July 2, 1957 J. M. CROM, JR 2,797,878

APPARATUS FOR APPLYING A TENSIONED WIRE WRAPPING TO CONCRETE ARTICLES

Filed Aug. 14, 1953 5 Sheets-Sheet 1

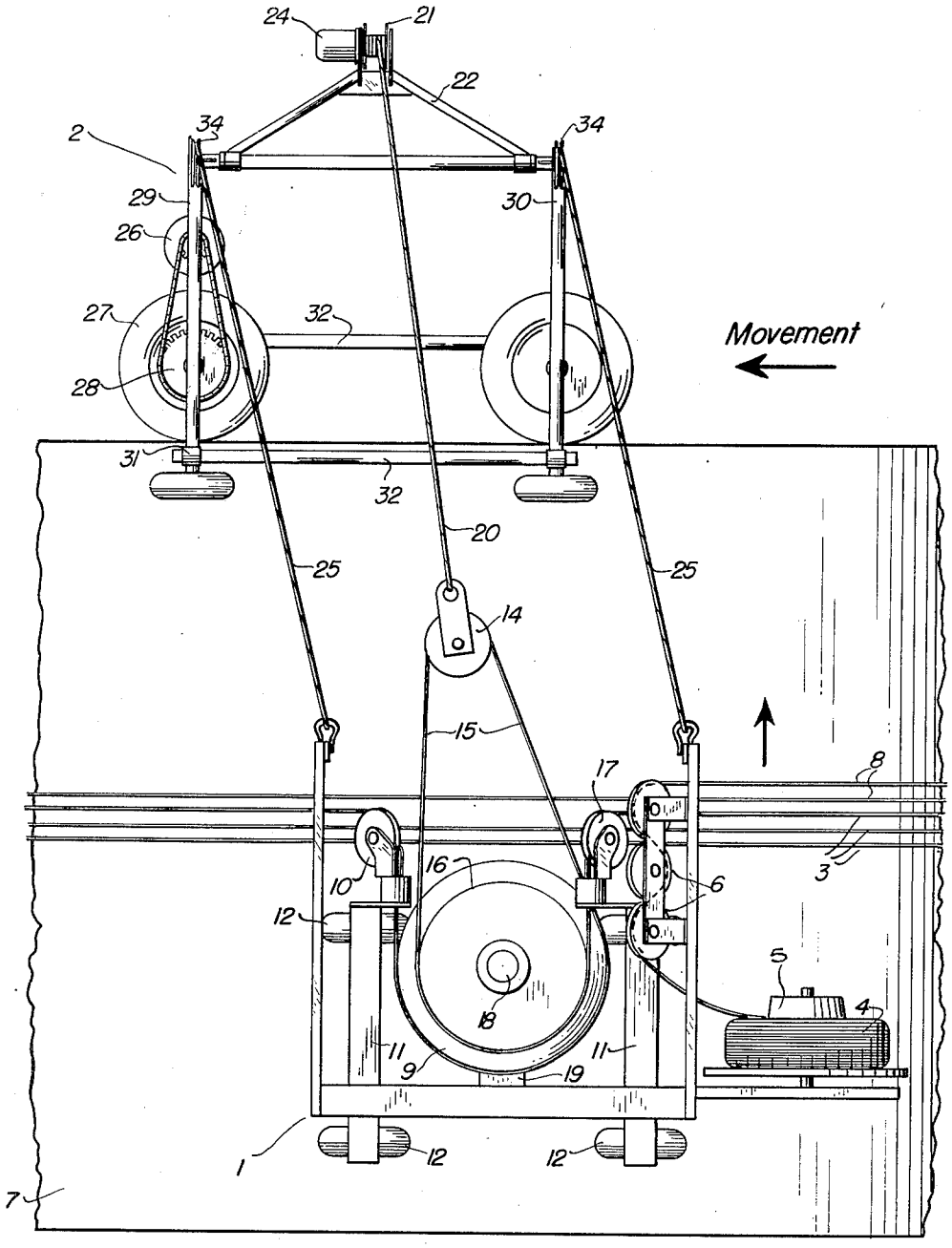


Fig. 1

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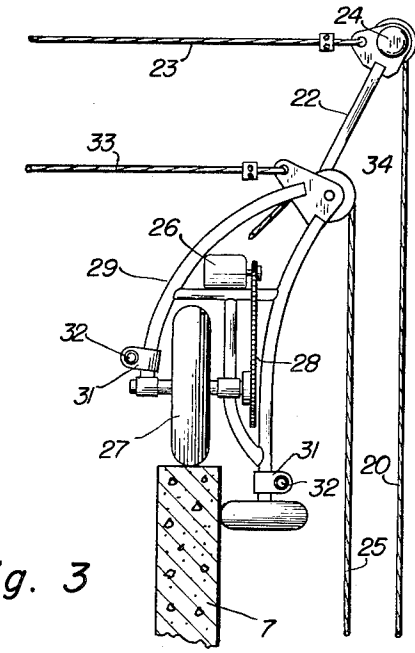


Fig. 3

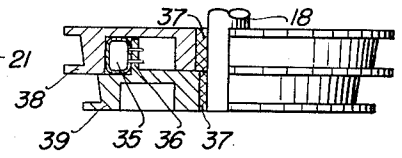


Fig. 5

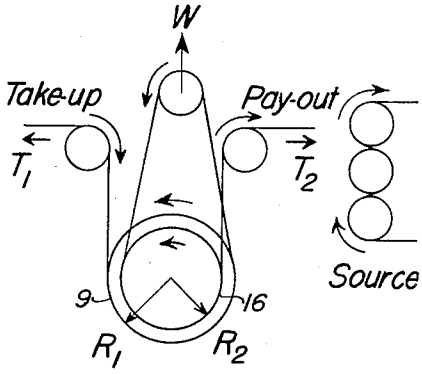


Fig. 4

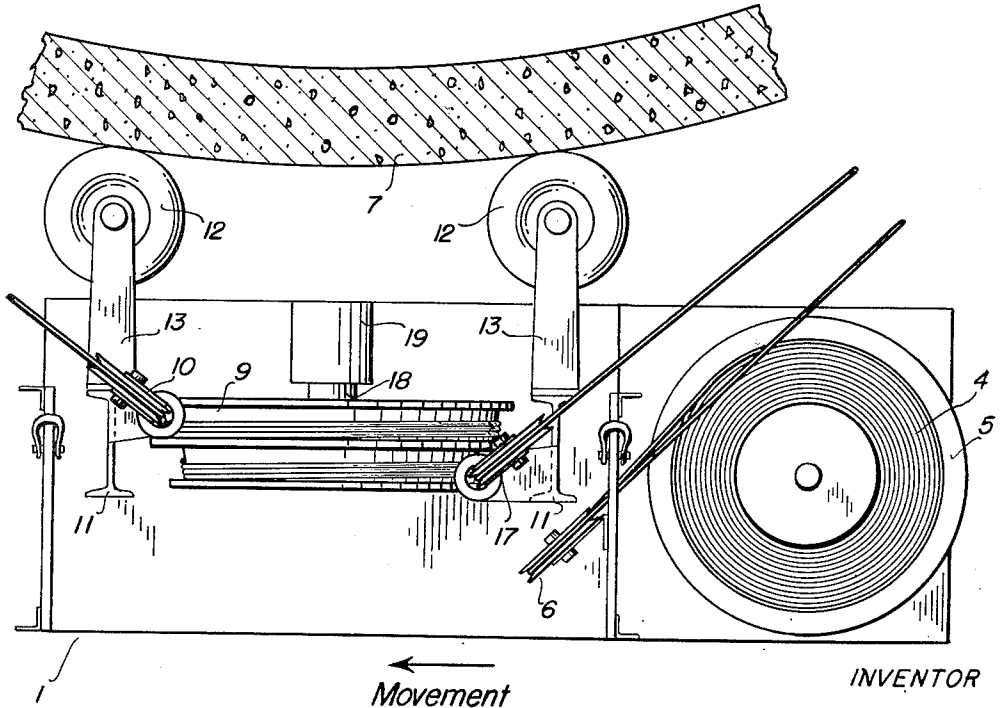


Fig. 2

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APPARATUS FOR APPLYING A TENSIONED WIRE WRAPPING TO CONCRETE ARTICLES

Filed Aug. 14, 1953 5 Sheets-Sheet 3

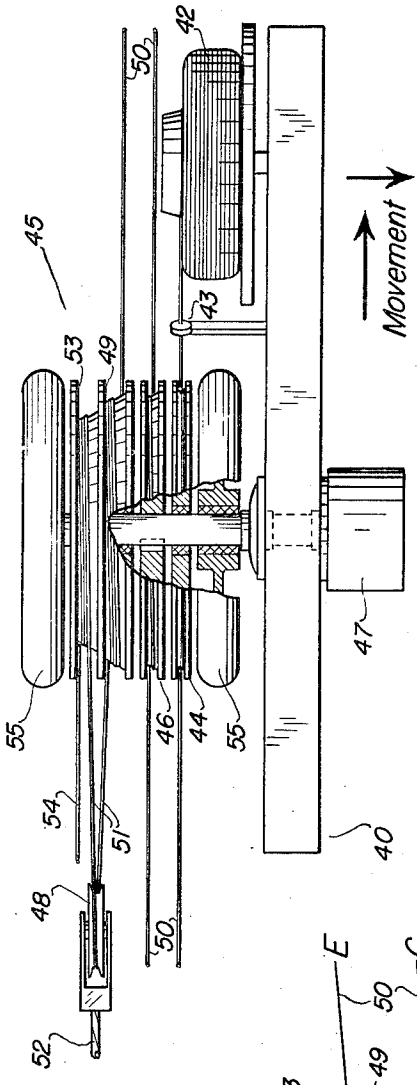


Fig. 7

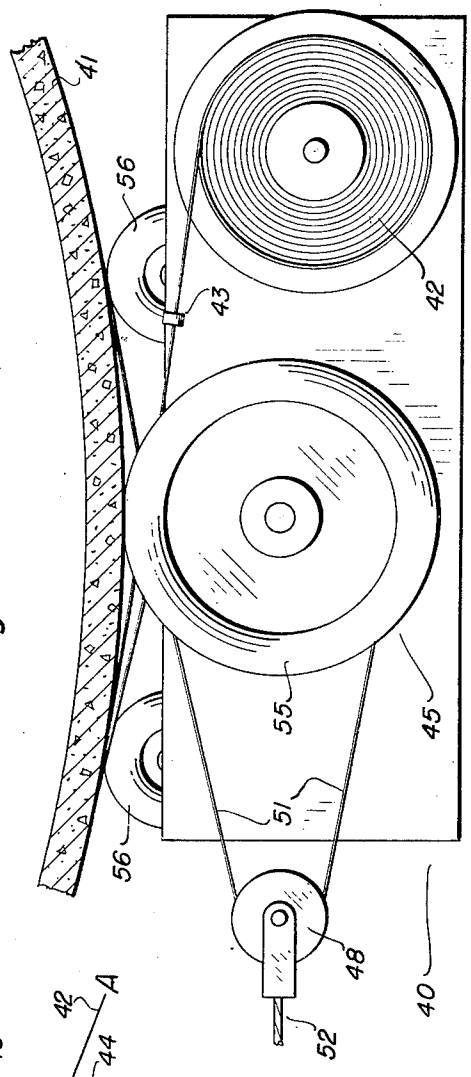


Fig. 6

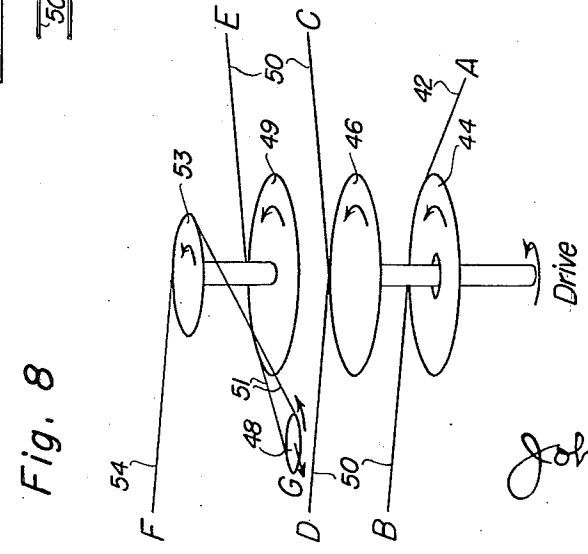


Fig. 8

INVENTOR

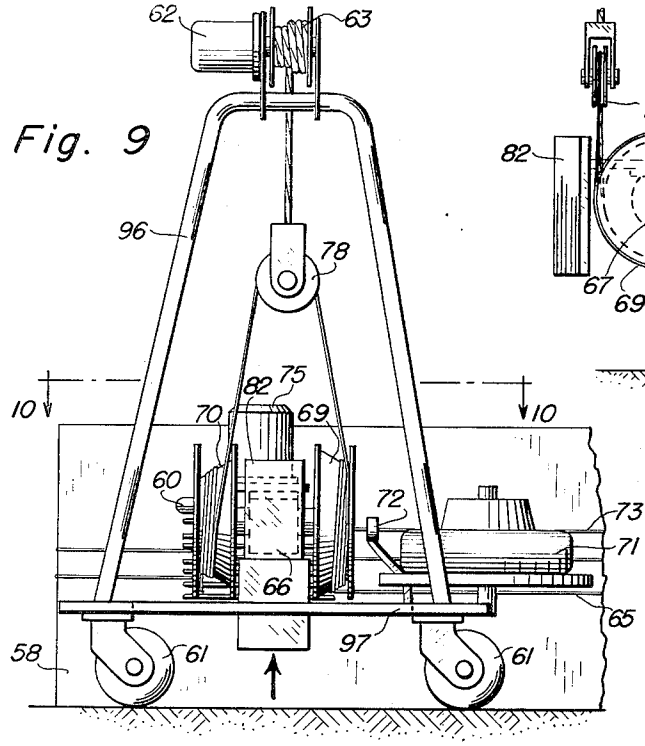
John M. Crom, Jr.

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APPARATUS FOR APPLYING A TENSIONED WIRE WRAPPING TO CONCRETE ARTICLES

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Fig. 9



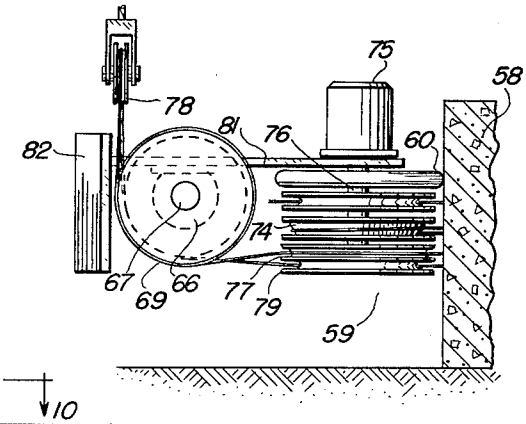


Fig. 11

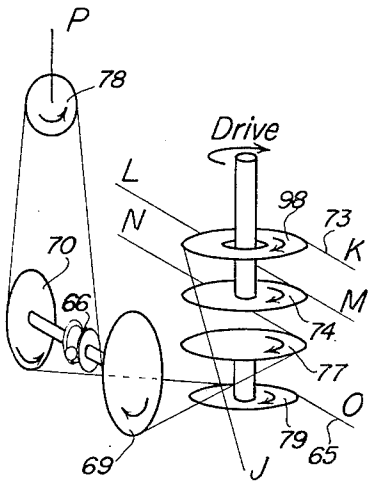


Fig. 12

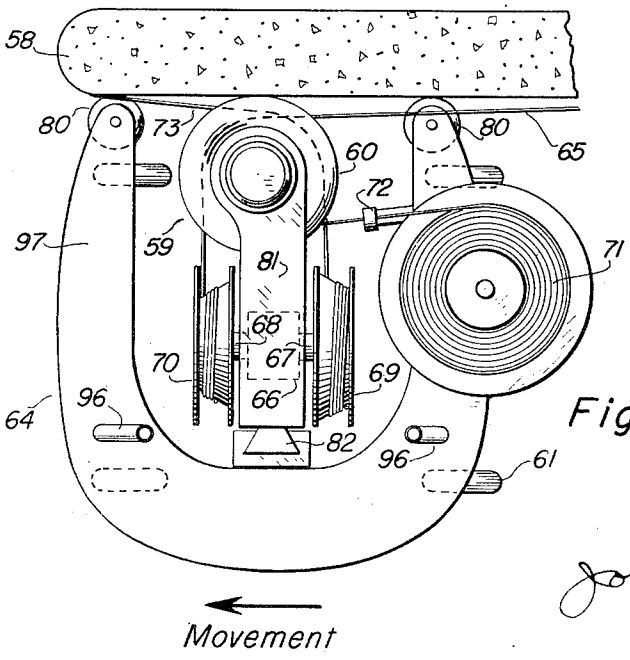


Fig. 10

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APPARATUS FOR APPLYING A TENSIONED WIRE WRAPPING TO CONCRETE ARTICLES

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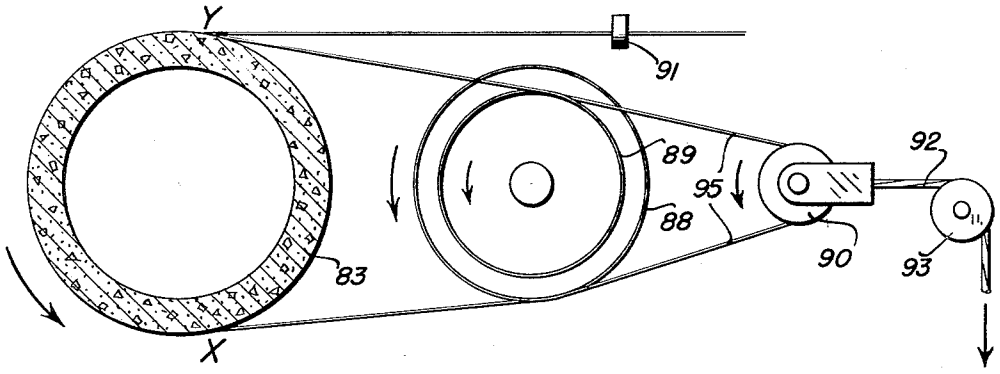


Fig. 14

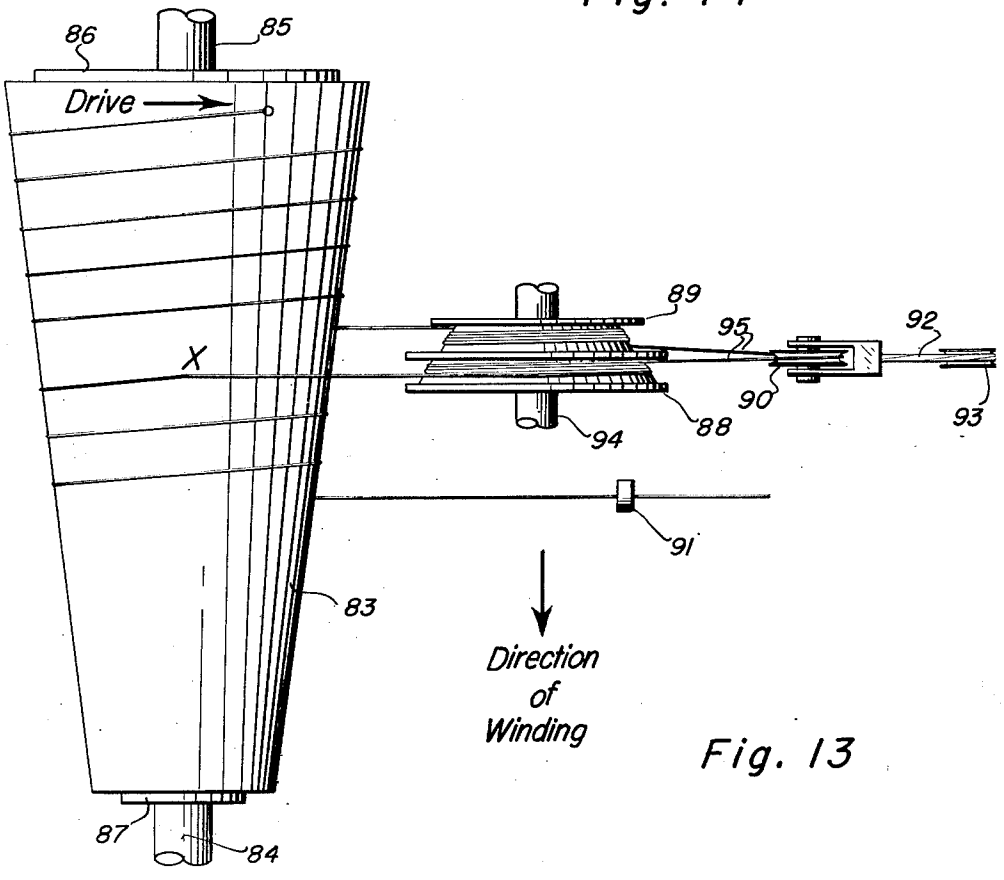


Fig. 13

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United States Patent Office

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APPARATUS FOR APPLYING A TENSIONED WIRE WRAPPING TO CONCRETE ARTICLES

John M. Crom, Jr., Falls Church, Va.

Application August 14, 1953, Serial No. 374,308

8 Claims. (Cl. 242—7)

This invention is concerned with an apparatus for winding with tensioned wire in the interest of prestressing large immovable or unwieldy structures such as tanks, silos, or the like having a circular, square, or any other geometrical cross-section. It is also adaptable for winding other stationary structures such as beams in the longitudinal direction. The invention is particularly concerned with the wire tensioning arrangement and the driving traction means.

This invention provides certain improvements over my pending application Serial No. 289,063, filed May 21, 1952, now Patent No. 2,749,054, issued June 5, 1956. In this prior application a method was disclosed for wrapping a tank with wire in the furtherance of the well known principle of prestressing for the purpose of economy in reinforcing steel and improved functioning of the structure, whereby tension was produced in the wire with expenditure of relatively little power by providing a reciprocity of action between pay-out of wire from a vehicle and movement of the vehicle around the tank, such as to pay out wire at a lesser speed than the linear forward movement of the vehicle around the tank. This was accomplished by means of a pay-out element mounted on the vehicle, meshing at the established speed ratio with a heavy roller chain in frictional, non-slipping contact around the circumference of the tank wall. The pay-out element was characterized as a rotatable device preventing slippage of wire around it, but discharging wire in proportion to its rotation. In the present invention elements of the same general type are used, also in a manner which will realize the same relatively low power expenditure, but which will eliminate the need for the heavy and costly roller chain while retaining uniformity and control in the degree of tensioning.

The basic tensioning means of the new invention consists of three principal elements located on the vehicle circumrotating about the tank or other structure. In operation the vehicle lays down a relatively loose wire as a temporary wrapping in traveling around the tank. The wire is returned again to the vehicle one or more turns later after it has acquired sufficient frictional resistance through contact with the tank wall to prevent any slipping back to the point on the vehicle where it is being laid down. On being returned to the vehicle, the wire is carried around the first of the elements for tensioning. The latter, a take-up element, is similar in characteristics to the element described in application Serial No. 289,063, now Patent No. 2,749,054, allowing a non-slippage discharge of wire in accordance with its rotation. The third element, a pay-out element, is also similar in its construction, and is connected for reciprocity of rotation with the first element. The connection between the two is such that the pay-out element will let out wire onto the tank as the permanent winding at a slower rate than it is picked up by the take-up element. The intermediate element is a device for absorbing the stretch in the wire continually developing as the wire is tensioned. This second element can be a suspended or floating

sheave around which the intermediate portion of wire is looped. The sheave must be counterbalanced by a weight or other force sufficient to keep slack out of the wire loop and to give the small back tension that may be necessary in the prevention of slippage around the take-up and pay-out elements. Tension in the wire is developed in accordance to the difference in rates of take-up and pay-out of the wire by separate elements on the vehicle itself in contradistinction to my referred-to earlier invention, which had no take-up element, the structure itself serving as the interconnected means of take-up.

A primary object of the invention is to provide a simple and improved means for applying tension to wire being wound on stationary structures, whereby the tensioning means is not dependent of engagement on the wire by reducing orifices, weights or beam balanced winches, brakes, or other resistances, all commonly known to the art.

Another object of the invention is to give improvement in the winding of tank structures over my prior invention, application Serial No. 289,063, now Patent No. 2,749,054, by permitting use of the wire itself as the means for securing frictional contact with the structure, thus eliminating the heavy and expensive roller chain required in my prior invention.

Another object of the invention is to provide a means giving other improvement in the winding of tank structures over my prior invention, application Serial No. 289,063, now Patent No. 2,749,054, by permitting winding of wire at considerable distances above or below the vehicle without introducing a horizontal force couple tending to tip the machine. In the prior invention the location of the traction roller chain was for all practical considerations fixed at the level of the vehicle body. Winding out the wire at any apprecibale distances above or below the machine necessary in some phases of tank winding, introduced difficulties requiring ballasting of the vehicle to keep it riding level. In the present invention the temporary wire wrapping for traction and the wire in final position can be maintained at the same elevation giving inherent stability to the vehicle, and permitting a very small and lightweight vehicle construction.

Another object is to provide a means for continuously winding a wire under tension that will require relatively little power as contrasted with many earlier methods where the wire was continuously pulled against a reducing orifice, brake, or other resistance means.

Another object is to provide a means for controlling the tension in a wire being continuously wound on a structure by engaging the wire through elements of a tensioning means from a loose, temporary wrapping around the structure, whereby a fixed ratio of speeds corresponding to the desired degree of tension is established in the elements for taking up wire of the temporary wrapping and for paying it out again to the structure as the permanent winding.

Another object is to provide a means for controlling the tension in a wire being continuously wound on a structure, which is not dependent on adjusting within close limits the speed ratios of the elements for take-up and pay-out from the temporary loose wrapping, but which is dependent on providing speed ratios tending to overtension the wire with relief to the desired degree of tension being attained by slipping through an interconnecting clutch.

Another object is to provide a means of tensioning wire continuously around a cylindrical tank structure with motive power being provided through the wheels of an overhead carriage which rides the top of the wall and supports the tensioning vehicle.

Another object is to provide a means of tensioning

wire continuously around a structure while introducing the driving power into the wire itself by engagement of a rotatable wheel on the wire of the temporary wrapping at least one wrap ahead of the point of take-up by the tensioning mechanism.

Another object is to provide a means of tensioning wire continuously around structures of any cross-sectional shape, such as square tanks or beams in the longitudinal direction by employing a contact wheel assembly which bears against the side of the structure on a vertical line contact enabling passage around corners, and which guides wire to and from the structure being wound as required by the tensioning mechanism.

Another object is to provide a means of tensioning wire continuously around any structure of any cross-sectional shape, which can be of a varying dimension, such as a pipe having a low pitch taper down which the wire will not slide.

These and other features of the invention will be best understood and appreciated from the following description of preferred embodiments thereof selected for purposes of illustration and shown in the accompanying drawings in which,

Figure 1 is a front elevation of a wire wrapping vehicle supported by an overhead carriage applying tensioned wire to a tank structure in accordance with the method of this invention.

Figure 2 is a plan view of the vehicle of Figure 1 in traverse around the tank structure.

Figure 3 is an elevation directed toward the leading end of the overhead carriage of Figure 1, showing method of drive.

Figure 4 is a diagrammatic representation of the paths taken by the wire in Figure 1 and of the force relationships in the wire.

Figure 5 is a view of an alternative arrangement of a pay-out and take-up element interconnected by a clutch, in partial section so as to show the interior construction.

Figure 6 is an alternative arrangement in plan view of a wire wrapping vehicle applying tensioned wire to a tank structure, with the drive being by engagement with the wire through one of the wheels of a contact wheel assembly.

Figure 7 is a front elevation of Figure 6.

Figure 8 is a diagrammatic representation of the paths taken by the wire in Figures 6 and 7.

Figure 9 is a front elevation of a vehicle adapted for winding tensioned wire on beams, and illustrating a modification of a contact wheel assembly from that shown in Figures 6 and 7.

Figure 10 is a sectional plan of the vehicle taken along line **10—10** of Figure 9.

Figure 11 is an elevation directed toward the trailing end of the removed detail of the contact wheel assembly.

Figure 12 is a diagrammatic representation of the paths taken by the wire in Figures 9, 10, and 11.

Figure 13 is a plan view of a further embodiment of the invention showing a tapered pipe section in rotation taking up a tensioned wrapping.

Figure 14 shows the tapered pipe of Figure 13 in cross-section with the elements of the tensioning means in side view.

Common to any embodiment of the invention are several requisites. First there must be an article to be wound with tensioned wire and machine elements exterior to the article to effect the winding. There must be a relative movement between the two for placing the wire, either by rotation of the article with the machine elements being fixed or by orbital movement of the machine elements around the article. As will be shown herein, the orbital path of the machine elements around the article does not have to be circular, it being necessary only that it conform to the cross-sectional shape of the article.

Second there must be a source of wire, usually from a roll of wire on a swift, that is loosely applied as a temporary wrapping around the article through relative movement between the article and the machine elements. There must be enough turns of wire in the temporary wrapping combined with the slight back tension present at the source that will offer frictional resistance against slippage at the point of application from the source.

In effect a continuous, non-slipping, relatively untensioned supply of wire is being provided through the temporary wrapping that bears the same path length around the article that the tensioned wire will finally occupy.

Third there must be a tensioning means among the machine elements continuously acting to shorten this supply of non-slipping, untensioned wire which is fed through it, with attending tension being a function of the shortening.

The novelties being claimed are in the means for shortening the wire supply of the temporary wrapping, and in the means for driving the tensioning means and other machine elements relative to the article.

One embodiment of these novelties is apparent in Figures 1, 2, and 3, wherein a wire wrapping vehicle **1** supported and driven from an overhead carriage **2**, is illustrated in the process of applying a tensioned wrapping of wire **3** to a concrete tank **7**. The source of wire is a roll **4** turning off swift **5**, and passing through a series of rollers **6** to create some slight back tension. Experience has shown that the back tension need be no more than about one twenty-fifth of the applied tension in the final wrapping **3**, this usually being sufficient to keep the wire snugly in position around the tank and without circumferential slipping going as far back as the source **4**. The series of rollers **6** provide a convenient means of obtaining the needed back tension, but other means, such as a brake block or a die, work equally well. The wire then passes onto the tank **7** to form the temporary wrapping **8**. The temporary wrapping **8** has a sufficient number of turns, usually no more than two or three being required, to create a friction path forestalling slippage at source **4** from the force differential between the fully tensioned wire of the permanent wrapping **3** and the relatively loose wire of the source **4**. The vehicle **1** advances around the tank **7** taking up the wire of the temporary wrapping **8** by the element **9** through guide means **10**. Guide means **10** is a freely rolling caster serving to align and direct the horizontal wire entering from the tank **7** into a path vertically downward as required by the location of the wheel of the take-up element **9**. An I-beam **11** supports the guide means **10**, as well as vehicle wheels **12** through bracket **13**. The wire is carried around the wheel of take-up element **9**, passing therefrom over free turning sheave **14** to form a loop **15**, from whence it goes around the wheel of pay-out element **16**. A second guiding means **17**, similar to first means **10**, transmits the wire from the wheel of pay-out element **16** into the final tensioned wrapping **3** on the tank **7**.

Elements for take-up **9** and pay-out **16** are similarly constructed wheels characterized by tapered faces. Wire, when wrapped several times around wheels of this construction, will not freely slip, although one end is under considerable tension, provided the other end has some measure of counter-tension. It can be shown by a recognized formula well known to the art that the frictional capacity around the wheel for two and a half turns of wire is 25, this figure representing the ratio in the tensions of the tight wire to the loose wire that can be supported without slippage for a coefficient of friction value of 0.205 for steel on steel. When the taper is correctly designed, such a wheel will continuously handle tensioned wire, each turn progressively sliding down the taper as the wheel rotates. The downward slide presents a slight amount of circumferential creep. This must be allowed for in considering a wheel diameter that will give a certain relative amount of take-up or pay-out. Hence this

type of wheel has ability to controllably check slippage of wire therearound, although not preventing slippage altogether. Other types of wheels can be substituted that have means for preventing slippage, such as wedges or fingers that are cam actuated to bear forcefully on the wire during its passage around the wheel.

The wheels of the take-up and pay-out elements **9** and **16** are interconnected. In Figure 2 the interconnection is by integral construction of the wheels, which are free to roll as one through bearings on shaft **18**, cantilevered from support post **19**. If the wheels were differently situated, the interconnection might be through gearing or sprockets and chain. In one situation to be described, the interconnection is by means of a clutch. Movement of one wheel produces movement in the other wheel, thus giving reciprocity of rotation. The hookup between wheels is such that any rotation will produce wire take-up by one wheel and pay-out by the other, the relative amount being in relation to wheel diameters and ratio of turning speeds through the interconnection.

Figures 1 and 2 show the wheel of the take-up element **9** to be larger than the wheel of the pay-out element **16**. Hence for the integral construction of the interconnection illustrated, it follows that the rate of taking up wire from the temporary wrapping **8** by virtue of traversing vehicle **1** around tank **7**, is greater than the rate at which wire is being paid out into the final wrapping **3**. Inasmuch as the path lengths for the wire around the tank are the same before and after engagement by the elements of the vehicle **1**, it is to be concluded that the wire must be stretching by the difference in take-up and pay-out in order that this requirement may be satisfied. As the take-up element **9** is picking up wire faster than pay-out element **16** is letting it out, wire is therefore accumulating between elements **9** and **16**, and hence it follows that the stretch must appear at locations other than intermediately to the elements **9** and **16**. Further the total stretch must equal the total accumulation between elements **9** and **16**. The stretching results in tension being produced in the wire approximately in proportion to the stretch.

In Figure 1 a free rolling sheave **14** is provided to control the loop of wire **15** forming as a result of wire accumulating between elements **9** and **16**. In effect sheave **14** is absorbing stretch being produced in the wire around tank **7** by action of the tensioning means, elements **9** and **16**. Sheave **14** is given upward pull by cable **20**, spooling from drum **21** located on the overhead carriage **2**. An A frame **22** mounting on the top of overhead carriage **2** and being braced by cables **23** running to a post not shown situated at the center of the tank **7**, supports the drum **21** and a motor **24**. The latter drives the drum **21**, imparting a relatively constant pull on sheave **14**. Due to sway of vehicle **1** that may occur during travel, adjustment of the sheave **14** upward or downward may be necessary. Motor **24**, therefore, should have constant torque characteristics and should allow overhauling in reverse to release any excess pull. It should be able to endure continuing stall. Many air and hydraulic motors have these characteristics. In an alternative arrangement a weight could be substituted for motor **24**. Here cable **20** would have been directed upward over a pulley on the A frame **22** to a weight acting to give pull on the cable **20**. Relatively little force need be exerted on sheave **14**, it being necessary only that the weight of sheave **14** be supported and slack eliminated in the wire loop **15**, such as to prevent wire slippage around elements **9** and **16**. Referring back to the example cited for the frictional capacity of the wheels of elements **9** and **16**, whereby the tension ratios of the tight were to the loose wire around the wheels needed to be no less than 25 to 1, it would then be necessary to provide a force on sheave **14** no more than about one twelfth the tension to be expected in the final wrapping **3**. This force could be reduced still further by providing more turns of wire around the wheels of elements **9** and **16**.

For a better understanding of the forces existing throughout the system, a diagrammatic representation of the path taken by the wire in its passage onto the tank as a wrapping in final tension is presented in Figure 4. All wheels of the diagram are on bearings, including the integral wheel combination of the take-up and pay-out elements, and therefore the torques from wire tensions are in balance about any wheel. Assuming the force, W, to be negligible in its action, it follows that there is this relation between tension forces, T_1 and T_2: T_1/T_2 equals R_2/R_1. It is therefore seen that considerable tension must exist in the wire just ahead of the take-up element **9**, inasmuch as R_2 and R_1 differ only slightly. This being the case, it means that the wire being engaged by the take-up element **9** has been prestretched. The take-up element must, therefore, handle an elongated supply of wire coming from temporary wrapping **8**, the stretch having developed in advance of the vehicle rather than behind the pay-out element **16**. Accordingly the wheel of take-up element **9** must be even larger with respect to the wheel of pay-out element **16** than would be the case if untensioned wire were coming to the take-up element. Calculation has shown that the theoretical ratio of R_1 to R_2 that will produce the desired tension in the wire of permanent wrapping **3** equals very nearly $(1+s)^2$, where s is the unit strain in the wire when under the desired tension. In a typical case, tensioning a No. 8 steel wire (0.162 inch diameter) to 2900 lbs. load will result in a strain in the range of 0.005. The theoretical ratio between wheel sizes of take-up and pay-out elements is then 1.01. The wire immediately ahead of the take-up element would have a theoretical tension of 2871 lbs. For all practical purposes there is counterbalance in the tensions of the wire between points immediately ahead of take-up element **9** and behind the pay-out element **16**.

Note that in rotation of the take-up and pay-out elements of Figure 4, power must be interchanged between the latter elements, because of the interconnection. Inasmuch as the tensions of wire in each element very nearly counterbalance each other, the interchange of power therebetween tends to be counteractive, requiring the addition of very little power to effect drive.

Referring again to Figure 1, vehicle **1** in combination with a tensioning means such as described above or any of equivalent character giving substantial counterbalance in the tensions of wire at points before and after engagement by the tensioning means, is pulled around tank **7** by the overhead carriage **2** through support cables **25**. Overhead carriage **2** is powered by a motor **26**, giving drive to wheel **27** through sprockets and chain **28**. The weight of vehicle **1**, in combination with a slight lag behind the overhead carriage **2**, evidenced by the inclination of support cables **25**, creates sufficient horizontal force component to overcome the sum of the relatively light drags still remaining from a counterbalancing tensioning means, from friction, and from back tension at rollers **6**.

Overhead carriage **2** has two end sections **29** and **30**, which are made up of welded tube members. End sections **29** and **30** are assembled in conformity with the curvature of tank **7**, being connected by means of clamps **31** to other tubular members that serve as spacers **32** and cross-braces (the latter not shown) to give a rigid construction. The whole is tied back by cables **33** to a post (not shown) at the center of tank **7**. The overhead carriage **2** is usually equipped with a means (not shown) that engages the ends of supporting cables **25**, running down over sheaves **34**, in order that vehicle **1** can be lifted progressively to give spacing in the wire wrappings.

Advantage is gained by having the counterbalancing wires entering and leaving the vehicle at the same elevation through guide means **10** and **17**. In this manner no force couples are introduced which would tend to un-

balance or tilt the vehicle, these being prevalent in some other winding machines known to the art. The I-beams **11** supporting guide means **10** and **17** can be arranged to allow adjustment vertically, thus controlling the elevation of the wire placement. It may be desirable also to provide a second pair of guide means **10** and **17** attaching to the bottom of I-beams **11**, in order that wire may be wound below the level of the vehicle.

In some instances it may prove difficult to establish the exact ratio in the wheel sizes of take-up and pay-out elements that will give the desired tension. This may be overcome by providing a greater ratio in wheel sizes tending to overtension the wire, and providing an arrangement such as is illustrated in Figure 5, to afford relief. Here illustrated is an interconnecting clutch means replacing the integrally constructed wheels of take-up and pay-out elements **9** and **16** as shown in Figures 1 and 2.

A torque can now be established at which the pay-out wheel **39** will slip relative to the take-up wheel **38**, by adjusting the air pressure going to sac **35**. Air sac **35** is attached to and extends completely around an inner rim **36** on the wheel of pay-out element **39**. Air pressure forces sac **35** into frictional engagement with the internal drum surface on the wheel of take-up element **38**. Wheels of elements **38** and **39** have individual bearings **37** running on shaft **18**. If the tension in the wire becomes excessive, countertorques are developed on the clutched wheel combination **38** and **39**, to produce relative slipping between the wheels. Such slippage shortens the loop of wire **15** accumulating between elements **38** and **39**, thus relieving the tension to normal.

The wrapping operation of Figure 1 is started by threading the wire from source **4** around rollers, tank, and wheels in the described sequence, and anchoring the wire end by means of a bolt to the wall of tank **7**. The wire is threaded snugly, leaving a loop **15** as small as possible around sheave **14**. Motor **24** is activated to place loop **15** under tension. The wire **3** is then tensioned by advancing the vehicle around the tank. When a roll of wire **4** has been exhausted, it has been found convenient to attach the beginning end of a new roll to the tail end of the old roll, using "line splices" well known to the art. The splice should be behind the rollers **6**, as it is not adapted to travel through the rollers. Winding is then continued until the splice arrives at the guide means **10**, whereupon the wire is permanently clamped to the tank wall behind guide means **17**. The tension may then be relieved in the wire through the various rollers and wheels on the vehicle. The splice can generally be worked through the latter impediments, when the wire is untensioned. Once the splice has arrived back of guide means **17**, the placement of tensioned wire may be resumed.

An alternative method for driving a wire tensioning vehicle around a tank or other structure is illustrated in Figures 6 and 7. Here shown is a vehicle **40** traveling around a structure **41**. Wire is supplied from a source **42**, the wire then being pulled through an orifice **43** to create the relatively slight back tension for the reason detailed in the embodiment of Figures 1 and 2. The orifice here replaces the series of rollers **6** of Figures 1 and 2. The wire is guided into temporary wrapping **50** on structure **41** by means of free rolling wheel **44**, it being one of a number of coaxial wheels constituting a contact wheel assembly **45**. It is to be noted here that the wire from the source can be guided directly to the structure through means other than a wheel of a contact wheel assembly without impairing greatly the efficient action of the contact wheel assembly in traveling around corners, such as in Figure 9. However it is generally convenient to have guidance around one of the wheels of the contact wheel assembly.

Driving wheel **46**, one of the wheels in the assembly **45**, picks up the wire of the temporary wrapping **50** around the structure **41** one or two convulutions back from the source **42**. The wheel **46** powered by motor **47** tractionally carries the wire around it, thus pulling vehicle **40** around the structure, and causing wire to flow around all of the free turning wire wheels of the assembly **45** and the sheave of stretch absorbing means **48**. Wheel **46** has a tapered face, and is similar in characteristics to the wheels of take-up and pay-out elements **9** and **16** of Figures 1 and 2. The wheel **46**, therefore, has capabilities of continuously exerting pull on the wire in advance of it, without noticeable slippage, while discharging it rearwardly onto the structure **41** as a continuation of temporary wrapping **50** at considerably less tension. After another turn, usually only one being required, around structure **41**, the wire is again picked up by the vehicle **40** and engaged by other wheels of the contact wheel assembly **45**, this time starting with the wheel of the take-up element **49**. The wire of the temporary wrapping **50** passes in almost non-slipping contact several turns around the wheel of take-up element **49**, finally emerging to form loop **51** being controlled and directed by the free rolling sheave **48**. A force from cable **52** on the sheave **48** keeps the loop **51** free of slack and provides sufficient back tension to prevent wire slippage around wheel elements **49** and **53**, in the same manner as was described in the embodiment illustrated in Figures 1 and 2. The wire of loop **51** is carried a number of turns around the wheel of pay-out element **53**, also a member of contact wheel assembly **45**, which deposits it in place on structure **41** as the final tensioned wrapping **54**.

Figure 8 is a simplified diagram of the course taken by the wire around the wheels of the contact wheel assembly **45** as it is taken from source **42**, until it is laid down as the final tensioned wrapping **54**. The wire is shown originating from source **42** at A, from where it passes over wheel **44** to start the temporary wrapping **50** at B. The wire continues one or more turns around structure **41** from B until it arrives at C from where it is engaged by driving wheel **46**, being tractionally carried around wheel **46** in one turn to be deposited at D. The wire continues from D in another turn around structure **41** arriving at E, from whence it is tractionally taken up in several turns by element **49**, thence passing over sheave **48**, and being paid out tractionally in several turns by element **53** into the final tensioned wrapping **54** at F.

The cable **52** originates from a means (not shown) supported by an outrigger (not shown) mounting to the front of vehicle **40**. This means consists of a drum and motor equivalent to those described and shown on Figures 1 and 3. Supporting mean for vehicle **40** are not shown, this depending on the rigging of the particular application. Wheels **56** keep the vehicle frame **57** from coming into contact with structure **41**. Free rolling wheels **55** take the radial load of the tensioned wires on the other wheels of the contact wheel assembly **45**, as well as keeping the same other wheels from touching the surface of structure **41**.

Wheels of take-up and pay-out elements **49** and **53** are again integrally constructed for reciprocity of rotation, with wheels of element **49** being larger than the wheel of **53**, such that the desired degree of tension is introduced into the final wrapping **54**. If desired, the alternate arrangement of the clutch of Figure 5 could have been incorporated.

As noted in the description for the embodiment of the invention in Figures 1 and 2, the tensions in the wire at either side of the tensioning means are substantially counterbalancing. If the drive wheel **46** were immediately in front of the tensioning means (for example at E in Figure 8), an additional load would be introduced to the wire equal to the force required to overcome the sum of any differential in the tensions of the wire through the tensioning means, the frictional resistance of the various wheels, the back tension on the wire from the orifice **43** at the start of the temporary wrapping, and possibly the resistance introduced from the vehicle supporting means not shown. The sum of these forces

would be in all likelihood enough to break the wire or at the least to subject it to severe yielding. A law of friction well known to the art provides that the tensions of a wrapping around a structure diminish rapidly from the tight side of the wrapping going back to the loose side in accordance with an exponential relation. Accordingly the tension in the wrapping generally about one turn or less forward of the tensioning means has been so reduced that the sum of the resistance forces enumerated above can be superimposed on the normal tension existing at that point, without overloading the wire to a dangerous degree. Thus we have a drive means acting on the wire at a point in advance of a tensioning means, the latter subjecting the wire to substantially counterbalancing tensions immediately before and after the tensioning means as illustrated in Figures 6 and 7. Such a drive means would work equally well in combination with tensioning means revealed by earlier patent art producing counterbalance in the tensions of wire fore and aft of the tensioning means employing a weight or force exerted on a loop in the wire between the temporary and the final wrapping.

The contact wheel assembly 45 illustrated in Figures 6 and 7 can operate in tensioning wire on structures having other than circular cross-sections, provided the diameters of all the wheels transmitting wire under tension are in close proximity with the structure, i. e. being very nearly as large as wheels 55 which freely roll against the structure 41, and which also are members of the contact wheel assembly 45. However the mechanics of winding tensioned wire on a non-circular structure can be better understood by referring to Figures 9, 10, and 11. Here a vehicle 64 is illustrated in the process of winding tensioned wire 65, on a horizontally situated beam 58. In this particular embodiment of the invention there is also a source of wire 71, a back tensioning means 72, a temporary wrapping 73, and a contact wheel assembly 59, having one wheel 60 rolling against the beam 58. The one wheel 60 is all that is required in this instance to keep the other wheels of the assembly 59 from touching the surface of the beam. This can be appreciated when it is considered that the overall axial length of the assembly 59 has been exaggerated for reasons of clarity in the illustration and also that vehicle 64 is sturdily enough supported by casters 61 so that the axis of assembly 59 remains very nearly perpendicular. The take-up and pay-out elements 69 and 70 are removed from the contact wheel assembly 59 in this embodiment. They are, however, connected for reciprocity of rotation at 1 to 1 reverse ratios through a speed reversing gear box 66 and keyed shafts 67 and 68. As in the other embodiments described, the wheel of take-up element 69 is larger than the wheel of pay-out element 70. Again elements 69 and 70 are constructed with tapered faces designed to controllably check slippage of wire therearound. Hence wire is tractionally taken up from temporary wrapping 73 faster than it is tractionally paid out as the final tensioned wrapping 65, thus having creation of tension.

Figure 12 is a diagrammatic illustration of the course taken by the wire in passing from the source 71 until placed as the final tensioned winding 65 around beam 58. This simplifies understanding of the paths taken by the wire in passing around the various wheels of Figures 9, 10, and 11. As in the earlier embodiment represented by Figures 6 and 7, the driving means for vehicle 64 is through forcible rotation of a driving wheel 74 situated in the contact wheel assembly 59. Driving wheel 74 is of tapered face construction, thus being able to tractionally carry around it the wire of temporary wrapping 73, in rotation by motor 75 through keying to shaft 76. Driving wheel 74 is shown picking up the wire of temporary wrapping 73 at L on Figure 12, the wire at this point being a one or more turn continuation around beam 58 from K, with further continuation over guide sheave 98 to the source 71 at J. The wire is tractionally carried around wheel 74 in one turn and returned to the beam at M, where it continues one turn around beam 58, to be picked up again by guide wheel 77 at N. The wire is guided by wheel 77 to the wheel of take-up element 69, around which it is carried several times, finally coming off above and passing around stretch absorbing sheave 78. From sheave 78 the wire is carried downward and several turns around wheel of pay-out element 70, discharging to guide wheel 79, which transmits the wire into final position on beam 58 at O.

Guide wheels 77 and 79 are members of contact wheel assembly 59. They are shown to be integrally joined together, freely rolling as one on shaft 76. Inasmuch as wire must be taken up faster than it is paid out, it is desirable that wheel 77 be larger than wheel 79 by the same ratio that wheel of take-up element 69 is larger than wheel of pay-out element 70. Otherwise there would be power losses in slippage around wheel 77. When the size ratios of wheels 77 and 79 are correctly designed, they can be considered as additional frictional surface of the take-up and pay-out elements. If desired, wheels 77 and 79 can be individual, each rolling independently on its own bearing. Their relative sizes would not be important in this case.

Vehicle 64 is supported by casters 61, which roll on the ground or other suitable supporting structures. Wheels 80 on the inside of vehicle 64 keep the horseshoe frame 97 of the vehicle from coming into contact with any part of beam 58. It can be seen from Figure 9 that as vehicle 64 reaches the rounded end of beam 58, contact wheel assembly 59 will remain in contact with beam 58 through wheel 60, by virtue of inward force components from various tensioned wires going around other wheels of assembly 59. Centrifugal force swings vehicle 64 around the end of beam 58 in following contact wheel assembly 59 as it rolls around the beam end until wheels 80 can again come into play against the side of beam 58. All wheels of the contact wheel assembly 59 picking up or laying down wire are advantageously provided of a size very nearly equal to wheel 60 so that wire will not have to be unduly lifted, and thus stretched as contact wheel assembly 59 rolls around the beam end. The invention is not limited to structures having broadly rounded corners, but will apply also to corners that are sharp.

Contact wheel assembly 59 is illustrated as having a bracket 81, supporting the drive motor 75, and the speed reversing gear box 66, these parts being shown removed from the vehicle 64 in Figure 11. The bracket 81 is attached to male dovetail 82. It is usually convenient to provide a means (not shown) for elevating dovetail 82 and thus contact wheel assembly 59.

Instead of driving the vehicle 64 through engagement of the wire of the temporary wrapping 73 by the drive wheel 74, the drive might have been along more conventional lines, whereby one or more of the supporting wheels (equivalent to caster 61) would be powered in traction to the ground.

The stretch absorbing sheave 78 is supported by the A-frame 96, which mounts a motor 62 and drum 63. These are equivalent to the corresponding components of Figure 1.

A scheme for winding tapered articles is illustrated in Figures 13 and 14. The embodiment of the invention as shown is that for a tapered pipe section 83 being rotated. The article could just as well have been a stationary tank or beam structure having a taper or other varying cross-sectional area, while still being applicable to the principles to be described for the tapered pipe section 83 picking up a tensioned wrapping in rotation.

The tapered pipe section 83 is horizontally situated, being supported by axial shafts 84 and 85 at each end. These shafts are connected to centering flanges 86 and 87. The shafts 84 and 85 are in bearings (not shown). One of the shafts 84 and 85 is connected to a power source (not shown) for rotating the pipe section 83,

The tensioning means comprising elements **88, 89,** and **90** is generally best mounted on a carriage (not shown) designed to traverse in a direction parallel to the axis of the pipe section **83**. The traverse of the carriage is best tied in with the rotation of the pipe section, in order that spacing of the wire wraps on the pipe section **83** can be controlled.

Wire from a source (not shown) is introduced through a back tensioning orifice **91**, of the same type and characteristics used in Figures 6 and 7. The orifice **91** is mountable on the traversing carriage along with the tensioning means. The wire is taken up in a temporary wrapping of several turns by the pipe section **83** in rotation, so as to develop traction in accordance with the principles already set forth.

The wire of the temporary wrapping leaves pipe section **83** at point X to be taken up by the wheel of take-up element **88**, which tractionally carries the wire several turns around itself finally discharging it to an equalizing element. The latter corresponds to the stretch absorbing element of the earlier embodiments of the invention, and consists of a free rolling sheave **90**, which is held back through a force on cable **92**, similar in character to the force described earlier in connection with the stretch absorbing element. There is also the similar weight or motor for providing the force on cable **92**. Sheave **93** keeps cable **92** in alignment. Sheave **93** also is attached to the traversing carriage (not shown).

From around sheave **90** the wire is brought to the wheel of the pay-out element **89**. Pay-out element **89** tractionally carries the wire in several turns, finally paying it out from whence it is taken up by the rotating pipe section **83** as the final tensioned winding at point Y.

The wheels of take-up element **88** and pay-out element **89** are again integrally constructed for reciprocity of rotation. They are fixed to horizontal shaft **94**, mounting to the traversing carriage (not shown) by bearings (not shown).

It should be observed that in applying a continuous wrapping of wire under the arrangement of Figures 13 and 14, wire is taken up along the taper at point X, and paid out again up the taper at point Y. The instantaneous path lengths of the wire around the pipe section **83** differ at points Y and X, this difference varying as the difference in diameters at these points. In this case the path length is longer around the pipe for the paid-out wire than it is for the taken-up wire. We have indicated earlier the relationship of the element diameters in winding cylindrical structures. Accordingly with the above taper the relationship of the wheel diameters of take-up element **88** to pay-out element **89** must be less than the corresponding relationship in cylindrical winding, so as to compensate for the increased path length of the paid-out wire, in order that the wire be stretched the correct amount for the desired degree of tension.

By winding down the taper with the arrangement shown in Figures 13 and 14, it will be noted that the accumulation of wire in the loop **95** between elements **88** and **89** will be less than for corresponding conditions in winding a cylindrical pipe. The reverse is true, if winding proceeds up the taper.

It can be seen that under certain conditions of taper and location of elements, the pay-out rate might conceivably have to be greater than the take-up rate. In this event the wire making up the difference must be drawn from the loop **95** being controlled by the sheave **90** of the equalizing element.

Frequently the taper on a pipe section or other structure might be discontinuous or vary in its slope. Here it is best to provide a ratio in the sizes of the take-up and pay-out elements of a maximum for the expected range of conditions so that the wire will tend to be overstressed. The stress in the wire would then be relieved to the correct degree of tension by controlled slippage through a means, such as the clutch of Figure 5. Thus, varying the pitch of the taper, would have no effect on the tension of the wire.

Although this invention has been shown in specific embodiments, it is nevertheless understood that various changes and modifications obvious to one skilled in the art may be made without departing from the spirit and scope of this invention.

I claim:

1. Apparatus for wrapping tensioned wire around an article comprising a vehicle adapted to be placed in rolling contact with an article, means mounted on said vehicle for holding a source of wire to be payed out, means mounted on said vehicle for taking wire from its source and temporarily wrapping it around the article, a take-up drum and a pay-out drum each mounted for rotation on said vehicle, means mechanically connecting said drums for rotation in common, the relationship of said drums and said means mechanically connecting same being such that when rotated in common the peripheral speed of said take-up drum is greater than the peripheral speed of said pay-out drum, floating means to hold wire passing from said take-up drum to said pay-out drum in the form of a loop, means to bias said floating means to maintain slight tension on the wire loop and to take up elongation of the wire resulting from pay-out by said pay-out drum being less than take-up by said take-up drum, and means to impart relative movement between said vehicle and the article whereby the wire of the temporary wrapping is picked up and passed to said take-up drum and passed via said floating means to said pay-out drum from whence it is laid around the article as a permanent tensioned wrapping.

2. Apparatus as defined in claim 1 wherein said means mechanically connecting said drums includes a clutch for relieving overtension.

3. Apparatus as defined in claim 1 wherein said means to impart relative movement between said vehicle and the article includes a self-propelled overhead carriage adapted to ride on the article and drag the vehicle thereover.

4. Apparatus as defined in claim 1 wherein said means to impart relative movement between said vehicle and the article includes a contact wheel mounted on said vehicle engaging the article in a rolling contact, a pulley wheel coaxially mounted with said contact wheel on said vehicle for engaging wire wrapped on the article, and a motor operatively connected to drive said pulley wheel whereby said vehicle is pulled around said article.

5. Apparatus for wrapping tensioned wire around an article comprising means holding a source of wire to be payed out as a temporary wrapping on the article, a take-up drum and a pay-out drum each mounted for rotation, means mechanically connecting said drums for rotation in common, the relationship of said drums and said means mechanically connecting same being such that when rotated in common the peripheral speed of said take-up drum is greater than the peripheral speed of said pay-out drum, floating means to hold wire passing from said take-up drum to said pay-out drum in the form of a loop, means to bias said floating means to maintain slight tension on the wire loop and to take up elongation of the wire resulting from pay-out by said pay-out drum being less than take-up by said take-up drum, and means to impart relative movement between the surface of the article and said drums whereby the wire of the temporary wrapping is picked up and passed to said take-up drum and passed via said floating means to said pay-out drum from whence it is laid on the article as a permanent tensioned wrapping.

6. Apparatus for wrapping tensioned wire around an article comprising means holding a source of wire to be payed out as a temporary wrapping on the article, a take-up drum and a pay-out drum each mounted for rotation, means including clutch means mechanically connecting said drums for rotation in common, the relationship of said drums and said means mechanically connecting same being such that when rotated in common the

peripheral speed of said take-up drum is greater than the peripheral speed of said pay-out drum, floating means to hold wire passing from said take-up drum to said pay-out drum in the form of a loop, means to bias said floating means to maintain slight tension on the wire loop and to take up elongation of the wire resulting from pay-out by said pay-out drum being less than take-up by said take-up drum, and means to impart relative movement between the surface of the article and said drums whereby the wire of the temporary wrapping is picked up and passed to said take-up drum and passed via said floating means to said pay-out drum from whence it is laid on the article as a permanent tensioned wrapping.

7. Apparatus for wrapping tensioned wire around an article comprising means holding a source of wire to be payed out as a temporary wrapping on the article, a take-up drum and a pay-out drum each mounted for rotation, means mechanically connecting said drums for rotation in common, the relationship of said drums and said means mechanically connecting same being such that when rotated in common the peripheral speed of said take-up drum is greater than the peripheral speed of said pay-out drum, floating means to hold wire passing from said take-up drum to said pay-out drum in the form of a loop, means to bias said floating means to maintain slight tension on the wire loop and to take up elongation of the wire resulting from pay-out by said pay-out drum being less than take-up by said take-up drum, and means to impart relative movement between the surface of the article and said drums including a self-propelled carriage whereby the wire of the temporary wrapping is picked up and passed to said take-up drum and passed via said floating means to said pay-out drum from whence it is laid on the article as a permanent tensioned wrapping.

8. Apparatus for wrapping tensioned wire around an article comprising means holding a source of wire to be payed out as a temporary wrapping on the article, a take-up drum and a pay-out drum each mounted for rotation, means mechanically connecting said drums for rotation in common, the relationship of said drums and said means mechanically connecting same being such that when rotated in common the peripheral speed of said take-up drum is greater than the peripheral speed of said pay-out drum, floating means to hold wire passing from said take-up drum to said pay-out drum in the form of a loop, means to bias said floating means to maintain slight tension on the wire loop and to take up elongation of the wire resulting from pay-out by said pay-out drum being less than take-up by said take-up drum, and means to impart relative movement between the surface of the article and said drums including a contact wheel mounted on said vehicle, a pulley wheel coaxially mounted therewith for engaging wire and a motor operatively connected to drive said pulley wheel whereby the wire of the temporary wrapping is picked up and passed to said take-up drum and passed via said floating means to said pay-out drum from whence it is laid on the article as a permanent tensioned wrapping.

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