April 2, 1940. H. W. JONES, JR 2,195,592

CORDAGE STRUCTURE AND METHOD OF MAKING SAME

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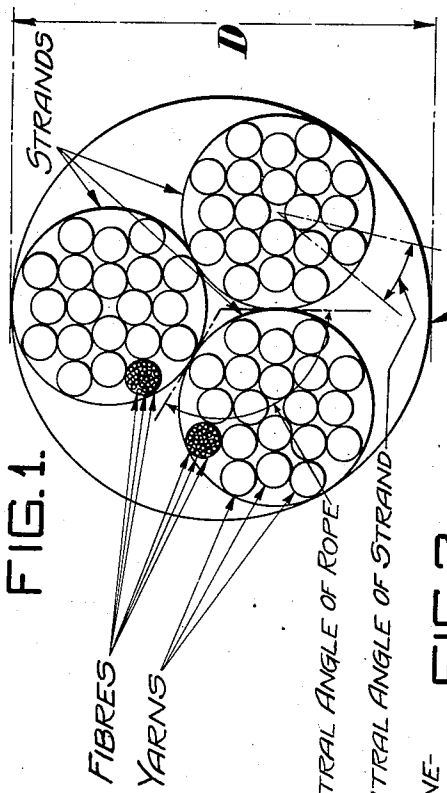


FIG. 1.

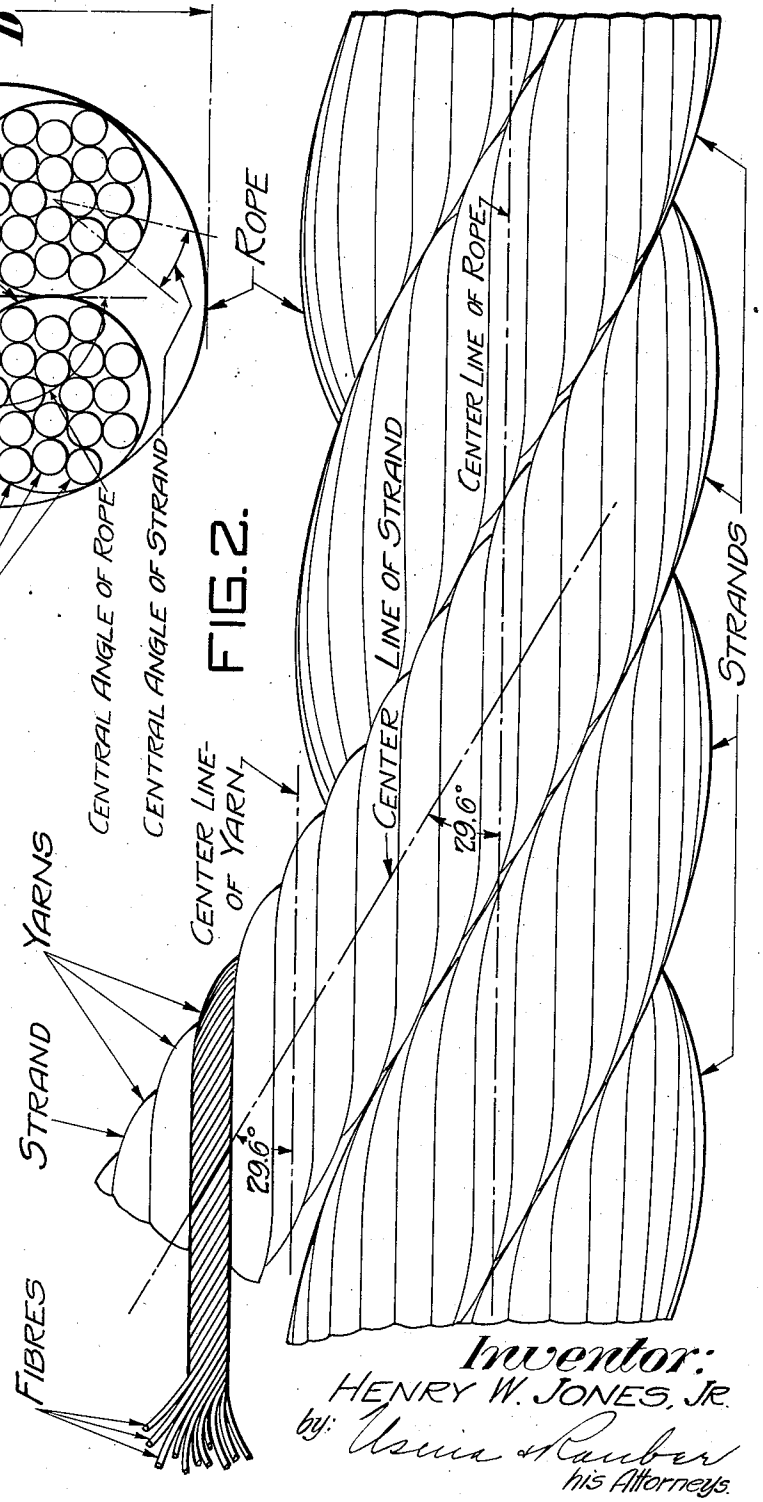


FIG. 2.

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CORDAGE STRUCTURE AND METHOD OF MAKING SAME

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5 Claims. (Cl. 57—144)

This invention relates to cordage and more particularly to cordage adapted for use as centers in wire ropes.

In the drawing:

Figure 1 is a diagrammatic cross sectional view of my rope center;

Figure 2 is a diagrammatic view showing the relation of the various elements of the rope.

In the manufacture of wire ropes, cables, and the like, it is customary to provide a rope of fibrous material to serve as a core or center about which the wire strands may be laid. The life and usefulness of the finished wire rope depend largely on the type of fiber center employed, and it is desirable and important that such core ropes possess certain characteristics which will be discussed hereinafter.

Due to the many variable factors necessarily entering into the fabrication of fiber rope, it has not heretofore been possible to provide rope centers having the desired characteristics with any degree of constancy and uniformity. A distinct difference in the behavior of rope centers made to the same weight and size by various cordage manufacturers in accordance with present day practices is apparent. A center made in accordance with certain specifications may prove satisfactory, but attempts to reproduce that center might yield a product that is highly unsatisfactory. Similarly, certain portions of a center rope may be well adapted for use as a wire rope core, whereas other portions of the same rope may be deficient in some respects.

This non-uniformity among rope centers, and within one rope center, is highly undesirable and is the result of many variable factors. These variables are occasioned by differences in the weight and size of component fibers; the resulting size of strands, and the lay of fibers and strands in the rope. In some cases, the ropes have soft portions that do not adequately support the overlying wires uniformly, whereby the wires are unduly flexed, distorted and strained in use. In other cases, the centers are too hard and highly compressed, whereby the compressing and flexing action of the wires on the center act to disintegrate the component fibers, thus breaking or weakening the rope center so as to seriously impair the life and utility of the wire rope.

Frequently, rope centers are made with excess fiber in their constituency to provide heavier and stronger cores. But, as this lends to the bulk of the rope, difficulty has been encountered in closing the wire strands about the center, which has rendered this practice undesirable.

The principal object of the present invention is the provision of a balanced rope center for wire ropes that will be absolutely uniform in weight, size and relation of parts throughout its length.

Another object is the provision of a method of manufacturing ropes having those uniform characteristics, and formulae for application to such method, which will insure faithful reproduction of ropes having the desired characteristics.

Other objects are the provision of fiber ropes having a maximum amount of fiber therein, thus affording increased weight and strength without impairing the ability to close them inside of wire ropes; the provision of ropes which will afford uniformity of support for the surrounding wires and which will be more durable due to the fibers being subjected to less distortion.

Other objects and advantages will become apparent hereinafter as the description proceeds.

According to the present invention, there is no radical departure made from the general practices followed in fabricating rope. That is to say, the rope will still consist of a plurality of strands; each strand will be composed of several yarns, and the direction of lay in yarns, strands and rope will be the same as that now produced by cordage mills. The differences which distinguish the present invention over conventional practices are: the number of yarns in each strand, and, particularly, the length of lay of the strands and rope; the relationship existing between the various lays for the various sizes, and the weight of fiber used.

Inasmuch as practically all wire rope cores are composed of three-strand fiber ropes, the description of the present invention will be confined to such ropes having three strands, although it must not be construed as being limited thereto. Many modifications and variations of the specific disclosure contained herein will become apparent to those skilled in the art, although such changes will not constitute departure from the spirit of this invention as defined by the appended claims.

Since the fibers which are spun into yarns comprise the smallest divisible component elements of a fiber rope, the approach to this invention will be made by first discussing the factors that must be considered in the selection, treatment and fabrication of the fibers into yarns.

The determination of the proper amount of fibers to be spun into a yarn is best made by

weight rather than by number of fibers employed, since the fibers, usually of hemp or sisal, are products of nature and vary widely in size. In determining the proper weight of fibers employed in the yarns, reference must first be made to the specifications for the center to be produced to ascertain the desired finished weight thereof. This weight may be given in one of three ways; namely, extracted weight, dry weight, or lubricated weight.

Extracted weight is the weight of the finished center wherefrom all lubricant and moisture have been extracted, as by the Soxhlet process. Dry weight is the weight of the center, the fibers of which have been treated with cordage oil during the processes prior to spinning the yarn. Lubricated weight is the weight of the center, treated with both cordage oil and a heavier lubricant. The heavier lubricant is applied to the yarns before they are made into rope.

According to my invention, I have determined that the proper extracted weight of a one-inch diameter center is .2960 lb. per foot, and have used this figure as the basis for determining all other weights.

By mathematical calculation the weight of the rope centers varies directly as the square of the diameter of the centers. Therefore, using the above figure of .2960 lb. per foot of one-inch rope as the base, the weight of any other than a one-inch rope may be determined by multiplying .2960 by the square of the diameter (d^2) thereof. Good manufacturing practice in the cordage mills permits the manufacture of centers having an extracted weight tolerance of ±3 per cent.

Cordage mill experience shows the necessity of approximately 11 per cent. cordage oil (by extracted weight of rope), with a tolerance of ±10 per cent. in the amount of oil applied. The maximum tolerance in the weight of dry centers will, therefore, be approximately ±3.6 per cent.

Experiments have proven that 5 per cent. heavy lubricant, based on extracted weight, is about the minimum that can be applied, while any greater amount will squeeze out of the center when inside of a wire rope which is working under load. Therefore, lubricated weights are approximately 5 per cent. greater than dry weights, and the tolerance is again ±10 per cent. in the amount of lubricant applied. The maximum tolerance in lubricated weights will be slightly less than ±3.9 per cent.

In view of the above, a table has been prepared in which X has been used to represent the extracted weights, and in which all other weights have been written as functions of X, as follows:

	Extracted Weight	Dry Weight	Lubricated Weight
Minimum	X−.03X= .97X	+.11X−.01X=1.07X	+.05X−.005X=1.115X
Average	X	=1.00X+.11X	1.11X+.05X =1.16X
Maximum	X+.03X=1.03X	+.11X+.01X=1.15X	+.05X+.005X=1.205X

By substituting .2960 d^2 for X in the above table, it is possible to obtain expressions for the weight of rope in lbs. per foot of all sizes, and all lubricants.

Having determined the proper amount of fiber to be used in the fabrication of a center of any predetermined size by application of the above weight formula, the next step is to divide the amount of fiber selected into as many groups of equal weight as there will be yarns in the finished rope. Before this can be done, however, it is first necessary to determine the proper number of yarns per strand.

Where hard fibers are employed, I have found that the best number of yarns that can be formed into each of the strands of a three-strand one-inch rope is twenty (20). I have also found that this figure of twenty yarns per strand in a one-inch rope may be taken as a base to determine the number of yarns per strand in ropes of other sizes. Thus, by application of the same number of strands to diameter of center ratio, it is found that the most desirable number of yarns per strand in a quarter-inch rope is five; ten yarns per strand in one-half-inch rope; fifteen yarns per strand in three-quarter-inch rope, etc., when the fibers employed are hard fibers whereby the following formula is derived:

$$\frac{D}{n}=1/20, \text{ or } n=D\times 20$$

Where n=number of yarns in one strand
and D=diameter of center in decimals of an inch.

The above formula is also applicable where soft fibers are employed, and everything remains unchanged except the number of strands to diameter of center ratio, which, instead of being 20 yarns per strand in a one-inch diameter center, is 32 yarns per strand in such center. The following table shows the comparison:

Diameter of center in inches	Yarns per strand	
	Hard fibers	Soft fibers
¼	5	8
½	10	16
¾	15	24
1	20	32

In every other respect, the hard fiber centers and the soft fiber centers are treated the same, whereby all tables and formulae appearing hereinbefore or hereinafter are equally applicable to both. Thus, by way of example, the total number of yarns in a one-half-inch diameter, hard fiber, three-strand center, is determined by computing the number of yarns per strand by application of the above formula as follows:

$n=D\times 20$
$n=.5\times 20$
$n=10$; $3\times 10=30$ (yarns in a 3-strand, ½" rope)

Thus, it has been found that the quantity of fiber for the completed center, selected by weight in accordance with the weight table given hereinabove, must be evenly divided to provide the components of thirty yarns of equal weight in the case of the one-half-inch diameter center used as an example herein. After this has been done, each of the thirty groups of fibers is spun into a yarn having certain characteristics obtained by twisting the fibers and completing the yarns in accordance with the following formulae:

$$T=K\sqrt{\frac{N}{W}}$$

Where:

T =Number of twists per foot in yarns
N =Number of yarns in rope
W=Extracted weight per foot of rope in pounds
K =A constant value equal to .695 with a plus or minus tolerance of 5%.

The constant K is a value reconciling the differences of weight and length of a yarn one foot long, and of a yarn laid into a rope one foot long. A number of yarns one foot long, and the same number of yarns twisted into a strand one foot long are of unequal length due to the take-up of the stranding operation by which there is an increment obtained by such stranding process. As is indicated above, I have determined that the best value for this constant in solving for T in the above equation is .695, with a plus or minus tolerance of 5%.

The values for T then become:

$$\text{Minimum } T=.66\sqrt{\frac{N}{W}}$$

$$\text{Average } T=.695\sqrt{\frac{N}{W}}$$

$$\text{Maximum } T=.73\sqrt{\frac{N}{W}}$$

By way of forwarding the example of the one-half-inch diameter, three-strand rope center employed hereinbefore, the above formulae are computed as follows:

T =To be determined (No. of twists/ft. in yarns)
N =30 yarns in one-half-inch, 3-strand rope
W=.0741 lb. per foot.
K=.695

Formula:

$T=K\sqrt{\frac{N}{W}}$ by substitution becomes—

$$T=.695\sqrt{\frac{30}{.0741}}=.695\times\sqrt{405}$$

$$T=.695\times 20.1$$

$$T=14$$

Each group of fibers, therefore, should be twisted to provide yarns having fourteen twists in each foot thereof. The above formula to determine T is such as to always make the lay of the yarns directly proportional to the diameter of the yarns, which has been found to be the best practice to follow.

The next fabricating step in the manufacture of my improved rope center is concerned with laying the yarns obtained, as above, into strands. In order that the strands may be formed with the most desirable characteristics, I have worked out a formula in accordance with the present invention whereby the yarns may be given the proper amount of turns to form the strands in question. The determination of the proper amount of turns for a three-strand hemp rope is calculated on a turns per foot of strand basis, and may be derived in accordance with the following, in which:

D=Diameter of center in inches
d =Diameter of strand in inches (.522D)
α =Angle of lay of both rope and strand. (This is a constant value of 29.6° for all sizes)
L=Length of lay of strand
X=Diameters lay of strand

$$\left(\frac{L}{d}\right)$$

n =Number of yarns in strand (not including center yarns)
θ =Central angle of strand

$$\left(\frac{180°}{n}\right)$$

t =Turns per foot in strand

$$\left(\frac{12}{L}\right)$$

With the above legend in mind, the formula for establishing relationship between X and α is as follows:

$$\frac{\pi}{X}\csc\alpha=\sin\theta+\sec\alpha$$

$$X=\frac{\pi\sec\alpha}{\sin\theta+\sec\alpha}$$

$$X=\frac{6.36}{\sin\theta+1.15}$$

Expressions for X are also as follows:

$$X=\frac{L}{D},\ X=\frac{\frac{12}{t}}{.522D},\ \frac{12}{.522Dt}$$

Therefore:

$$\frac{.522Dt}{12}=\frac{1.15+\sin\theta}{6.36}$$

$$t=\frac{12(1.15+\sin\theta)}{(6.36)\ (.522D)}$$

$$t=\frac{3.61(1.15+\sin\theta)}{D}$$

or

$$\frac{4.15+3.61\sin\theta}{D}$$

A plus or minus tolerance of 5% is allowable to compensate for differences occasioned by machine gearing, etc., which will establish a range within which the turns per foot of strands must fall, as follows:

$$\text{Minimum } t=\frac{3.43(1.15+\sin\theta)}{D}$$

$$\text{Average } t=\frac{3.61(1.15+\sin\theta)}{D}$$

$$\text{Maximum } t=\frac{3.79(1.15+\sin\theta)}{D}$$

In applying the above formulae to the example of the one-half inch diameter, three-strand rope center employed hereinbefore, the average formula has been selected. It will be observed that all values occurring in the formulae for the determination of t are constants except for the sine of the central angle (sin θ) of the strand, and the diameter of the center in inches (D). By reference to the legend it will be seen that the central angle (θ) is equal to 180° divided by the number of yarns in a strand exclusive of its center yarns. As has been fully brought out hereinbefore, there are ten yarns per strand in a three-strand, one-half-inch diameter rope, which are the specifications of the rope in the instant case. Therefore, the central angle (θ) is equal to 180° divided by 10, which equals 18°. Therefore, the central angle of the strand is 18°, and the sine of 18° is 0.3090. The legend indicates that D represents the diameter of the center in inches, hence, in the example given, D equals one-half-inch.

Thus, the formula

$$t=\frac{3.61(1.15+\sin\theta)}{D}$$

is expressed

$$t=\frac{3.61(1.15+.309)}{.5}$$

$$t=10.53, \text{ or } 10.5$$

The number of turns per foot of strand are, therefore, 10.5, which the legend indicates is equal to 12 divided by the length of lay of strand. Thus, the length of lay is established at slightly more than 1⅛ inches (1.143'').

The final step in the fabrication of the center relates to laying the strands, formed in accordance with the above, into rope. This final step is accomplished in accordance with the present invention by determining the angle of lay of a hemp center by application of the following formula:

L=Length of lay in inches
D=Diameter of center in inches
X=Diameters lay of rope

$$\left(\frac{L}{D}\right)$$

α=Angle of lay
n=Number of strands
θ=Central angle

$$\left(\frac{180°}{n}\right)$$

Formula:

$$\frac{\pi}{X}\csc\alpha=\sin\theta+\sec\alpha$$

As has been mentioned hereinbefore, the value for α is 29.6°, and the central angle (θ) is always equal to 60° in a three-strand rope. I have found the best value for X to be approximately 3.15, which is derived by substituting the known values in the above formula and solving for X as follows:

$$\frac{3.1416}{X}\quad 2.025=.866+1.15$$

$$\frac{6.36}{X}=2.016$$

$$2X=6.36$$

$$X=3.18$$

It has been shown that the number of times the diameter of the center will go into one lay of rope, which is 3.18, the value of X in the above formula, is equal to the length of lay (L) divided by the diameter of the center in inches (D). Thus, in a three-strand, one-half-inch diameter center, if:

$$X=\frac{L}{D}$$

we obtain by substitution:

$$3.18=\frac{L}{.5}$$

wherein:

L=1.590, or a lay of approximately 1½ in.

This conforms to the practice heretofore recognized as desirable; namely, that the lay of the rope should equal approximately three times the diameter thereof. I have found a shorter lay often causes trouble, hence I have set the limits as follows:

Minimum 3.00 diameters=3X
Average 3.15 diameters=3.15X
Maximum 3.30 diameters=3.3X

where X equals the diameter of any rope. It will be observed that the above limits establish in effect a zero minus tolerance and a 10% plus tolerance.

From the above it will be seen that I have provided complete formulae and descriptive matter relative to the fabrication of ropes, which, if practiced, will be productive of ropes having all of the characteristics and desirable properties recited in the forepart of this specification, rendering them ideally adaptable for use as wire rope centers. It will be found that wire ropes embodying centers made in accordance herewith will be more durable and capable of long service under various flexing and bending stresses and loads, whether of a static or fatigue character.

It will be observed that I have established a definite relationship between the weight of a center and its size, such relationship being based on the manner in which the center is constructed. Also, in accordance with my invention, there is a constant proportionality between the number of yarns in the center and the size thereof. To those who are familiar with present day and prior practices in the cordage industry, it will be apparent that this proportionality between the number of yarns and size of center is a radical departure therefrom. Usually, in standard practices, the number of yarns is less in the smaller sizes of centers, and almost double in the larger sizes of centers than are the numbers prescribed therein, nor have the increases or decreases in the past been accomplished commensurately with nor in proportion to the size of the centers. No regard has ever heretofore been given this proportionality which I have found so important and desirable.

Furthermore, of the greatest importance is the maintenance of a definite relationship between the angle of lay of the center or rope, and the angle of lay of the individual strands. This relationship is recognized in the approximate equality of the angles in question, and represents a constant for all sizes of rope, regardless of the number of yarns in the individual strands. By the present invention, I also maintain a definite relationship between the angle of lay of rope and the twist in the yarn.

Cordage completed in accordance with the foregoing is more evenly balanced than any heretofore made. It has proven to be a superior supporting medium for steel strands because of its greater uniformity in cross section when under compression inside a wire rope, and is a more durable center by virtue of its individual fibers being subjected to less distortion than has heretofore been the case in cordage used as hemp centers. In other words, in my improved center the lay of fibers in the yarns; the yarns in the strands, and the strands in the rope are so proportioned as to permit of a maximum amount of fiber to be employed without incurring the risk of not being able to suitably close a wire rope thereabout when the fiber rope is being utilized as a center therefor. The deformation of my improved center upon being enclosed within a wire rope causes it to assume a shape whereby it affords the overlying wire strands maximum support, and exerts upon such strands a pressure

of maximum uniformity throughout their length, without any resulting deleterious compression and pressure to cause fiber disruption therein.

In accomplishing this, it is required that the rope elements be assembled in definite relationships, brought out hereinbefore, whereby the completed rope will offer a substantially uniform and continuous support for wire strands. This feature of uniform support is not found in conventional types of centers now in use, since in the conventional types, the flow of hemp under pressure results in disruption of the component fibers where the centers are too hard, and where they are too soft, the wire strands are not afforded reasonably adequate support.

I claim as my invention:

1. A hemp center for wire ropes and the like comprising a rope composed of fibers, yarns and strands, in which the number of twists per foot of yarn is approximately equal to the square root of the fraction represented by total number of yarns in the rope divided by the extracted weight per foot of rope when said root is multiplied by a numerical value included within the range of 0.66 and 0.73.

2. A hemp center for wire ropes and the like comprising a rope composed of hard fibers, yarns and strands, the number of yarns in each strand being equal to twenty times the diameter of said rope expressed in inches, said rope weighing in pounds per foot extracted weight not less than .287 times the square of said diameter, nor more than .357 times the square of said diameter lubricated weight, and the angle of lay of said strands approximately 29.6°.

3. The method of forming wire rope cores of rope which includes spinning fibers into yarn by twisting the fibers approximately .695 times the square root of the quantity equal to total number of yarns in the rope divided by the extracted weight per foot of rope in pounds, stranding said yarns into strands having turns per foot in number approximately equal to 4.15 plus 3.61 times the sine of the central angle of strand divided by the diameter of rope, and laying the strands into rope with lays at least equal to three times its diameters.

4. The method of forming wire rope cores of ropes which includes stranding yarns by imparting thereto a number of turns per foot approximately equal to 4.15 plus 3.61 times the sine of the central angle of strand divided by the diameter of the rope.

5. A hemp center for wire ropes and the like comprising a rope composed of soft fibers, yarns and strands, the number of yarns in each strand being approximately equal to thirty-two times the diameter of said rope expressed in inches, said rope weighing in pounds per foot not less than .287 times the square of said diameter extracted weight nor more than .357 times the square of said diameter lubricated weight, and the angle of lay of said strands approximating 29.6°.

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