 wherein all elements of the strand comprise said center and helical sub-strand.

6. A wire strand according to claim 2 wherein there are a plurality of layers of helical sub-strands surrounding the center sub-strand in each element.

7. A wire strand according to claim 6 wherein all layers surrounding each center sub-strand are comprised of said side-by-side helical sub-strands.

8. A wire strand according to claim 6 wherein the outermost layer surrounding each center sub-strand is comprised of side-by-side helical wires.

9. A wire strand according to claim 6 wherein filler wires are disposed in interstices between said layers surrounding each center sub-strand.

10. In a wire rope which includes a core and at least one layer of helical side-by-side wire strands surrounding the core; each strand including a core element, at least one intermediate layer of side-by-side helical elements surrounding the core element, and an outer layer of side-by-side helical elements surrounding the intermediate layer; said rope being improved in that in each of said strands each element of at least one of said intermediate and outer layers thereof comprises

(a) a center sub-strand comprising a central wire and at least one layer of side-by-side helical wires surrounding the central wire, and

(b) at least one layer of side-by-side helical sub-strands surrounding the center sub-strand, each of said helical sub-strands comprising a central wire and at least one layer of side-by-side helical wires surrounding the central wire, and

(c) each of said center and helical sub-strands being in an individually pre-reduced condition with the wires thereof deformably compacted together and the outer surface thereof substantially smooth.

11. A wire rope according to claim 10 wherein the helical elements in each strand have a lay opposite in direction to that of the strands.

12. A wire rope according to claim 10 wherein the helical elements in each strand have a lay which is the same in direction as that of the strands.

13. A wire rope according to claim 10 wherein all elements of each strand comprise said center and helical sub-strands.

14. A wire rope according to claim 10 wherein there are a plurality of layers of helical sub-strands surrounding the center sub-strand in each element.

15. A wire rope according to claim 14 wherein all layers surrounding each center sub-strand are comprised of said side-by-side helical sub-strands.

16. A wire rope according to claim 14 wherein the outermost layer surrounding each center sub-strand is comprised of side-by-side helical wires.

17. A wire rope according to claim 14 wherein filler

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wires are disposed in interstices between said layers surrounding each center sub-strand.

18. In a tension-bearing electrical cable which includes an insulated conductor assembly and at least one layer of side-by-side helical elements surrounding the conductor assembly, said strand being improved in that each of said elements comprises

(a) a center sub-strand comprising a central wire and at least one layer of side-by-side helical wires surrounding the central wire, and

(b) at least one layer of side-by-side helical sub-strands surrounding the center sub-strand, each of said helical sub-strands comprising a central wire and at least one layer of side-by-side helical wires surrounding the central wire, and

(c) each of said center and helical sub-strands being in an individually preswaged condition with the wires thereof deformably compacted together and the outer surface thereof substantially smooth.

19. A cable according to claim 18 wherein there are two concentric layers of helical elements of opposite lay surrounding the conductor assembly.

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20. A cable according to claim 18 wherein there are a plurality of layers of helical sub-strands surrounding the center sub-strand in each element.

21. A cable according to claim 20 wherein all layers surrounding each center sub-strand are comprised of said side-by-side helical sub-strands.

22. A cable according to claim 20 wherein the outermost layer surrounding each center sub-strand is comprised of side-by-side helical wires.

23. A cable according to claim 20 wherein filler wires are disposed in interstices between said layers surrounding each center sub-strand.

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W. S. BURDEN, *Assistant Examiner*.