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3,124,927

METHOD OF MAKING WIRE ROPE

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8 Claims. (Cl. 57—161)

This invention relates to wire ropes and more specifically to a method of manufacturing wire ropes which results in prolonged life of the product in machinery applications, particularly where the rope duty imposes torsional and bending stress from changes in load. These are more or less uniformly distributed throughout the rope. The other type of duty results in more or less non-uniformly distributed stress in the rope usually caused by coiling and uncoiling and/or abrasion due to contact between the wires and with parts of the machinery.

In the following description, a wire rope will be considered as composed of one or more strands laid about a center strand or core (if there is more than one strand in the rope) and each strand, as composed of several individual wires laid about a center wire. The neutral axis for a strand is then its center wire, and, when the strand is laid into a rope of a plurality of strands, each strand lies with its center wire in the form of a helix. Likewise, each fire in a strand, when laid around the center wire of the strand, is formed into a helix. Each wire around the center wire in a strand of complete rope might be termed a compound helix.

In the usual laying operation for forming a strand or for forming a rope, a normally straight wire, or a normally straight strand, is subjected to twisting around the center wire or core, respectively, either in one direction or the other. This twisting is characteristic of almost every rope making process, whether the rope is a regular, lang lay or alternate lay. Because of the manner of rope making by this twisting opperation, the individual strands will always tend to unwind unless the strand happens to be preformed before the rope is laid, and certainly this will be a tendency of each of the individual wires regardless of how the rope is made. In no case, however, will the strands, even if free from all restraint, or the wires return to an absolutely straight condition after they are once laid. It follows, therefore, that, in the twisting operation of rope manufacture, the wire is stressed a plurality of times in bending and torsion to a degree where it takes a permanent set. The fact that the individual wires will take a set is significant. It indicates that during rope making, or strand making, or both, the wire has been stressed considerably. The metallurgical effect may be explained by stating that when so stressed, there is a plastic deformation which takes place, and these repeated stresses on the individual wire produce microscopic yieldings and a tendency towards a condition in which the wire is non-uniformly stressed in cross-section. This, according to metallurgic theory, is accompanied by a slipping between certain crystalline grains in the metal which distort and misalign along atomic planes and/or slightly rotate. Residual stresses are then set up in the wire, some compressive, some tensile, some shear at the edges of these grains some of which are at the surface. It is, therefore, possible to have a tendency for surface fatigue cracks to start, and, when once started, each minute crack is a stress raiser.

It is well recognized that if a ductile metal is stressed beyond its yield strength at room temperature, it is said to be cold worked. It is generally known that cold work may increase the yield strength of wire, but whether it does this or not, at the same time, it will adversely affect ductility, flexibility. This is so because cold working usually sets up the aforementioned residual stresses in the metal. Cold working may be done by stretching, compressing, bending, twisting, cold rolling, cold drawing, or by shot blasting. Most authorities agree that as a result of such processes, metals increase in hardness and especially steel at least in the range of low hardness. With hardness goes brittleness which is certainly a characteristic to be avoided if the wire is to subsequently flex.

From the above discussion, it will be readily appreciated that in the processes involved in wire rope manufacture, the individual wires are subjected to what may be accurately described as cold working which causes them to acquire totally unfavorable qualities from those desired. Hardness and brittleness in the rope make it stiffer and harder to handle as well as reducing its fatigue resistance. This is quite the opposite of the characteristics desired. Surface hardness of the wire is desired, but not brittleness and resistance to fatigue and flexibility are the real goal.

Along this same line, it should also be realized that another step in wire rope making involves drawing the wire to size. Perhaps half the resulting objectionable hardness and brittleness may be attributed to the effect of this additional cold working operation. Furthermore, the drawing step forms a soft decarburized layer on the wire which has low abrasion resistance. A practical solution to residual stressing and elimination of the decarburized layer on drawn wire has never been discovered, although it was readily apparent to those skilled in rope manufacture that a solution would increase rope durability by increasing resistance to abrasion and fatigue life. No doubt ever since the causes of premature wire failure in a rope were ascertained, some form of heat treatment has been considered and then dismissed as impractical.

It has never occurred to those skilled in the art that the subsequent adverse metal characteristics induced by cold working the wire during rope manufacture might be partly or wholly overcome by cold working treatment of the wire either before or after the rope is made.

This invention, however, is based upon the discovery that if the decarburized thin skin of the drawn wire is subject to shot blasting with a hard metal shot of small size and for a time sufficient to produce a lightly dimpled surface, then subsequent cold working steps of rope manufacture on the wire have less adverse effect on wire strength, flexibility, and abrasion resistance. The reasons for this are not entirely apparent, but physical examination of wires from ropes so treated reveal that this treatment compresses the ferrite layer and the metal adjacent thereto. It also dimples the surface without producing minute cracks which would be stress raisers. The dimpled and compressed surface seems to readily accommodate stretching and compression without noticeable sharply induced stresses therein. It forms an envelope which, when compressed or stretched, will not in turn impose reverse stresses within the metal below the surface thereof. It has also been discovered that shot blasting the wire in this manner can be used to obtain beneficial results when the individual wires are treated before being layed up into a strand, after the strands have been preformed, or after the rope itself has been closed. In all cases, stiffness is reduced in some degree and there is improved fatigue and abrasion resistance. In addition when used on a rope after it was closed which was not layed up of preformed strands, both strands and wires obtained a characteristic of preformed rope in the sense that its tendency to unwind was decreased to a marked degree.

It was one of the objects of the present invention to provide an improved wire rope for machine operations.

It is still another object of this invention to provide a method by which a wire rope can be constructed which will have a greater useful life in machinery applications.

Further objects and advantages will appear from the following detailed description which is in such full, clear, concise and exact terms as will enable anyone skilled in the art to use the method and to make the product by this method especially when taken with the accompanying drawings forming a part thereof and in which:

FIG. 1 is a plan view of a section of wire rope;

FIG. 2 is a section taken on the line 2—2 of FIG. 1;

FIG. 3 is a reproduction of a photomicrograph of one portion of a wire in FIG. 2;

FIG. 4 is a reproduction of a photomicrograph of another portion of a wire in FIG. 2;

FIG. 5 and FIG. 6 are reproductions of curves representing the fatigue life of wire ropes some of which have been treated according to this invention; and

FIG. 7 is a view in elevation and schematically illustrating a manner of treating wire rope.

FIG. 1 illustrates a short section of wire rope R which has eighteen strands, those visible are indicated as 1 through 9, inclusive. This is, as illustrated, a right lay regular lay wire rope. With reference to FIG. 2, the separate strands 1–18, inclusive, are layed up over a core in this case, indicated as 19, which is a single strand surrounded by two layers of twisted strands. The inner layer is indicated as A and the outer layer is B. The inner layer has six strands and the outer layer twelve, so that the total number of strands is eighteen. In this example of wire rope (regular lay) the twist of the wires in each strand is opposite to the twist of the strands in the rope so that the strands lie lengthwise of the rope, as viewed in FIG. 1. Each strand S may be formed of eighteen wires twisted about a central wire and layed up in the same way as the strands in the rope.

In order to form each strand S, it is necessary to lay the wires around a center wire, and this involves a powerfully applied twisting action. The same will be true of the step of laying the strands to form the rope. In both cases, bending and torsional stress is imposed from the twisting action of the machine which lays the wires and again to lay the strands. These stresses are concentrated at and adjacent the wire outer surfaces and produce a prestress in the wires changing the metal characteristics by cold working.

This is true whether the strands are preformed to the lay of the rope or not. If preformed, most of the stress will occur at the preforming jig or fixture. Since the wires are usually cold drawn steel, iron Monel, or bronze, the cold working, which occurs in the steps of rope manufacture (wire drawing and laying up), result in residual tension stresses and shear stresses in the individual wires. Most of the stress is concentrated at and adjacent the outer surface which can then be said to be weakened by improper prestressing which leaves a residual stress from the steps in manufacture. When the rope goes into service, the abrasion of drums or pulleys impose wear on these surfaces, and, by still further bending, increase the stress at the outer surface of each wire. Since the outer surface of each wire has residual stresses therein from the steps in manufacture predominantly in tension, it becomes the weakest part of the wire. Repeated bending and twisting of the wire shortens the life of the entire rope, because if failure is going to take place in a wire, it will start with nicks or tiny fractures which are stress raisers at the outer surface of a wire. Wire failure begins at the surface and then progresses until the wire breaks. When several wires have broken, repair is no longer practical and the rope must be replaced.

Even after this reason for individual wire failure was generally recognized as caused by cold working and the residual stressing resulting therefrom, no practical solution to the problem occurred to any one skilled in the art. It was always known to be possible to reduce residual stressing by a process of annealing. This could be resorted to for both the individual wires as well as on rope, but this process would in turn raise new problems. The abrasion resistance of the individual wires and, of course, the rope would be greatly reduced. Further this raises the question of how to lubricate the strand or the rope after heat treatment, or how to heat treat a rope after it was lubricated. It certainly did not occur to others, so far as it is known, that the effects of several cold working operations might be eliminated by a cold working operation.

To test out this theory, the outer surface of a rope wire was shot blasted with shot no larger than 0.011 of an inch in diameter. The shot was propelled at high velocity against the wire surface so that indentations approximately one half to one thousandths of an inch were formed in the exterior surface. FIG. 3 is a replica of a photomicrograph illustrating the grain structure (magnified 100 times) of a cold drawn wire before shot blasting. FIG. 4 is a view of another portion of the wire after exposure to shot blasting. According to FIG. 3, the grain structure 20 of the wire is normal for this type of drawn wire, and on the outer edge of the wire at 21, it will be noted that a constant grain structure is found which is somewhat different than at the inner portion 20 of the wire. This difference will be noted by the thin light colored layer at the wire surface. This lighter colored surface 21 is a concentration of loose ferrite caused by the decarburization of the wire at its surface. The ferrite layer is, of course, softer than the interior. Turning now to FIG. 4, which is a cross-section of the same wire shown in FIG. 3 that has been shot blasted. Examination of this photomicrograph will indicate that the inner grain structure of the wire at 20 is identical to that shown in FIG. 3. The outer grain structure of the wire, however, indicates quite a difference. The outer grain structure at 21' evidences the effect of shot blasting which has produced the indentations 22, 23 and 24. It also evidences that the ferrite layer 21' has been compacted in depth so as to seal the grain boundaries of the wire. The effect of the shot blast has penetrated into and even beyond the surface of the wire for quite some distance, and the grains adjacent the surface are compacted, indicating the fact that some compression has taken place local to the surface 21'. Although this photomicrograph does not illustrate the fact, it will be appreciated that the indentations 22, 23 and 24 have a similar dimension lengthwise of the wire as diametrically, and that, therefore, the outer surface of the wire is dimpled. Such a surface has an important significance, since not being smooth, it is more capable of extension and contraction without serious localities of stress concentration. Figuratively speaking, it simply straightens to allow the surface to stretch easily as the powerful twist is applied by the machinery during the wire laying operation making the strand and the strand laying operation making the rope. This slight stretching operation, when applied to a surface which is obviously under compression to start with, will avoid opening fatigue cracks or minute fissures in the surface which act as the stress raisers and contribute to the early failure of the wires. The shot blasting treatment of the individual wires to obtain the effect illustrated in FIG. 4 is possible by using a shot size and velocity which will produce indentations of the size indicated for a duration of time to provide the coverage. The same size and velocity of shot will produce this effect over a wide range of wire diameters by simply varying the time exposure or duration. The indentations produced in the wire surface should be in the range of one half to one thousandth of an inch, as illustrated in the reproduced photomicrograph in FIG. 4. From the result therein illustrated, it does not appear that the coverage has to be complete.

It has also been discovered that there are other ways in which the wires may be stress relieved by cold work to obtain the same beneficial results. In other words, the shot blasting may be performed not only on the individual wires but also on the assembled rope, on the core alone for the rope, or on the core and strands before assembly. In the latter case, it is preferable that the strands are treated after being preformed for laying the rope. Test results on this type of rope treatment, when completely assembled and lubricated, were obtained by blasting the rope with a mixture of shot no more than .011 inch in size and somewhat irregular in shape at a maximum velocity no greater than 3000 feet per minute. Variation in coverage was obtained by changes in the feeding speed of the rope through the blast between streams of shot arranged at 120° with respect to one another. The variations were obtained by changing the number of passes at a fixed feeding speed. This will be indicated in the test results, however, as a difference in feeding speed. The test results below were also obtained by using three samples of rope for each test result, all of which were from the same reel of rope. Each sample of rope was subject to the same loads and the same degree of flexing and abrasion in the same testing machine driven at the same speed. The average result obtained from these tests are set forth in the table identified as A below and plotted as curves in FIG. 5:

Table A

Standard Rope Untreated—No. of Revolutions	Samples Shot Blasted at 4⅗ Feet Per Minute—No. of Revolutions	Samples Shot Blasted at 3⅙ Feet Per Minute—No. of Revolutions	Number of Broken Wires	Percentage of Increase Over Untreated Samples at 4⅗ Feet Per Minute	Percentage of Increase Over Untreated Samples at 3⅙ Feet Per Minute
21,500	60,000	59,900	5	132.8	178.5
27,000	58,500	71,800	10	116.5	166.0
30,500	63,000	74,500	15	106.5	144.4
33,300	66,000	75,000	20	96.7	125.5
34,900	68,000	75,000	25	94.9	115.0
36,000	69,089	75,000	30	91.7	108.3
36,500	69,700	75,000	35	91.0	105.5

To further explore the possibilities of application, a second group of tests were run on samples taken from the same reel of rope. In this series of tests, the shot used was substantially less than .011 inch in diameter and at a velocity of under 3000 feet per minute. Rope sample No. 4 is standard rope without treatment of any kind. Sample No. 5 is a similar length of standard rope shot blasted at a feeding speed of about 28 feet per minute. Sample No. 6 is a similar length of standard rope which has been disassembled and each individual strand shot blasted at a feeding speed of approximately 28 feet a minute. This would be the equivalent of shot blasting each preformed strand in a rope. The strands were then reassembled and designated sample No. 6. Sample No. 7 were tests on an assembled rope which had been disassembled and the wire rope core shot blasted at the same feeding speed. The rope strands were then assembled around the treated core, shot blasted and then tested as sample No. 7. The result of the tests on these samples is set forth in Table B below and plotted as curves in FIG. 6:

Table B

Sample No.	No. of Revolutions	No. of Broken Wires	Percentage Increase, percent
4	27,800	5	----------
5	72,000	5	159
6	51,000	5	83.5
7	44,000	5	58.4
4	38,700	10	----------
5	74,300	10	92
6	62,500	10	61.5
7	53,000	10	37
4	46,300	15	----------
5	74,800	15	61.5
6	66,100	15	42.8
7	57,800	15	24.8

With reference to the results of the above tests, it should be noted that samples 4 through 6, inclusive, were shot blasted at a feeding speed of 28 feet a minute, whereas sample No. 7 was shot blasted at approximately six-tenths of a foot per minute feeding speed. This seems to indicate that the operation had proceeded beyond the point of maximum return in benefits due to resistance in fatigue and abrasion. The remaining tests, however, indicate that the extremely small shot used nevertheless produced considerable gain in durability of the rope and its resistance to fatigue and abrasion. Consequently, it appears with this particular ratio of shot size and velocity, that beneficial results can be obtained over a wide range of feeding speeds for the rope through the shot blast. It is contemplated that with larger shot, lower shot velocities would be employed and the feeding speed increased since the coverage of the larger shot would be greater. Of course, the size of the pellets will depend to some extent at least upon the size of the wire used in the rope, but it is contemplated that pellets in the size range of approximately thirty thousandths of an inch would be equally suitable, and that as the pellet size was increased, the shot velocity would be decreased and the feeding speed of the rope increased. This is true because the mass of the pellets would be greater and their velocity would not have to be as high to produce the same dimpled effect on the outside surface of the wires. Since the area impacted by larger pellets would be many times as great, the coverage would be better and the feeding speed accordingly higher.

FIG. 7 illustrates one manner in which the above described method may be carried out in a schematic manner. For example, herein is illustrated a cable making machine, or a strand making machine, CM which includes a frame that is stationary having the cradles 30, 40 and 50 bolted securely to a foundation 60. Cradles 30, 40 and 50 are interconnected by frame members 31, 41, etc. Each of the cradles carries a plurality of rollers indicated on cradle 30 as 32 and 34. These are suitably journalled on bearings in the cradle member 30. Likewise, cradle 40 carries a series of supporting rolls 42, 44, etc., similarly mounted on the cradle 40. On the cradle 50 are corresponding rolls 52, 54, etc., which are similarly mounted. These rolls in turn carry the rotatable frame 90 which is cylindrical and has its outer pheriphery supported on the several rollers above described. Within the rotatable frame 90 are a plurality of cradle supports for the reels of wire or strands, such as 38, 48, etc. These cradles so support the reel 38, 48, etc., that they remain stationary within the rotatable frame 90. The wires or strands 39, 49, etc., are threaded through the head through suitable spaced openings in the head 100 and are guided by the ring 101 into a die 102 supported on the frame 103. The twisted wires for the strand or the rope 110 emerging from the die 102 are wrapped around a capstan 111 rotatable on bearings in the frame 112 also mounted on the foundation 60. From the capstan 111, the cable 110 passes to a reeling mechanism and is layed upon a reel, neither of which are shown. The speed of rotation of the rotatable frame 90 is so synchronized with the rotation of the capstan 111 as to achieve the designed lay of the strand or rope being formed, i.e. the number of turns per foot. So far the construction described is conventional, but to carry out the steps of the present method requires an additional structure. This additional machine or structure is a shot blasting machine, generally designated as SB. In this case, it is located between the die and the capstan of the cable making machine. As shown schematically, inside the shot blasting machine is a hopper 120 containing a plurality of shot 121. In the bottom of the hopper are a plurality of gates which are independent and indicated as 122, 123 and 124. Connected with the gate 122 is a chute 125 extending to a nozzle 127 directed at the strand or rope 110. Air for the nozzle 127 is supplied from a manifold 129 and this blast of air propels the shot coming down the chute 125 directly against a surface of the wire or cable 110.

Connected with the gate 123 is a chute 130 for supplying shot 121 to the nozzle 132. This nozzle is also connected to an air manifold 129 which supplies air under pressure to propel the shot coming down the chute 130 against another surface of the strand or rope 110. Preferably, the surface is 120° spaced from the surface exposed to the nozzle 127.

From the gate 124, a chute 141 connects with a nozzle 142. This nozzle is supplied with air under pressure from the manifold 129 as are the others. Preferably, the surface exposed to the blast from the nozzle 142 is 120° removed from both surfaces exposed to the nozzles 127 and 132. This arrangement of nozzles, therefore, covers the entire surface of the strand or rope 110.

It will be realized that the speed of the capstan 111 and of the strand or rope 110 may vary slightly depending upon the lay of the rope or strand being formed, but this is not a wide variation and is not one which would effect a great change in linear speed of the strand or rope 110 through the machine SB. Consequently, a certain size of shot or pellet 121 will be suitable to obtain the desired results over a wide variety of products.

Changes in and modifications of the invention described may be made without departing from the spirit thereof or sacrificing any of its advantages.

Having thus described the invention, what is claimed and desired to be secured by Letters Patent is:

1. A method of manufacturing a strand for a wire rope which includes the steps of laying the wire about a core in a rope stranding machine by twisting and bending the wires and subsequently treating the exposed surfaces of the wires in the strand by cold working to produce thereon a dimpled surface capable of expansion and contraction during the twisting and bending operations performed on the strand during laying of the strand into a rope to thereby eliminate localized stress concentrations at the exposed wire surface.

2. A method of manufacturing a strand for use as a core in a stranded wire rope which includes the steps of laying up the wire into a strand to form a core in a rope stranding machine by twisting and bending a plurality of wires about a central wire and subsequently treating the exposed surfaces of the wires by cold working to produce thereon a dimpled surface capable of expansion or contraction to stress relieve the said surfaces after the twisting and bending operations performed during the stranding of the core thereby eliminating localized stress concentration at the wire surfaces of the stranded wires of the core.

3. A method of manufacturing a stranded wire rope which includes the steps of laying wire into a strand in a wire stranding machine by twisting and bending the wires, and subsequently treating the exposed surfaces of the wires in the strand by cold working to produce thereon a dimpled surface and to stress relieve the said surfaces after the twisting and bending operations performed during laying the wires into a strand and then laying the strands into a rope.

4. A method of manufacturing a strand for a stranded wire rope which includes the steps of laying the wire about a center wire in a wire stranding machine by twisting and bending the wires and subsequently subjecting the exposed surfaces of the wires in said strand to a

shot blasting treatment by the impact of small hard pellets propelled at velocities high enough to produce relatively closely spaced shallow deformations in the range of one-half thousandth of an inch to one one-thousandth of an inch in the treated surfaces of the wires.

5. A method of manufacturing a stranded wire rope core for use in a wire rope which includes the steps of laying the wire about a central wire in a wire stranding machine by twisting and bending the wires surrounding the central wire and subsequently subjecting the exposed surfaces of the wires of the core to a shot blasting treatment by the impact of small hard pellets propelled at velocities high enough to produce relatively closely spaced shallow deformations in the range of one-half thousandth of an inch to one one-thousandth of an inch in the treated surface of the wires.

6. The method of stress relieving the residual stress produced by cold working during the laying of wire into a rope comprising the step of subsequently performing a cold working operation forming dimples on the surface of the wires in the rope.

7. A method of manufacturing a preformed strand for a wire rope which includes the steps of laying wire into a strand in a wire stranding machine by twisting and bending the wires into a strand, preforming the strand by twisting and bending the strand into a helix, and subsequently treating the exposed surfaces of the wires in the preformed strand by cold working to produce thereon a dimpled surface to stress relieve the said surfaces after the bending and twisting operations performed during laying the wires into a strand and preforming the strand into a helix.

8. A method of manufacturing a stranded wire rope core for use in a wire rope which includes the steps of laying a plurality of wires about a central wire in a wire stranding machine by twisting and bending the wires around the central wire to form a plurality of strands, laying up the wire core about a central strand in a rope making machine by twisting and bending a plurality of strands around the central strand and subsequently subjecting the exposed surfaces of the wires of the complete core to a shot blasting treatment by impact of small hard pellets propelled at velocities high enough to produce relatively closely spaced shallow deformations in the range of one-half thousandth of an inch to one one-thousandth of an inch in the treated surface of the wires.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,124,927 March 17, 1964

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It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 24, after "wires" insert a comma; line 28, for "fire" read -- wire --; line 39, for "opperation" read -- operation --; column 3, line 46, after "iron" insert a comma; column 7, line 18, for "pellet" read -- pellets --.

Signed and sealed this 21st day of July 1964.

(SEAL)

Attest:

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Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents

P098

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METHOD OF MAKING WIRE ROPE

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FIG.1

FIG.2

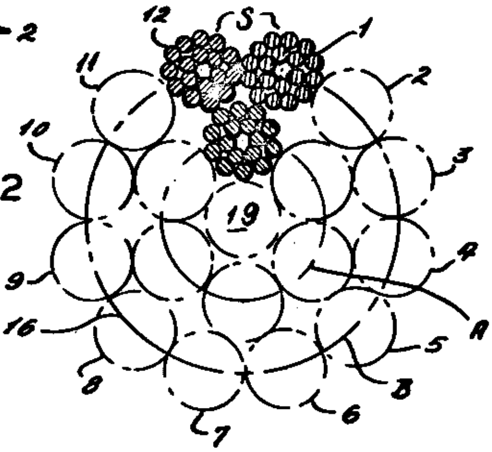

FIG.3

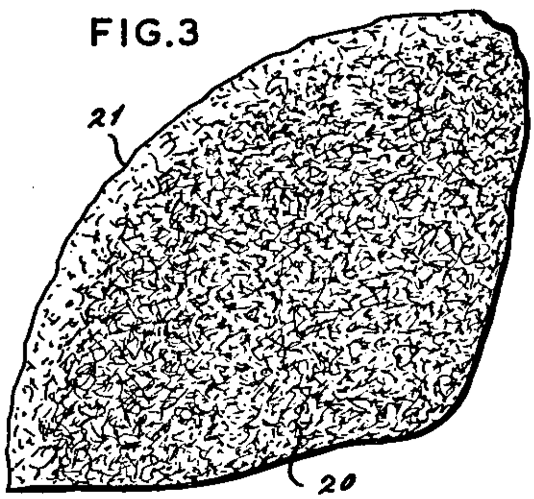

FIG.4

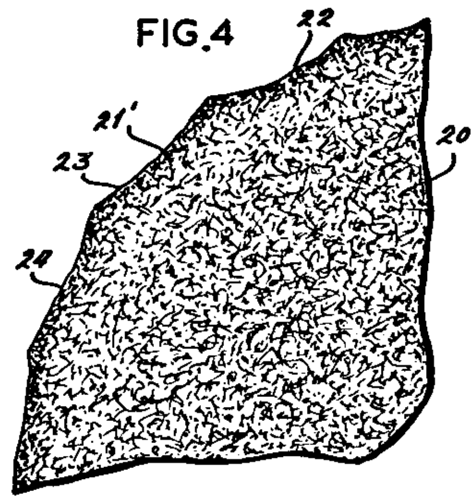

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FIG. 5

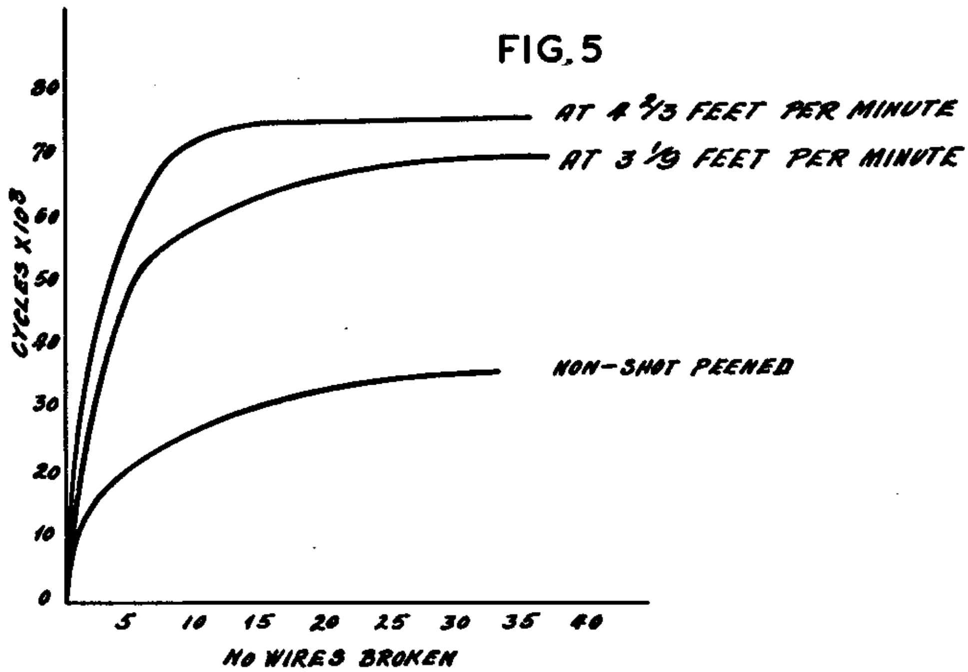

FIG. 6

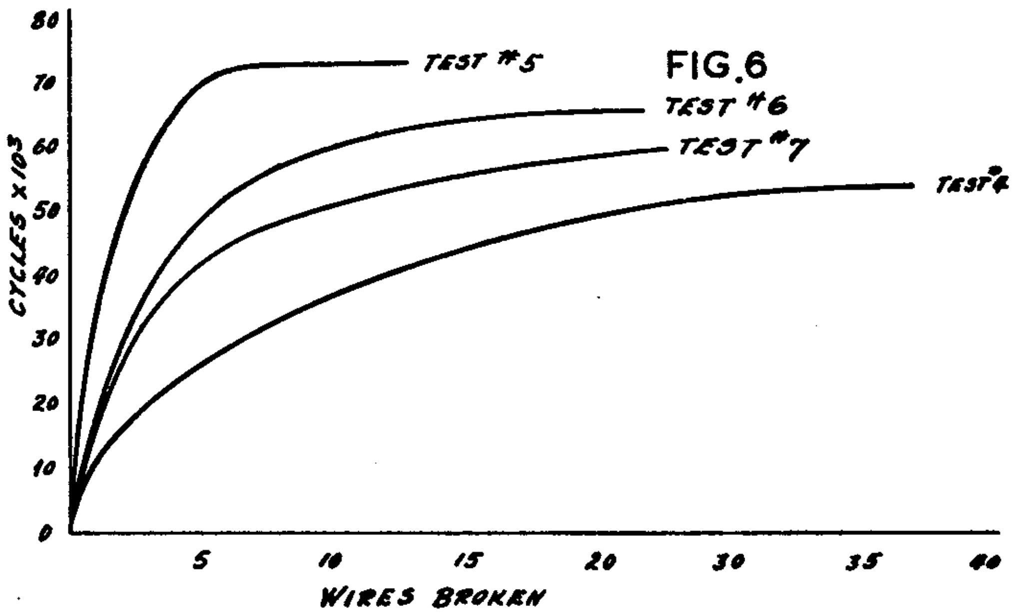

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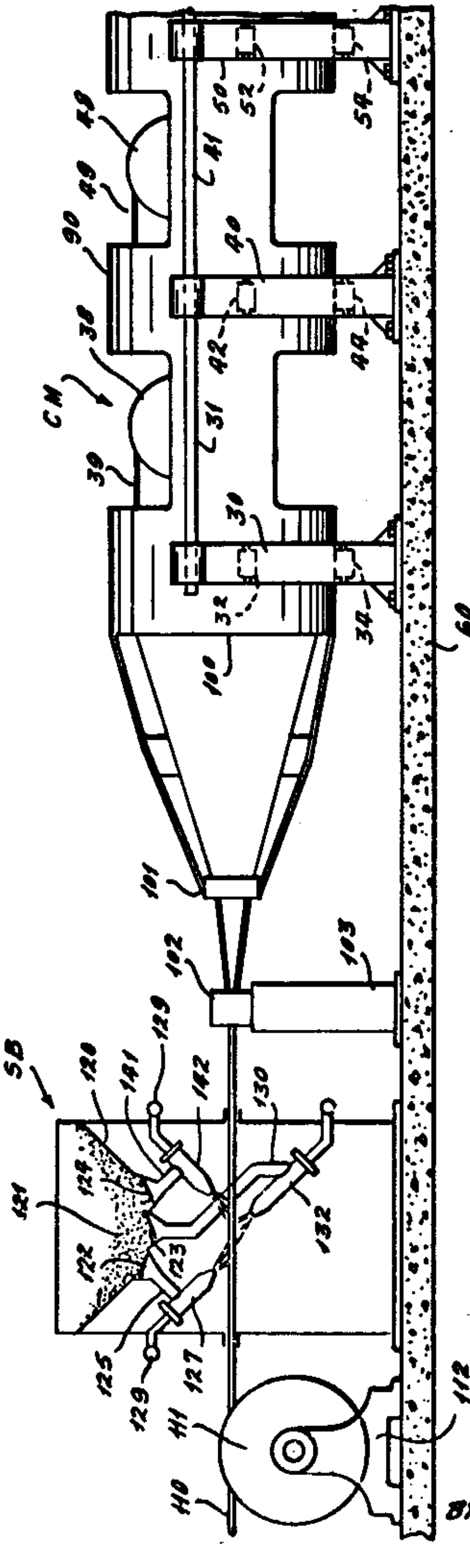
FIG.7



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