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Orser

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[54] BRAIDED ROPE

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[63] Continuation-in-part of Ser. No. 65,965, Aug. 21, 1970, abandoned.

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[51] Int. Cl. D04c 1/12, H01b 7/04, H01b 7/18

[58] Field of Search 87/5-8; 174/120-124

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[57]

ABSTRACT

A plurality of strands are plaited together to form a rope. Each strand includes a plurality of yarns which are enclosed within a tubular braided cover and lie substantially parallel to the axis of the cover. An electrical conductor runs longitudinally within each of the strands.

12 Claims, 2 Drawing Figures

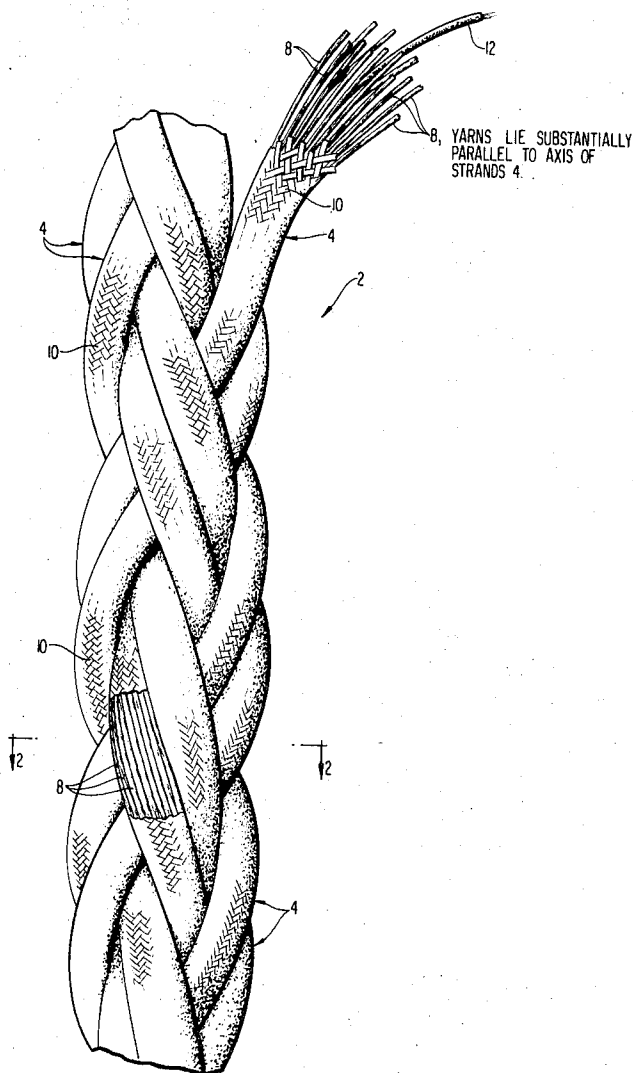


FIG. 1

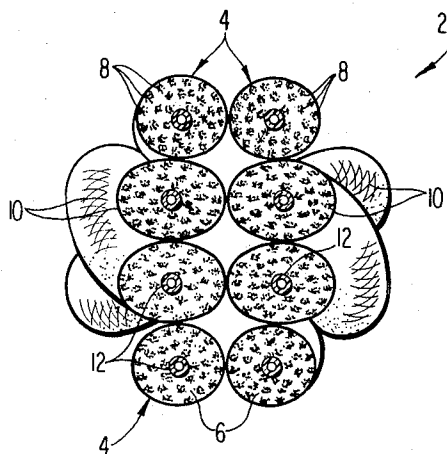
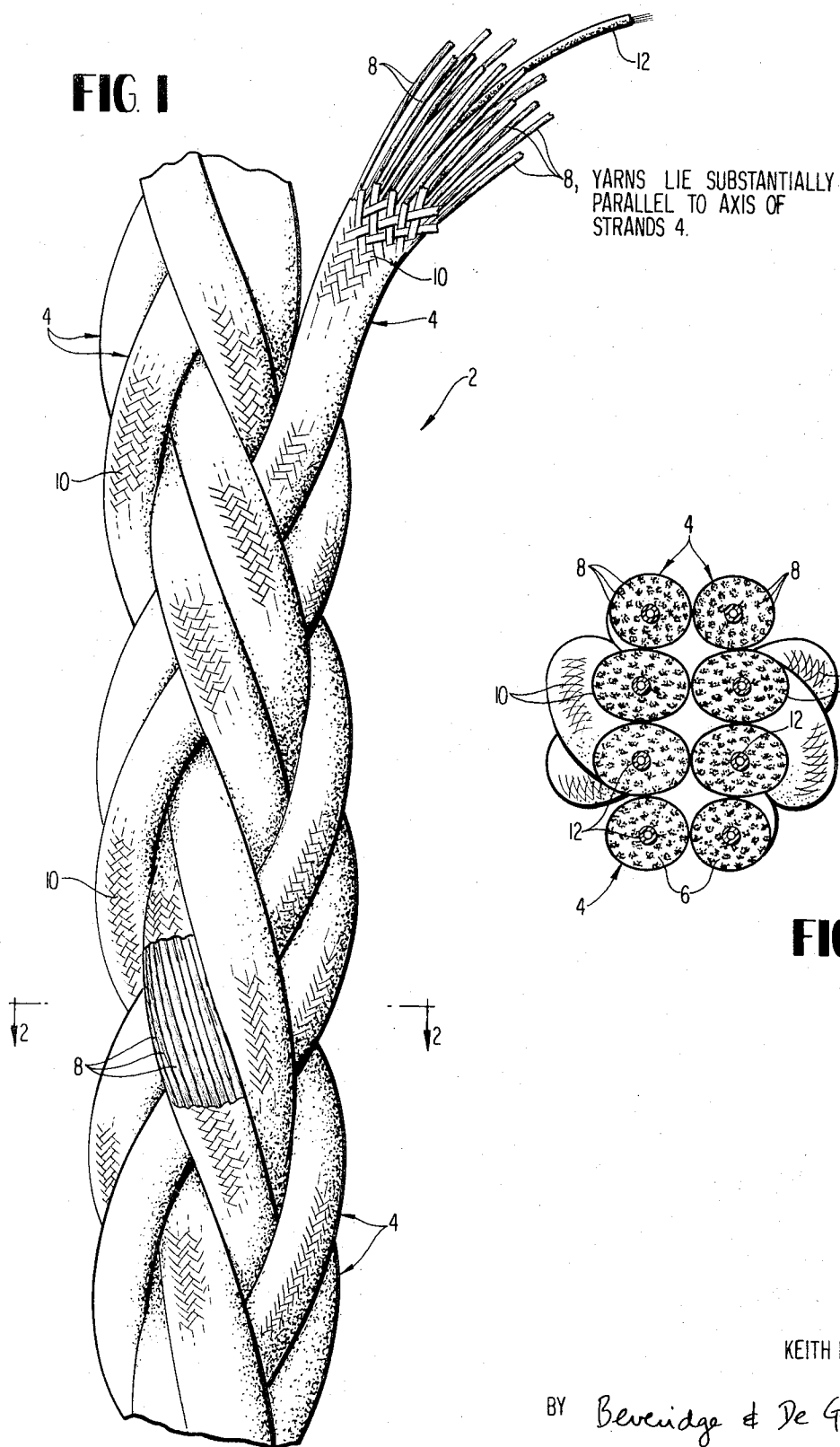


FIG. 2

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ATTORNEYS

BRAIDED ROPE

This is a continuation-in-part of my earlier application Ser. No. 65,965 filed Aug. 21, 1970, now abandoned.

This invention relates to a rope having unusually high strength and characteristics which enable it to function properly while passing over sheaves, drums, capstans and the like. Further, the rope has elongation characteristics which make it particularly suitable for carrying electrical conductors of the type used for mooring oceanographic buoys.

For centuries, it has been common to manufacture cordage products such as rope by twisting together a plurality of subunits to form a larger unit.

The basic unit in rope is a yarn which may be formed of staple fibers held together by twisting or continuous filaments which are twisted together. Yarns may be plied by twisting three of them together, and a plurality of single or plied units are then twisted together to form a strand. Strands may then be twisted together to form the rope. Each twisting operation is normally performed in a direction opposite to the preceding twisting operation, and factors such as diameters, fiber characteristics and intended usage are considered in determining the suitable amount of twist. If the laid rope is properly balanced, the resulting product is strong, flexible and able to maintain its integrity in use. However, under some conditions, it has been found that even properly balanced laid rope possesses a natural tendency to twist or untwist when suspending a weight, and there are occasions where laid ropes kink, hockle or form loops which at least causes serious inconvenience and probable local weakness.

A prior effort to overcome the disadvantages of conventional laid rope and to provide more flexibility is represented by a product sold under the trademark PLI-MOOR made by Columbian Rope Company, the assignee of the present invention. This construction is achieved by plaiting an even number of twisted strands together, in contrast to conventional twisting operations. Four pairs of strands are used, with half of the pairs being twisted in one direction and half in the other direction, with the plaiting operation being performed in a direction opposite to its twist. Such rope is completely neutral, having no predisposition to twist or turn in either direction, and no tendency to kink or hockle.

The PLI-MOOR rope discussed above, although ideal for many purposes, also suffers in loss in fiber strength utilization and increases in elongation over that of its fiber because of the multiplicative effects of twist on twist.

Briefly, the reason why the twisted structure possesses the disadvantages expressed above is that each of the units in the strand forms a helical path which lies at a certain angle, termed helix angle, with respect to its axis. This has a twofold effect on the breaking length or the strength of a rope of a given weight.

First, the contribution which the stress in a subunit makes to the stress in the unit in which it lies is the product of its straight tensile strength and the cosine of the helix angle; therefore, there is a loss in overall strength which increases with the helix angle which depends on amounts of twist and size of unit. This effect is multiplicative since there is a loss from a single end to the single ply yarn, from the single yarn to the three

ply yarn, from the three ply yarn to the strand and then from the strand to the rope. The reduced strength due to twist in any unit is the ratio of the length of the unit in helical form to its straight length. This ratio is the cosine of the helix angle. The overall reduced tensile strength is the product of the ratios or cosines of subunits and also of the laid or plaited rope. It is also the ratio of the rope length to the length of the smallest subunit. In ropes of conventional construction an individual element such as a filament may be 50 percent or more longer than the rope so that the strength of the rope may be less than 50 percent of the combined strength of the elements therein. Accordingly, only a percentage of the potential fiber strength is utilized in the rope.

A second effect of twist is that the weight of each unit per given length is increased over the sum of the weights of the subunits comprising it by the ratio of their lengths. This effect is likewise multiplicative, so that the weight of the finished rope per unit length is greater than the sum of the weights of the individual filaments comprising it by the product of the individual unit length ratios, which is the ratio of the length of a filament to the length of the finished rope.

Thus, this ratio not only reduces the strength of the rope, but increases its weight at the same time, so that it must be applied twice in considering the reduction in the strength of a rope of a given weight caused by the twist in its various elements. In other words, when it is necessary to have a rope of given strength characteristics, the weight per unit length of a conventional rope is much greater than of a rope constructed according to this invention.

Prior to this invention, there have been ropes typified by the product sold under the trademark NOLARO by the assignee of this invention which enclose a plurality of parallel members in an extruded jacket. The parallel elements are most often loosely twisted yarns of continuous synthetic filaments which produce a high strength to weight ratio. Unfortunately, this product is unsuited for many applications in that it lacks the requisite flexibility and in larger sizes are stiff and suffer a stress concentration when bent through a small radius as around a sheave, drum or capstan because the path of the outer parallel elements is somewhat larger than that of the inner ones. Such usage also tends to flatten the structure. A few years before arriving at the present invention, applicant's assignee sought to overcome these shortcomings by forming twisted and plaited rope with strands of the extrusion-jacketed NOLARO rope. Three-strand twisted ropes and eight strand plaited ropes were made using conventional rope manufacturing machinery. The resulting products exhibited some improvement, but were still considered to be too stiff for many uses.

It now has been discovered that the use of a textile covering for each of the plaited strands will provide the essential handleability of the rope, while providing a rope with a superior breaking length. According to present invention, the rope is formed of strands each of which includes a more flexible braided cover which encloses a plurality of units such as yarns which extend substantially parallel to the central axis of the tubular cover. The strands are plaited together in order to form a rope which avoids or minimizes the disadvantages outlined above which are inherent in previously known rope construction.

It has been found that this invention provides a rope which combines the desirable features of high strength to weight ratio, low elongation, flexibility, good handling properties, abrasion resistance and good wearing qualities. The product does not have a tendency to kink, hockle or loop, it has a very much improved strength to weight ratio, its elongation is relatively low and it is suited to many practical uses. One such use is in the mooring of oceanographic buoys where it is necessary to have electrical conductors extending through the rope from submerged sensing devices to a radio transmitting device on the buoy. The conductors carry signals which indicate oceanographic or other information which is transmitted to a monitoring station. The low elongation characteristics of rope made according to this invention will minimize the danger of breakage of the electrical conductor, and avoids the tendency of the conductor to work its way radially out of the strand of the rope when the rope is subjected to varying tensile forces.

The rope of this invention has a further advantage of affording a reliable visible warning when there is an impending loss of strength due to abrasive wear. This warning is given when the braided strand covering wears through, indicating that any further wear will occur in the load-bearing fibers which constitute the core of the strand. The visibility of such a warning may be improved by making the cover and the core of materials which have different colors.

A preferred embodiment of rope construction according to the invention is illustrated in the accompanying drawings wherein FIG. 1 is a side elevational view of the rope and FIG. 2 is a cross sectional view thereof taken along the line 2—2.

In the drawings, it will be seen that the rope 2 is formed of eight strands 4 which are plaited together in pairs so that each pair of strands runs together throughout the rope structure.

Each of the strands 4 has a core 6, formed of a plurality of yarns 8 which are held together by a tubular cover 10 which preferably is braided. The illustrated braided cover 10 may have a large helix angle and contribute little to the tensile strength of the construction but principally serves to hold the yarns together. The cover may also be designed to make a contribution to tensile strength. Preferably the weight of the tubular cover is no greater than about 20 percent of the weight of the strand excluding the conductor. Where high rope strength is the objective, the ratio of the weight of the cover to the weight of the strand should be as low as possible; however, where abrasion resistance is a prime consideration, the corresponding relative thickness and weight of the cover may be increased to about 45 percent for nylon and about 40 percent for Dacron and still retain an advantage in strength to weight over conventional constructions.

The core itself is formed of a plurality of yarns which extend substantially parallel to the axis of the cover 10. Each individual yarn may possess a twist, preferably slight in the order to about 0.5 - 0.8 turns per inch to facilitate their handling during manufacturing operations. The twist of the fibers within the core should be such that the length of any section of the strand is at least 99 percent of the length of a major portion, i.e. at least 50 percent, of the fibers which form that section.

For large rope sizes where the overall diameter is greater than 2.5 inches, it is desirable to give a very slack twist (about 0.6 to 0.9 turns per foot, preferably about 0.8 turns per foot) to the bundle of parallel yarns prior to applying the braid which holds them together. This makes the resulting rope sufficiently flexible to bend around bobbin barrels and pulleys of small diameter without distorting the braided jacket. This amount of twist is significantly less than the twist of 2.5 to 4.0 turns per foot used for conventional rope construction.

Extending centrally within each of the strands, there may be one or more insulated electrical conductors 12 which preferably is of the type described in U.S. Pat. No. 2,456,015. The low elongation characteristics of this rope structure reduces the danger of tensile failure of the electrical conductor 12 and reduces its tendency to work its way out of the structure, but most important, the braided cover positively contains the conductor and prevents it from popping out to the surface where it might be damaged by abrasion, etc. as is characteristic in conventional rope structures.

The strands are typically plaited together using a Herzog P36 or similar plaiting machine in substantially the same manner used for the previously-discussed PLI-MOOR construction, to provide the desired pick lengths.

The rope is preferably made of continuous nylon or polyester fibers such as Dacron; however, it may be made of any textile fibers used in rope construction such as rayon, polypropylene and the like. Many fiber combinations are possible. The cover may be of a different material from the core. Both core and cover can consist of more than one material. In some instances, it may be desirable to form the cover 10 of a material having special properties such as abrasion or heat resistance much superior to the core material, or to form the core from a less dense and more buoyant material than the cover. A core may include yarns of different textile fibers given different degrees of twist. For example, a buoyant rope may be made by using nylon and polypropylene core yarns, with the polypropylene yarns being given a greater twist than the nylon yarns, whereby both types of yarns will contribute to the strength of the rope and will have similar elongation-at-break properties.

To demonstrate the advantages of rope constructed according to the invention, experiments were conducted to compare physical characteristics with ropes of standard eight-strand plaited (Pli-Moor) and ropes of the construction of this invention. The results of this testing are presented in the following table:

TABLE 1

Rope	Nylon		Dacron	
	Pli-Moor	New	Pli-Moor	New
Circumference, inches.....	5½	5½	5½	5¼
Ft/lb. ¹	1.2	1.65	1.02	1.47
Lbs/ft. ¹	.833	.607	.98	.68
Breaking strength lbs.....	78,000	88,000	67,800	70,000
Breaking length ft. ²	93,600	145,000	69,150	103,000
Elongation at break percent, percent.....	50	25	35	16

TABLE 1-Continued

	Nylon		Dacron	
	Pli-Moor	New	Pli-Moor	New
Basic yarn (number × denier).....	6 × 2520	7 × 2520	16 × 1100	21 × 1100
Twist				
Single yarn				
TPI	2.3	.8	2.4	.8
3 ply yarn				
TPI	1.0	—	1.23	—
Strand yarn				
TPI	.38	—	.38	—
Length ratio.....				
Singles/1				
end.....	.985	.997	.975	.997
3 ply/singles...	.955	1.0	.955	1.0
Strand/3 ply...	.925	1.0	.925	1.0
Rope strand...	.78	.84	.78	.85
Rope/end (product of ratios).....	.68	.84	.67	.847

¹ Excludes weight of conductor.

² Calculated excluding weight of conductor which contributes little to strength.

It will be seen from the table that the nylon rope according to this invention is about 25 percent lighter than the standard nylon PLI-MOOR construction (in the order of about 0.23 lbs./ft. less in the improved construction). Despite the lighter weight, the breaking strength of the improved construction is greater, and

Additional samples were made and tested, using the improved construction in both nylon and Dacron in order to ascertain the relative characteristics of ropes made from these materials. In the case of the nylon ropes, the core is formed of 39 parallel yarns, each formed of 2520 denier DuPont 707 nylon given 0.8 turns per inch for handleability. The parallel yarns were passed through a braiding machine which applied the cover. The braiding machine had 32 carriers, each of which was supplied with three ends of 840 denier nylon. The braider provided 16.5 picks per inch. Ropes 5, 6 and 7 were stabilized by preshrinking them in hot water. In 100 feet of strand, the conductor weighed 0.675 lbs., the core weighed 5.30 lbs. and cover weighed 1.11 lbs. The core of the Dacron samples had 32 yarns per strand, each yarn being made of 21 ends of 1,100 denier Dacron 67 made and sold by the DuPont Company of Wilmington, Delaware. The cover was formed in a braider having 32 carriers, each supplying two ends of 1,100 denier Dacron 67. The conductor 12 is a special elastic insulated conductor having a resistance equal to No. 22 AWG. Each strand has a weight of 7.66 pounds per hundred feet, with the conductor contributing 0.57 pounds, the core contributing 6.2 pounds and the cover contributing 0.89 pounds. The total breaking strength of an individual strand was in excess of 11,000 pounds. Seven different test samples are described in the following table:

TABLE 2

	Rope							
	1	2	3	4	5	6	7	8*
	Material							
	Dacron	Dacron	Dacron	Nylon	Nylon	Nylon	Nylon	Dacron/ Nylon
Pick length (in.).....	5.75, dry or wet.	6.7, dry or wet.	8.6, dry or wet.	5.75, dry; 5.54, wet.	5.33, dry; 5.54 wet.	6.38, dry; 5.57, wet.	8.0, dry; 8.4, wet.	47/16.
Circumference (in.).....	5 1/4	5 1/8	5	5 1/2	5 1/8	5 7/16	5, wet.....	3 3/16, dry.
Lbs/100 ft. (total) dry.....	73.4	68.3	66.7	66.7	68.5	64.1	61.2	—
Lbs/100 ft. (fiber only) dry.....	68.1	63.2	61.6	60.4	62.6	58.4	55.3	21.8.
Length of strand per ft. of rope (in.) dry.	14.3	13 3/4	13.1	14.0	14.3	13.95	13.1	13.5.

*Rope of this invention having a braided cover of 2 × 1100-17 ppi Dacron 67 and a core of 3-28 × 2520 Nylon 718.

the breaking length which is the product of the breaking strength (expressed in pounds) and the rope weight (expressed in feet per pound) is considerably higher (about 55 percent higher). The table also shows a similar increase in breaking length for the Dacron rope.

Although breaking length is defined above, perhaps clarification of its significance is needed. Briefly, breaking length provides a method of comparing ropes of different weights, sizes, strengths and materials. To one experienced in the art, the increases in breaking length shown in Table 1 are extremely significant.

An explanation for these improved results may be found in the description of the length ratios in the preceding table where it will be seen that for any given length of one unit (units may be ends, singles, plies, strands or rope), the next smaller subunits have a greater length. The length of the PLI-MOOR rope, both in the case of nylon and Dacron, is only about 68 percent of the length of the fibers therewithin, contrasted to a figure of about 84 percent for improved rope made according to this invention.

The testing of these ropes, both in wet and dry conditions, produced the following results:

TABLE 3

Rope	Moisture condition	Percent elongation at breaking	Breaking strength (lbs.)	Breaking length (ft.)
1.....	Normal.....	21.2	70,000	103,000
	Wet.....	20	74,400	
2.....	Normal.....	17.5	82,000	130,000
	Wet.....	17.5	84,000	
3.....	Normal.....	16.8	95,400	155,000
	Wet.....	15.0	94,000	
4.....	Normal.....	26.5	88,000	145,000
	Wet.....	34.3	75,400	124,000
5.....	Normal.....	38.1	80,400	129,000
	Wet.....	31.2	74,000	118,000
6.....	Normal.....	33.3	88,000	151,000
	Wet.....	25.0	78,000	133,000
7.....	Normal.....	28.8	90,000	163,000
	Wet.....	25.0	84,200	152,000

Comparative abrasion tests were made with a variety of typical 1 inch diameter standard ropes made in U.S. of different materials and combinations thereof including laid three strand, plaited eight strand and double braid, and a 1 inch diameter rope made as per this invention. The strand of the invented rope consisted of a substantially parallel core of 3—28 × 2520 Type 718 DuPont nylon weighing 0.0165 lbs./ft. enclosed by a tubular braid of 32—2 × 1,100 DuPont 67 Dacron at 17 ppi weighing 0.0073 lbs/ft. The braided cover was applied by a conventional Butt braider. Eight such strands were plaited in pairs to form a rope 3 3/32 inch Circ., 4 7/16 inch pitch, having a strand to rope ratio of 13.5/12 and a weight of 0.218 lbs/ft. In the abrasion test, the newly invented rope moved longitudinally 12–14 inches, while under 628 lbs. tension, back and forth over an AlSiMg surface until the braided jacket was just barely worn through. It was found that 1,182 cycles accomplished this on wet rope. An attempt was made to subject standard ropes of the same size and different materials in standard constructions to this same number of wet abrasive cycles under the same load the travel distance. The complete test data is shown in Table 4 which follows:

ing length of about 70,000 ft. This test data not only shows the superiority which rope of this invention has over typical previous rope constructions in abrasion resistance but also clearly shows its superiority in breaking length.

On the basis of these tests, it will be appreciated by those skilled in the art that this rope does indeed have characteristics which are superior to prior ropes for many applications.

Its strength to weight ratio is much higher than for any other known construction. Its wet and dry abrasion resistance is unexpectedly good and superior to all other ropes and much superior to most. It has substantially lower elongation than conventional stranded ropes. Electrical conductors can be more readily incorporated and contained in it. In addition, it has the flexibility and other handling qualities needed for most applications. This unexpectedly superior combination of characteristics results from a novel combination of elements of construction disclosed in this application.

Obviously, the illustrated construction may be modified within the spirit of the invention to achieve the desirable result and characteristics attributable to this im-

TABLE 4

Type rope	Material	Nominal breaking strength (lbs.)	Nominal ft/lb.	Breaking length (ft.)	Wet abrasion cycles	Breaking strength after wet abrasion	Percent strength retained ea. of 2 Av/2
Rope of this invention.....	Dacron cover nylon core...	28,000	4.65	130,000	*1214 1182	28,250 24,350	100 87
Pli-Moor.....	Dacron.....	22,000	3.3	72,500	1182 1185	17,500 12,500	80 57
Pli-Moor.....	S. Duo-Syn.....	14,000	3.7	52,000	1022 1023	0 0	0 0
Pli-Moor.....	Duo-Syn.....	15,000	4.28	65,000	760 618	0 0	0 0
Pli-Moor.....	Nylon.....	25,000	3.8	95,000	255 442	0 0	0 0
Pli-Moor.....	Polypro.....	14,000	5.5	77,000	208 192	0 0	0 0
3 strand.....	Dacron.....	22,000	3.3	72,500	1182 1182	16,700 18,500	76 84
3 strand.....	S. Duo-Syn.....	14,000	3.7	52,000	1182 1182	10,600 10,100	76 72
3 strand.....	Duo-Syn.....	15,000	4.28	65,000	1182 1182	6,700 3,950	45 26
3 strand.....	Nylon.....	22,000	3.8	95,000	692 785	0 0	0 0
3 strand.....	Polypro.....	14,000	5.5	77,000	197 273	0 0	0 0
Double concentric braid.....	Nylon.....	28,000	4.0	112,000	*200 *166	395 346	0 0
Double concentric braid.....	Nylon/Polypro.....	25,000	4.0	100,000	*337 *375	998 891	0 0
Double concentric braid.....	Polyester/Polypro.....	28,000	3.56	100,000	1182 1182	20,800 26,100	75 93.5

*Cycles to wear through outer braid without damage to core yarns. Second identical specimen wore through and did slight damage to core yarns.

It will be noted that 1 inch rope according to this invention retained an average of 94 percent of its original strength while eight of the other ropes tested, including some containing as much polyester, wore completely through. The other five ropes did not wear through but lost more strength. With a 10 percent greater loss in strength, the rope having a polyester braid over a multi-pro braid had a breaking length of only 100,000 ft. compared with about 128,000 ft. for the rope of this invention. The 1 inch polyester three strand rope and plaited rope are much heavier and have a lower break-

provement. Further experimentation may show that ropes may be made of strands which are twisted together and bonded rather than being plaited together. It may be found that covers for the strands may be applied by wrapping a textile fiber cover around the core yarns rather than by braiding. Therefore, the invention is not limited to the disclosed embodiments, but encompasses all rope products falling within the terms and spirit of the claims which follow.

I claim:
1. A rope comprising a plurality of strands, each of

said strands being formed of a plurality of core yarns enclosed within a tubular braided cover of textile fibers, a major portion of the core yarns in the strand lying substantially parallel to the longitudinal axis of the cover, said strands being plaited together to form the rope structure, the weight of the tubular braided cover being no greater than about 20 percent of the combined weight of the cover and the yarns, and, for any longitudinal portion of the rope, the length of a strand being at least 99 percent of the length of a major portion of the yarns therein.

2. A rope according to claim 1 wherein there are only four pairs of strands with the strands in each pair running together and being plaited to the other pairs of strands.

3. A rope according to claim 2 wherein at least some of said strands have an electrical conductor extending longitudinally therewithin.

4. A rope consisting essentially of a plurality of inter-engaged strands which are plaited together; each of said strands including a plurality of fibers and a tubular braided cover of textile material surrounding the fibers to maintain the integrity of the strand, a length of the strand being at least 99 percent of the length of the major portion of the fibers therewithin, the weight of the tubular braided cover being no greater than about 20 percent of the combined weight of the cover and the fibers.

5. A rope according to claim 4 wherein there are only four pairs of strands with the strands in each pair running together and being plaited to the other pairs of strands.

6. A rope according to claim 5 wherein at least some of said strands have an electrical conductor extending longitudinally therewithin.

7. A rope comprising four pairs of strands engaged by having the strands in each pair running together and being plaited to the other pairs of strands, each of said strands being formed of a plurality of core yarns and a cover, said core yarns being substantially parallel to the axis of their respective strand, and each said cover being a tubular cover of textile yarns braided together to surround the core yarns of the respective strand, the weight of said cover being no greater than about 20% of the combined weight of the core yarns and cover.

8. A rope having low elongation characteristics for transmission of electrical signals, said rope comprising a plurality of strands, each of said strands being formed of a plurality of core yarns enclosed within a tubular

braided cover of textile fibers, a major portion of the core yarns in the strand lying substantially parallel to the longitudinal axis of the cover to impart low elongation characteristics to the strand, at least some of said strands including an electrical conductor which extends longitudinally therewithin parallel to the core yarns whereby the braided cover positively contains the electrical conductor and prevents its from popping out to the surface of the rope, said strands being plaited together to form the rope structure.

9. A rope comprising four pairs of strands engaged by having the strands in each pair running together and being plaited to the other pairs of strands, each of said strands being formed of a plurality of core yarns and a cover, said core yarns being substantially parallel to the axis of their respective strand, and each said cover being a tubular cover of textile yarns braided together to surround the core yarns of the respective strand, the weight of said cover being no greater than about 30 percent of the combined weight of the core yarns and cover.

10. A rope comprising a plurality of strands, each of said strands being formed of a plurality of core yarns enclosed within a tubular braided cover of textile fibers, a major portion of the core yarns in the strand lying substantially parallel to the longitudinal axis of the cover, said strands being plaited together to form the rope structure, at least some of the strands having an electrical conductor extending longitudinally therewithin.

11. A rope comprising a plurality of strands, each of said strands being formed of a plurality of core yarns enclosed within a tubular braided cover of textile fibers, a major portion of the core yarns in the strand lying substantially parallel to the longitudinal axis of the cover, said strands being plaited together to form the rope structure, the weight of the tubular braided cover being no greater than about 20 percent of the combined weight of the cover and the yarns.

12. A rope consisting essentially of a plurality of interengaged strands which are plaited together; each of said strands including a plurality of fibers and a tubular braided cover of textile material surrounding the fibers to maintain the integrity of the strand, a length of the strand being at least 99 percent of the length of a major portion of the fibers therewithin, at least some of the strands having an electrical conductor extending longitudinally therewithin.

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