May 31, 1955

H. E. WELLCOME

2,709,553

METHOD OF WIRE COILING

Filed Aug. 20, 1951

2 Sheets-Sheet 1

FIG. 1

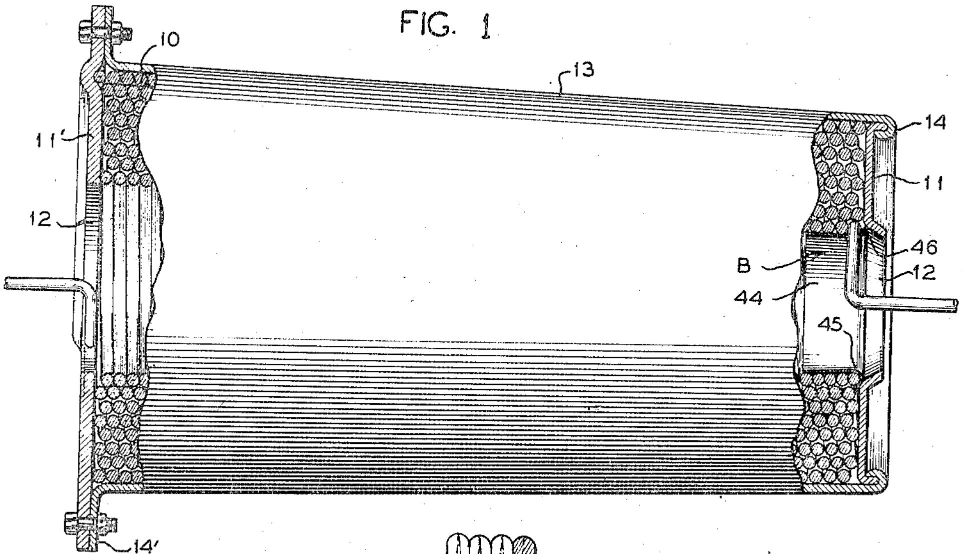

FIG. 2

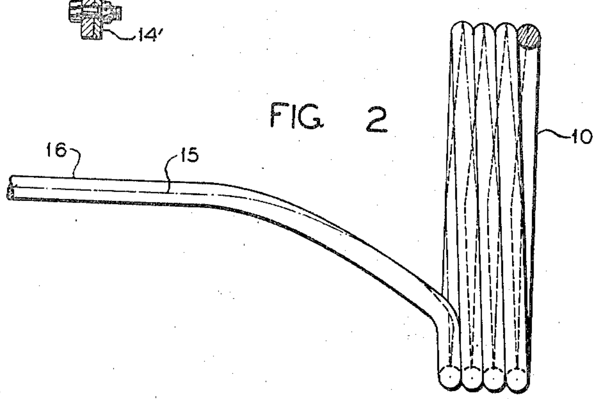

FIG. 3

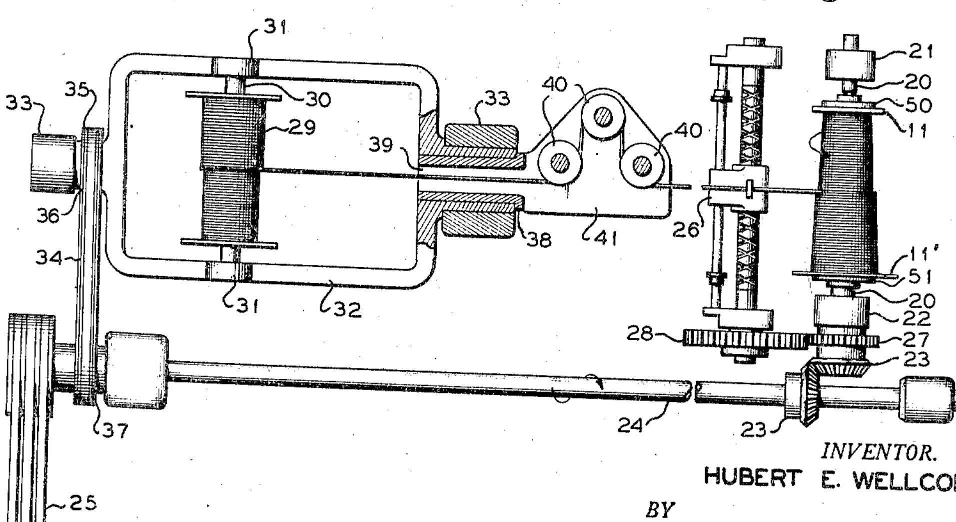

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FIG. 4

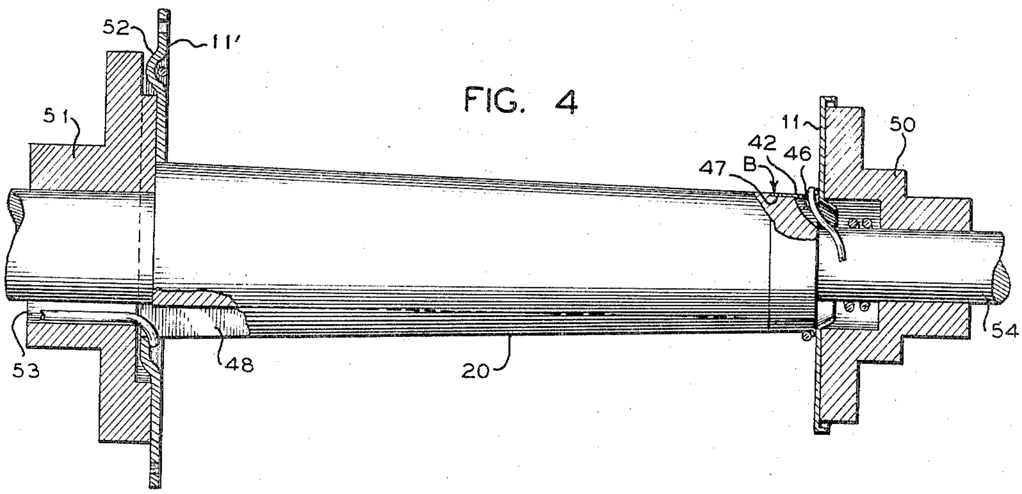
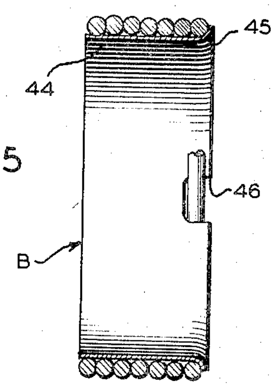


FIG. 5



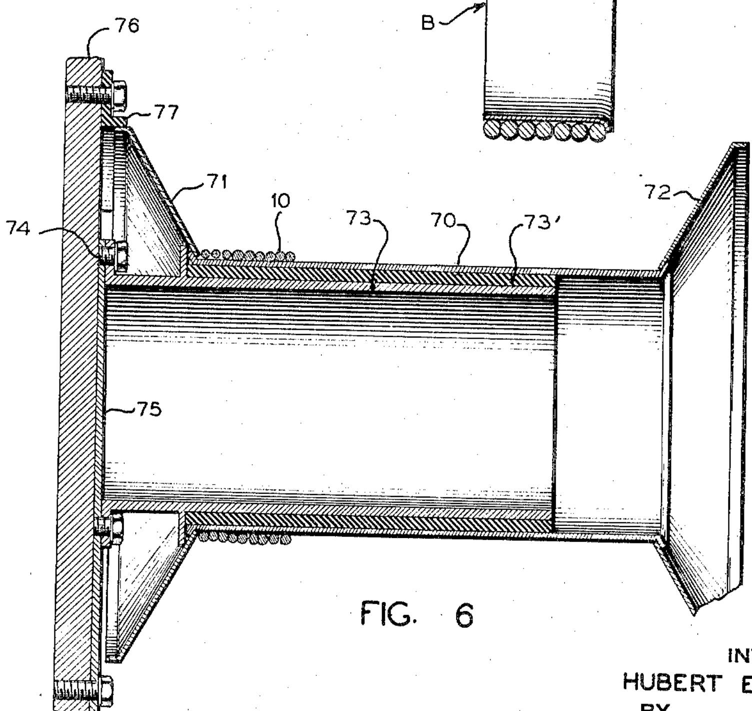


FIG. 6

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METHOD OF WIRE COILING

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Application August 20, 1951, Serial No. 242,733

2 Claims. (Cl. 242—54)

This application is a continuation-in-part of application Serial No. 630,528, filed November 23, 1945, now abandoned.

This invention relates to wire coils and to methods of and machines for making them, and particularly relates to coils of wire from which the wire may be drawn at high delivery speed without rotation of the delivered wire relative to the coil and without development of stress in the delivered wire.

The delivery of soft fiber lines such as hempen and similar rope, is readily obtained since the soft fiber line can be flaked down to pay out readily or wound in a criss-cross pattern to run out without twisting to any extent that gives excessive difficulty. There is no factor of elasticity which offers trouble in such soft fiber lines. But with wire and metal cable, difficulties arise since they cannot be coiled in any way which produces sharp turns or bends in the wire or cable because this would set the wire or cable. In addition, the elasticity of the metal makes it necessary to provide a coil in which the tendency of the wire to straighten out does not cause the line to snarl at the coil. These considerations are particularly important when the wire or cable is to be delivered at relatively high speeds such as in excess of one hundred feet per second, or what may be called projectile speeds, as in the paying out of life lines in sea rescue, and in military activities of various types as for example in operations carried out from moving airplanes.

In prior art devices, the problems were never solved. The wire or cable was delivered at very slow speeds, substantially below one hundred feet per second, and frequently there was snarling and kinking also resulting in the wire or cable snapping and resultant failure of the operation. Special types of winding convolutions and coiling operations did not eliminate the difficulties.

Among the objects of the present invention is a wire coil which may be unwound as rapidly as feasible without bodily rotation of the coil.

Other objects include such wire coils in which rapid delivery of the wire at high speed is possible without difficulty.

Further objects include such wire coils in which the wire leaves the coil in untwisted, relaxed condition.

Additional objects include methods and machines for making such wire coils and their utilization.

Still further objects and advantages of the present invention will appear from the more detailed description set forth below, it being understood that this more detailed description is given by way of illustration and explanation only, and not by way of limitation, since various changes therein may be made by those skilled in the art without departing from the scope and spirit of the present invention.

In connection with that more detailed description, there is shown in the accompanying drawing, in

Figure 1, a front elevation, partly in section, of one form of wire coil produced in accordance with the present invention, in

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Figure 2, an enlarged fragmentary view illustrating the uncoiling wire and forces operative thereon; in

Figure 3, a plan view of one form of machine that may be utilized in producing the articles of the present invention and carrying out the methods thereof; in

Figure 4, a mandrel ready for the application of wire thereto, partly in section, with fragments of wire in place for illustrative purposes; in

Figure 5 a section of a means for holding the wire in position; and in

Figure 6, a front elevation, partly in section, of a modification of the present invention.

In accordance with the present invention a coil of wire or metallic cable is produced adapted to deliver the wire by withdrawal therefrom even at high delivery speed without rotation of the delivered wire relative to the coil and without development of torsional stress in the delivered wire, the latter leaving the coil in untwisted relaxed condition. These results are made possible even at delivery speeds of one hnudred feet a second and as high as is obtainable with present day projection as for example 900 to 1000 feet per second, by utilization of the wire in coil form under conditions of stress that upon delivery exactly neutralize any stress that would normally arise in paying out such wire or cable if not compensated. For these purposes, the coil is a close, substantially cylindrical spiral of helically wound wire (or cable), of elastic metal, supported between spaced rigid end flanges that confine the coil. The end flanges are maintained in spaced relation in contact with the ends of the coil in any desired way.

The wire in the coil is in a state of elastic deformation, the angle of said torsional deformation being substantially the same for each convolution of the coil. It is essential that such deformation be within the elastic limit of the material of the wire. Consequently the wire must be metallic and of metal with a sufficiently high elastic limit for the particular purposes in hand. It may be noted, however, that if a wire is of a material that can be formed into a circle of the desired diameter (i. e. of the smallest convolution of the desired coil) without taking a permanent set, it has been empirically determined that the material is satisfactory for the purpose intended.

The coil of wire under elastic torsional deformation is adapted to deliver the wire very rapidly in unkinked and unstressed condition. The wire does not take any permanent set in the coiled condition, and is free from kinks or twists in the relaxed condition. Thus, the coil of wire under torsional deformation in the coiled condition restrained by the end flanges presents a "live wound" coil which may be instantaneously converted into the straightened relaxed wire; the delivery of the wire from the coil taking place at startling speeds of from 900 to 1000 feet per second.

One method for determination of utility of any particular material for a specific article may be made in accordance with the formulation given below which will indicate the minimum coil diameter which may be used, namely:

$$D=\frac{E\times d}{S}$$

where D is the diameter of the smallest convolution of the coil, E is Young's modulus, d is the diameter of the individual wire (whether single or stranded, laid or cabled into a larger diameter wire line), and S is the tensile strength of the material within its elastic limit. Where this equation is satisfied, the wire can be coiled and twisted to produce the article desired without taking a permanent set. In theory, this equation relates to closely wound coils, but modification for coils with a spacing of ten wire diameters (which is about as widely as they are wound), is relatively slight. By taking S at a good safe value (which must be done in any event because of variation in any ordinary material), no difficulty is experienced in properly coiling the wire without endangering the operation due to permanent set.

From these considerations it can be seen that steel sufficiently work-hardened or tempered is very suitable, since E is high, but S is very high. A material such as bronze wire, with E half that of steel, has however a value of S which may be one-third to one-fifth that of steel. Accordingly, bronze wire may be used to make articles under the present invention but for a given individual wire diameter (d), a coil from bronze wire would require a larger diameter D than one from steel wire.

In actual practice, given a sample of wire desired to be coiled, it is feasible merely to form the wire successively into circles of varying diameter, noting the diameter at which the wire does not straighten out. The coil diameter should then be larger than the diameter of the circle which did not straighten out.

The angle of the torsional deformation is substantially the same for each convolution of the coil, and desirably is made equal to one turn per convolution opposite in direction to the direction of unwinding of the wire as viewed from the end of the coil from which the wire is drawn. The term wire is used herein as intended to cover any metallic line whether wire or cable, and whether of single or multiple strand, etc.

Where the line is paid out from the inner periphery of the coil, the coil may be placed within a rigid casing that is substantially cylindrical and is in direct contact with the outer peripheral layer of the coil, the casing being attached to the flanges to hold them in spaced relation. One of the flanges may be provided with an opening through which the wire is delivered. Where the line is delivered from the outer periphery of the coil, the coil is retained on the rigid mandrel on which it was initially wound, the mandrel carrying the end flanges attached thereto, and the flanges being in direct contact with the ends of the wire coil.

The term substantially cylindrical is used herein since it is not essential to have the coil exactly cylindrical. In fact it is preferable to have the coil taper slightly from end to end, for example about 4°. In such case the mandrel on which the winding of the coil is carried out may be given the desired taper. The main purpose of the taper is to permit withdrawal of the mandrel when desired. An included angle of 2° may be used, but withdrawal of the mandrel may be more difficult than desired. Also the outer casing when used, will taper in the same way in order to maintain its contiguity with the outer layer of the coil. The end flanges may be set at right angles to the mandrel, or may taper either inwardly or outwardly. In the case of a coil which is withdrawn from the interior periphery, an outward flare, that is, one in which the outside layer of wire is longer than those in the center, should not be so great as to lead to kinking of the wire as it is withdrawn. It will be understood that in the case of a coil dispensed from the exterior periphery of the coil, the flare may be considerable. This dishing of the flanges serves the purpose, among others, of making them rigid, especially if they are of thin material. The number of layers in the coil may be as desired.

Referring to the article as illustrated in Figure 1 of the drawing, the body **10** of the coil of wire is retained within the torus-shaped end flanges **11, 11′** which are in direct contact with the ends of the body **10** of the coil. Each flange carries an opening **12** through one of which the wire may be withdrawn for delivery from the inner periphery of the coil. In the illustrated form, the wire is withdrawn through the opening in flange **11**. At this point it might be noted that after the coil is formed, it is necessary to draw the line through the

proper flange, otherwise a severe twist will be imparted to the line upon withdrawal. The end flanges **11, 11′** are maintained in spaced relation by rigid casing **13** in direct contact with the outer periphery of the coil body **10**. The casing may carry these flanges **11, 11′** in any desired way as for example by providing the casing **13** with an inturned flange or bead **14** at one end, and an outwardly turned flange **14′** on the other end, to match with corresponding parts on the peripheries of the end flanges. The casing can be assembled on the completed coil by slipping over the beaded flange and bolting to the other flange, so that the casing and end flanges will mutually support each other in desired position. The article as shown in Figure 1 is provided with a taper, the coil of wire and casing both showing such taper in equal amount.

It is desirable to provide means to assure that the wire remain in position before it is intended to be withdrawn. One desirable expedient that may be used for this purpose is illustrated in Figure 1, and in section, in rotated position, in Figure 5. The flange and mandrel have been omitted from Figure 5 for the purposes of clarity, although it is to be understood that of course the relation of wire to bushing does not exist except in conjunction with the flanges. As shown, it may take the form of a thin tear-out bushing B, of any desired material such as soft aluminum or the like, shaped to conform closely with the inner periphery of the coil of wire **10**. It is thus substantially cylindrical in shape, in the form of a collar, as shown at **44**, having its outer peripheral edge **45** flared to lie contiguous to the end convolution of the wire at that point. The bushing has an opening **46** through which the pulling end of the wire passes. The opening **46** may be a hole, but is preferably simply a notch or slot in the edge of the bushing. When the wire is withdrawn, it bears against the aluminum, the latter tears and distorts and passes out of the casing, releasing the wire for ready withdrawal. If the preferred notch in the edge of the bushing is utilized, the bushing is free of the line once it is distorted and collapsed, no tearing being necessary which would be required to free the wire of the bushing if a hole were used.

In the enlarged fragmentary view shown in Figure 2, a dot-dash line **15** is shown on the wire leaving the coil **10**. In the uncoiled portion **16** of the wire, the line **15** is parallel to the axis of the wire, and may be considered an element of its cylindrical surface in the normal, relaxed condition of the wire there being no torsional strain. However, in the body **10** of the coil, the line **15** is shown as extending helically with respect to the axis of the wire, thus representing the twist or torsional strain in which the wire is coiled. While the direction of this twist is represented in the drawing, it can most readily be described as follow: looking at that end of the coil **10** from which the wire is withdrawn, and looking along the wire coming from the coil, the coil (Figure 2) appears to unwind clockwise, while the twist, as the point of observation advances along the wire, is counterclockwise. This is true both when the wire is being taken from a layer wound as shown or from an adjacent layer where the winding is from the opposite end. Quantitatively, the twist is equal to approximately one turn per convolution of the wire in the coil. This amount of twist presupposes a closely wound helix of comparatively large diameter, compared to the diameter of the line. This is the usual case with steel rope or wire, as the minimum diameter of coil is fixed by the ability of the rope to bend without taking a permanent set.

The degree of twist is dependent on the diameter of the coil, the diameter of the wire, the pitch of the convolution, i. e. how closely wound the helix is, and on the metal of the wire. All these factors must be taken into account in producing a coil in which the wire has not been converted into a condition of permanent set. The latter must be avoided, and accounts for the failure of the prior art to eliminate the difficulties. In general, the necessary condition is satisfied by specifying that the torsional deformation is within the elastic limit of the wire.

While as illustrated, the coil convolutions may be wound close, that is, with adjacent convolutions touching, the convolutions need not touch but may be spaced from one another for example as much as ten wire diameters between turns in "random" winding.

Articles as disclosed herein may be made in any desired way as for example by the machine shown in Figure 3, which is illustrative.

The mandrel **20**, having a portion tapered to produce the taper evident in Figure 1, is supported in bearings **21** and **22** for rotation. Bearing **21** is removable, to permit the flanges **11, 11'** to be placed thereon, and the withdrawal of the completed coil. In order to rigidly support the flanges, which may be of sheet material as shown, collars **50** and **51** may be provided affixed to the mandrel **20**, and against which the flanges **11, 11'** engage. Collar **50** must, of course, be removable, in order to permit the withdrawal of the mandrel, the collar **51** may also be removable if desired. The mandrel **20** is driven by the bevel gears **23**, which in turn are driven by shaft **24**. Shaft **24** may be driven by a belt **25** or any other suitable drive. In order to assure even spooling of the wire on the mandrel, the distributor mechanism **26** is provided, which consists of a conventional double threaded screw and traveler provided with limit stops reversing the direction of motion of the traveler, as is well known in the art. The distributor screw is driven by gears **27** and **28** from the mandrel shaft, thus assuring a definite distributing motion for every revolution of the mandrel.

When a bushing B is used as explained above, the mandrel may be provided with a slight shoulder **47** as shown in Fig. 4, the depth of which is equal to the thickness of the metal of the bushing B so that the latter will be flush with the mandrel surface on which the wire is coiled. In the event that the standing end of the coil is secured to another, similar, coil, it is desirable to have the standing end pass through the center opening of the flange opposite to the flange through which the wire is withdrawn. To this end, the flange **11'** is provided with a projecting or upstruck spiral, in which the standing end may be inserted. When this is done, it is of course necessary for the mandrel to be grooved, as shown at **48** (Fig. 4), to permit withdrawal of the completed coil without shearing off the wire. Of course, a notch in the flange could be provided, to obviate the necessity of a groove in the mandrel, but this may sometimes result in a tendency of the wire from the adjacent dispenser to bind as it runs out of its dispenser.

In order to produce the twist referred to, the supply reel **29** is mounted in such a fashion as to rotate about an axis parallel to the line of the wire. The reel is mounted on a shaft **30**, which is held by separable bearings **31** to the flier frame **32**. This frame is mounted to rotate in bearings **33**, and is driven by the chain **34** which engages sprocket **35** fixed to the shaft **36** and sprocket **37** on shaft **24**. The two sprockets have been shown the same size, as are bevel gears **23**, which is one way of achieving the required one twist per revolution of the mandrel **20**.

The shaft **38** of the flier **32** has a bore **39** through which the wire passes to the mandrel. It is desirable to provide the guide wheels **40** which help to transmit the twist to the wire being paid off from the supply reel **29**. These wheels may be rotatably mounted on the hollow shaft **38**.

A suitable brake mechanism (not shown) may be applied to the supply reel or its supporting shaft to impart the desired tension to the wire being wound on the mandrel.

The article thus made includes the coil mounted on a rigid mandrel **20** between rigid end flanges **11, 11'**. This article is removed from the bearings **21** and **22** and the casing such as **13** in Figure 1 is applied before the mandrel **20** is removed. When the casing **13** is in position, the mandrel **20** is removed giving the finished article as shown in Figure 1.

In order to make the entire winding and withdrawal of the mandrel entirely clear, reference is had to Figure 4. The flanges **11, 11'** and the bushing B, as well as the collar **51** being in position on the mandrel, the wire end (which is to be the pulling end of the wire) is passed through the opening **46** of the bushing, through a slot **42** in the mandrel **20**, and wrapped around the mandrel at the reduced region **54**. This is a mere matter of convenience, and any other means may be utilized to provide the necessary end for pulling. The collar or flange **50** is then placed on the mandrel, and pinches the right hand flange **11** against the end of the tapered portion of the mandrel. The assembly is mounted in the bearings **20** and **21**, and the machine is started. No real stress is exerted on either flange **11** or **11'**, and it is therefore unnecessary to provide any support except for the collars **50, 51**. Collar **51** may be grooved at **52** to provide clearance for the struck-out spiral referred to before.

After the machine has run sufficiently to bring the level of the wire in the coil to the proper height it is stopped, and the wire cut and threaded into the struck-out spiral in flange **11'**. It will issue from a slot **53** in the collar **51**, and is drawn out to make the last turn on the outer periphery of the coil flush with the others. The outer casing **13** is slipped in place, and bolted or riveted to the flange **11'**. If desired, the bead **14** may be clinched for greater rigidity of the casing.

The end collar **50** is then removed, and the mandrel **20** withdrawn. The slot **48**, which of course must register with the point of exit of the wire from the struck-up spiral, permits such withdrawal of the mandrel **20** without shearing the standing end of the completed coil.

To exemplify articles produced in accordance with the present invention, 576 feet of 3/16" 7 x 7 aircraft cable may be formed into a solenoidal coil having an internal diameter of 6½", an outside diameter of 8¾", and a length of 8¼", the convolutions in the coil being contiguous to one another. The angle of the torsional deformation was equal to one turn per convolution of the coil. The wire may be of steel.

A modified form of spool is shown in Figure 6 adapted for use on machines for taking back-twisted wire from a stationary spool to deliver torsion free wire to a fabricating machine. In this case the wire coil **10** is wound on the spool barrel **70** having end flanges **71, 72** attached thereto. The mounting mandrel **73** carries a corrugated rubber layer **73'** bonded to the mandrel **73** and wedged between the barrel **70** and mandrel **73** so that a unitary structure is obtained. Mandrel **73** is provided on its inner end with an annular lip **74** enabling the mandrel to be attached to wall plate **75** on wall **76**. A stop **77** bolted to wall **76** is shown at the upper portion of the inner flange **71**, against which the flange engages. A conventional rotating flier (not shown) is used to remove wire from the spool. The spool may be wound in this case as described above for other modification, with as many convolutions of back twisted wire as desired. For securing the end of the wire after coiling, cellulose tape has been found sufficient.

In both types of articles produced in accordance with the present invention, there is no rotation of the delivered wire relative to the coil, the wire is delivered in unstrained, relaxed condition, high speed of delivery such as from 100 to 1000 feet/second is possible, without kink, snap or other difficulty.

Having thus set forth my invention, I claim:

1. The method of making a coil of wire adapted to deliver said wire by withdrawal therefrom at high delivery speed without rotation of the delivered wire relative to the coil and without development of torsional stress in the delivered wire, said method comprising winding wire of elastic metal on a rigid mandrel between rigid end

flanges carried on said mandrel, rotating said mandrel to wind the wire thereon in a close substantially cylindrical helical coil the ends of the coil being in direct contact with said flanges, twisting said wire about its axis as said wire is winding on said mandrel to give said wire torsional deformation within the elastic limit of the material of the wire, there being one complete twist for each convolution of the wire on the mandrel whereby the angle of said torsional deformation is substantially the same for each convolution of the coil, the direction of twist being opposite to the direction of ultimate unwinding during withdrawal of the wire from the coil, applying a rigid casing over and in direct contact with the outer layer of the coil, and anchoring said casing to said flanges to retain the latter in spaced relation.

2. The method of making a coil of wire adapted to deliver said wire by withdrawal therefrom at high delivery speed without rotation of the delivered wire relative to the coil and without development of torsional stress in the delivered wire, said method comprising winding wire of elastic metal on a rigid mandrel between rigid end flanges carried on said mandrel, rotating said mandrel to wind the wire thereon in a close substantially cylindrical helical coil the ends of the coil being in direct contact with said flanges, twisting said wire about its axis as said wire is winding on said mandrel to give said wire torsional deformation within the elastic limit of the material of the wire, there being one complete twist for each convolution of the wire on the mandrel whereby the angle of said torsional deformation is substantially the same for each convolution of the coil, the direction of twist being opposite to the direction of ultimate unwinding during withdrawal of the wire from the coil, applying a rigid casing over and in direct contact with the outer layer of the coil, anchoring said casing to said flanges to retain the latter in spaced relation, and removing the mandrel from within the coil after the casing has been anchored in position.

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