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WINDING DEVICE

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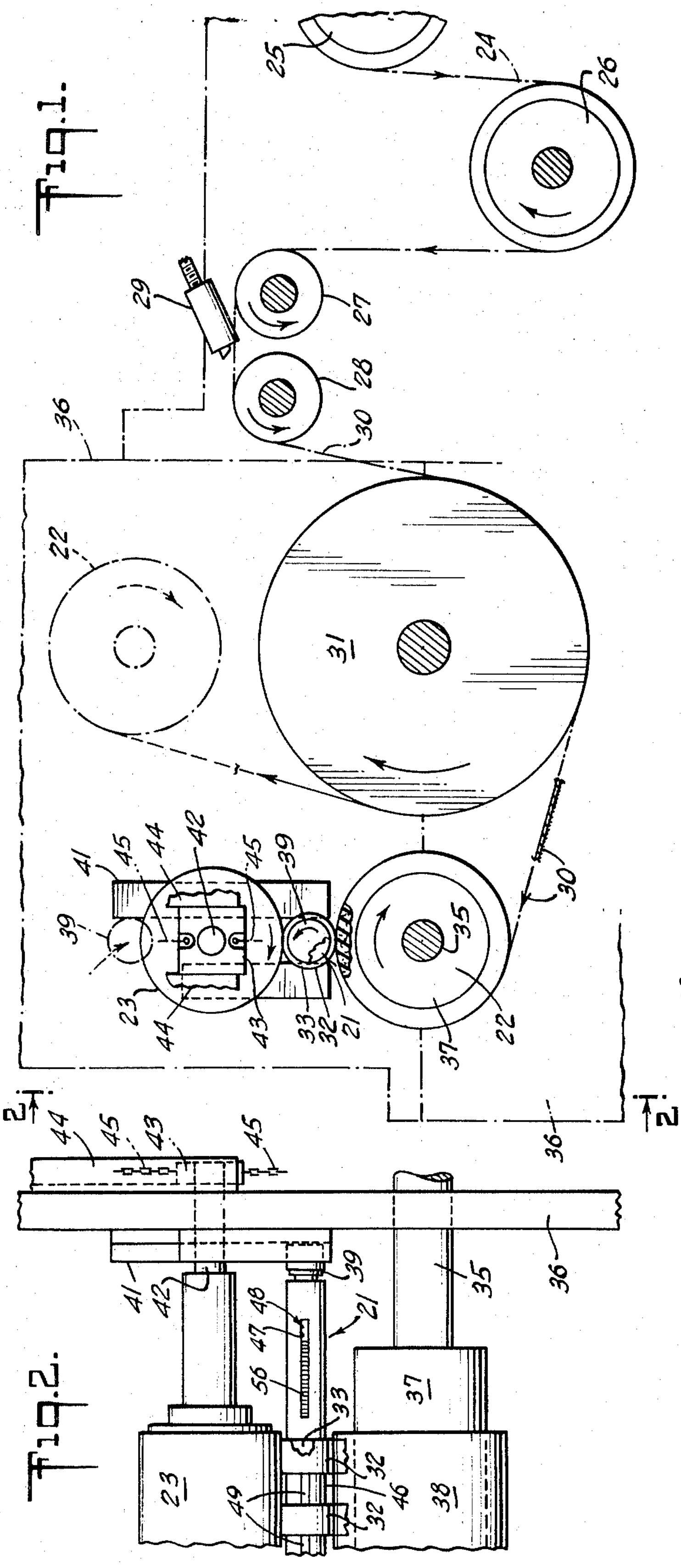

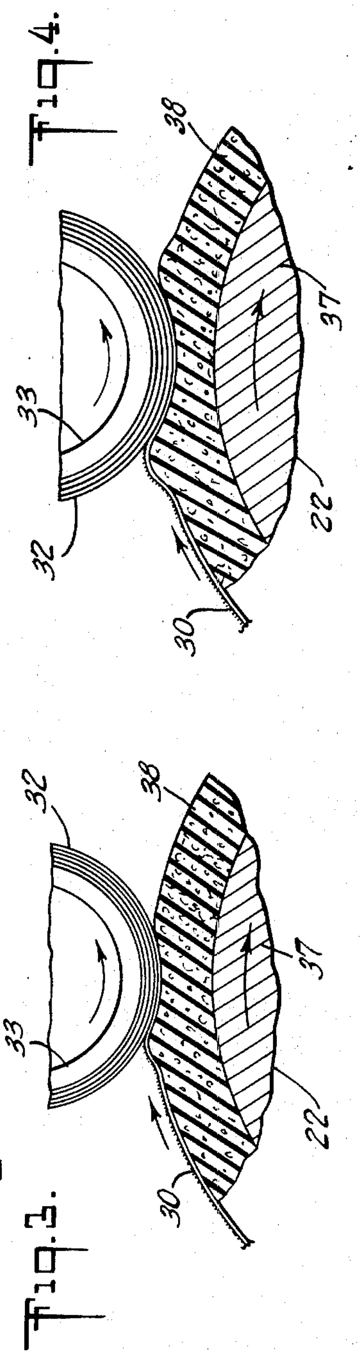

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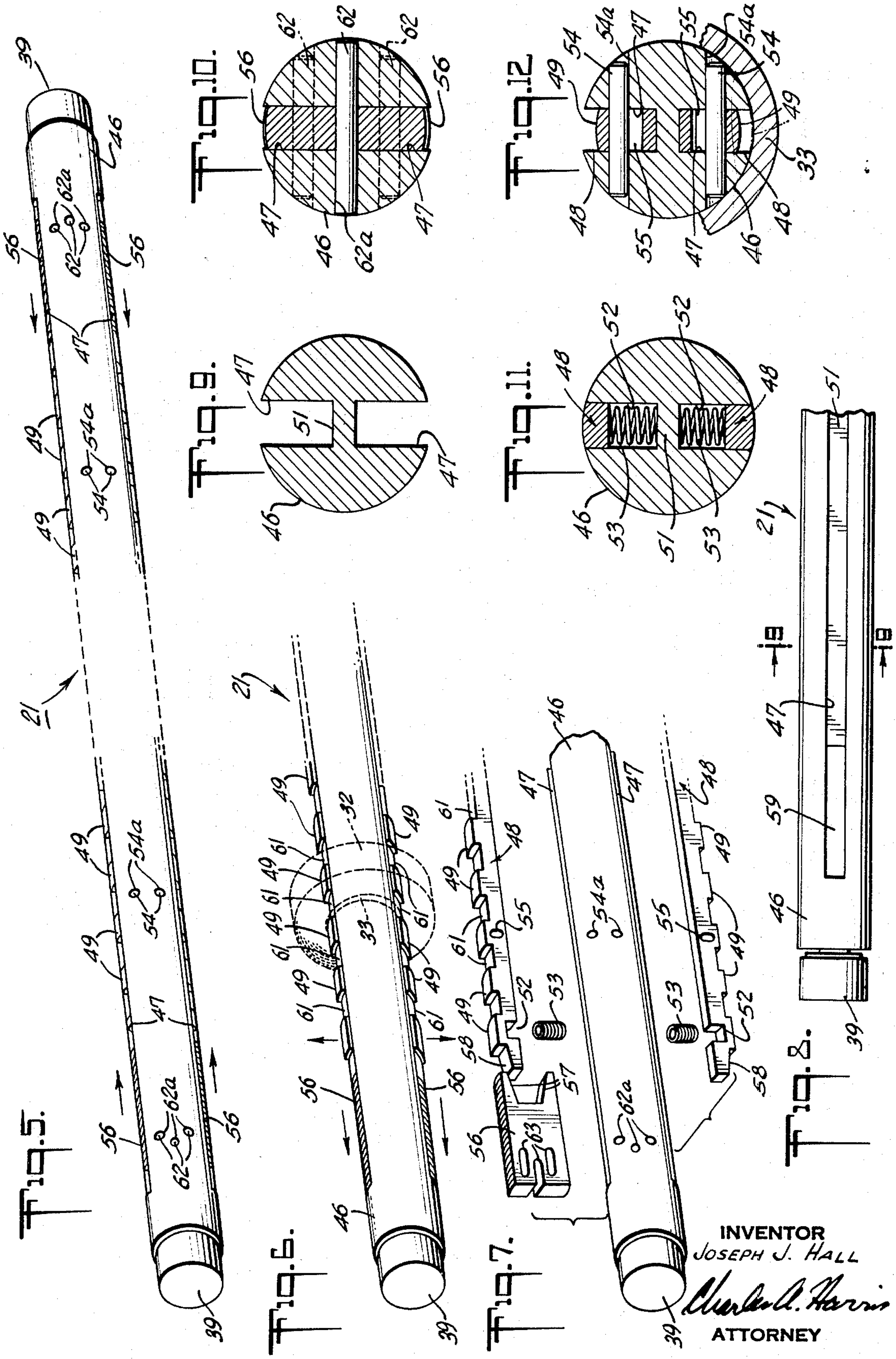

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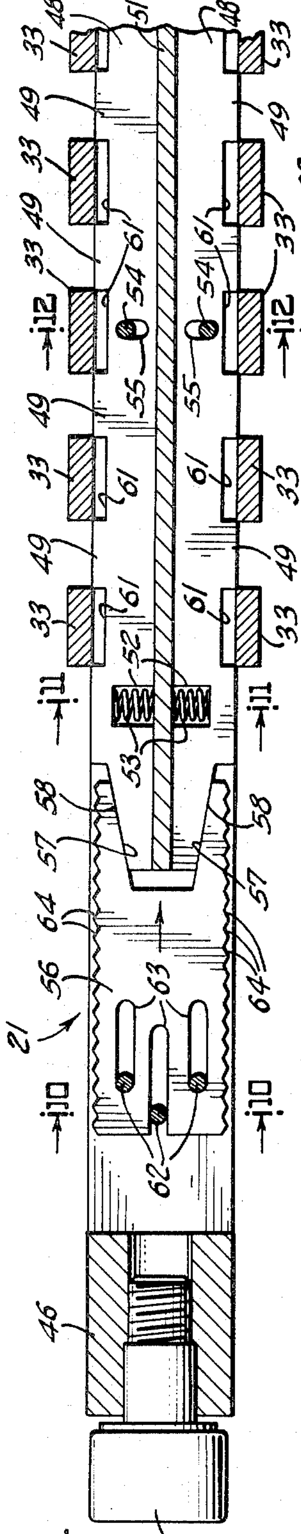

Fig.13.

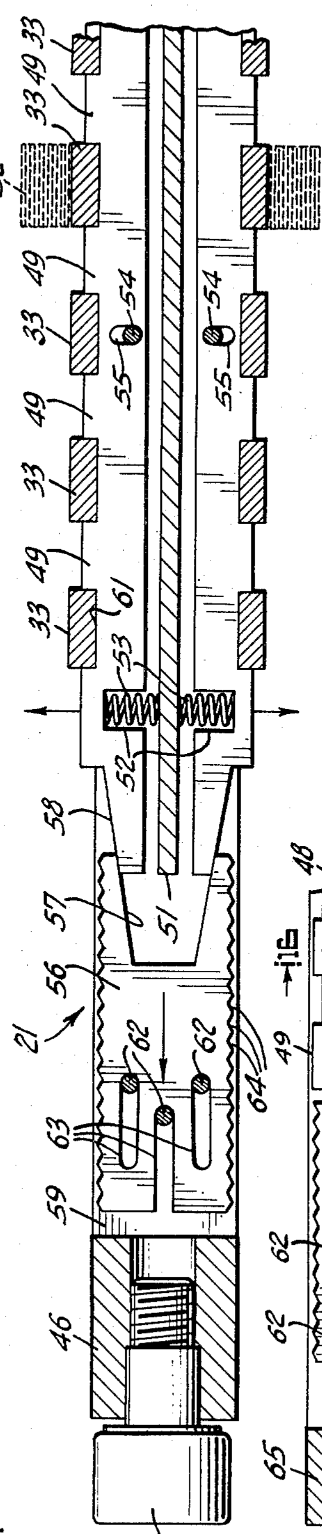

Fig.14.

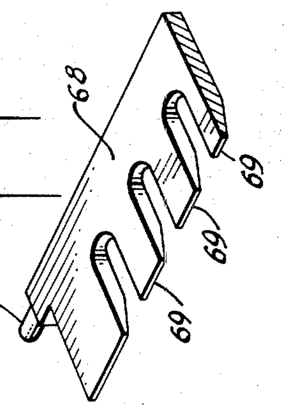

Fig.18.

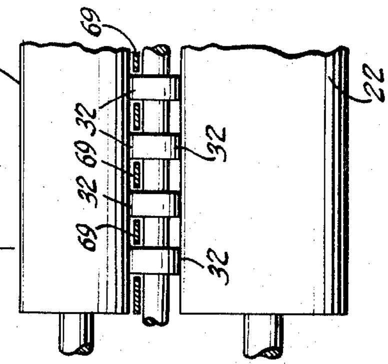

Fig.17.

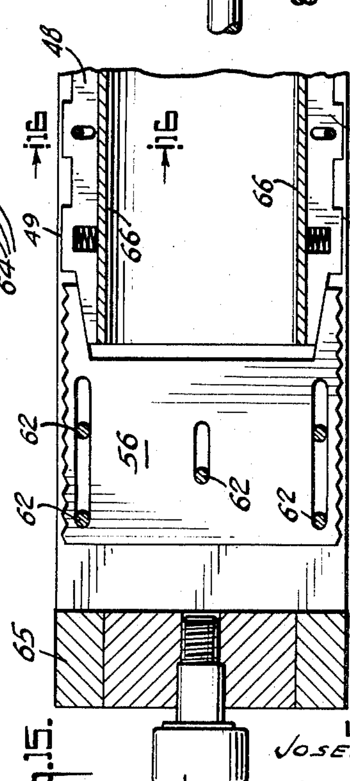

Fig.15.

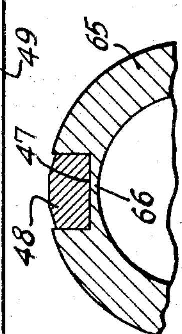

Fig.16.

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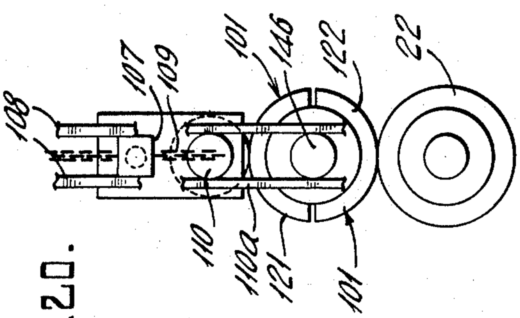

Fig. 20.

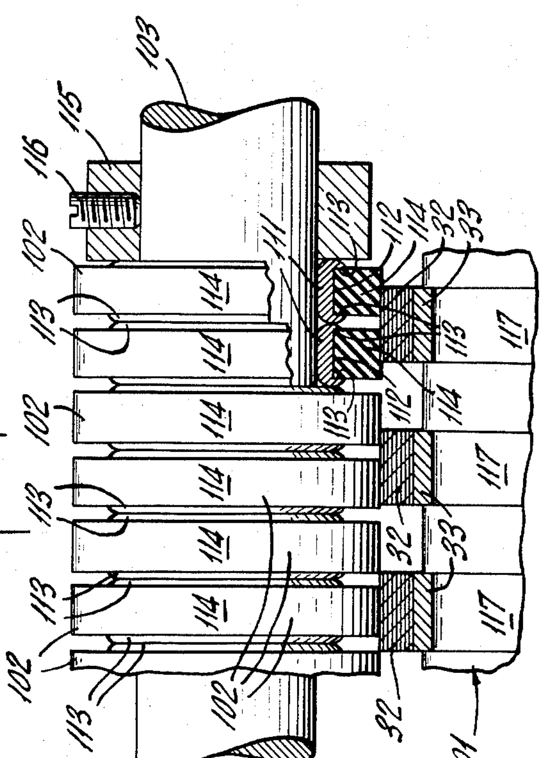

Fig. 21.

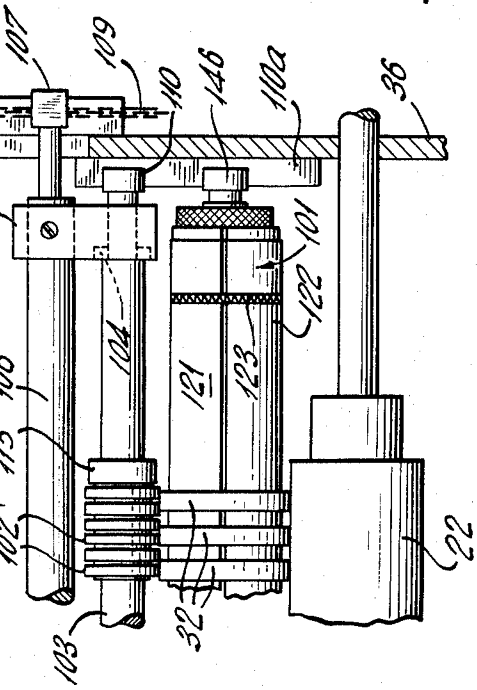

Fig. 19.

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Fig. 26.

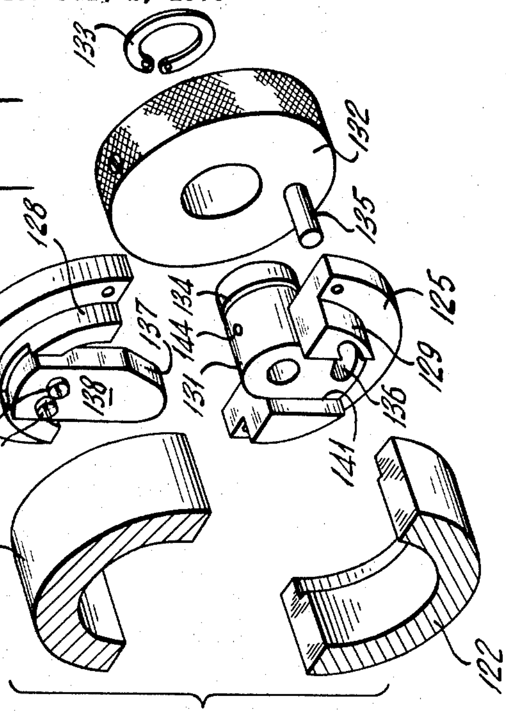


Fig. 25.

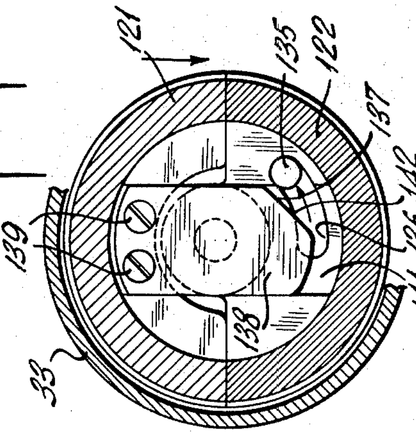


Fig. 24.

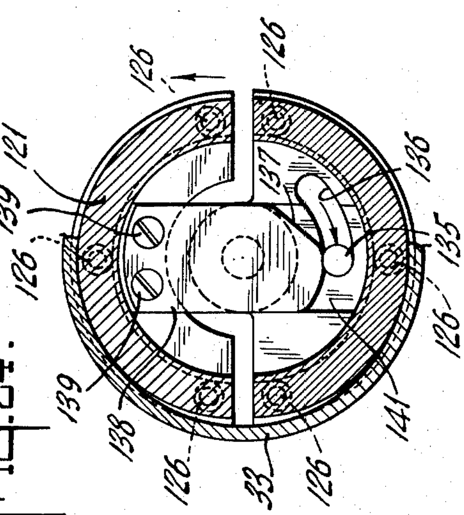


Fig. 23.

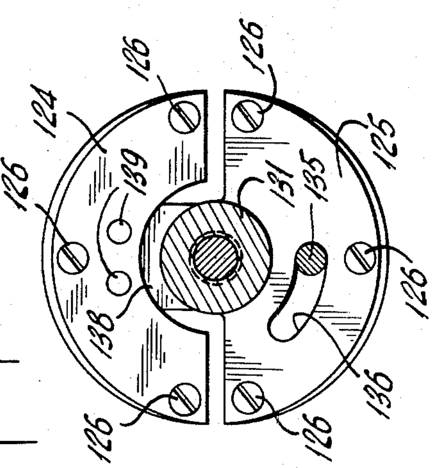
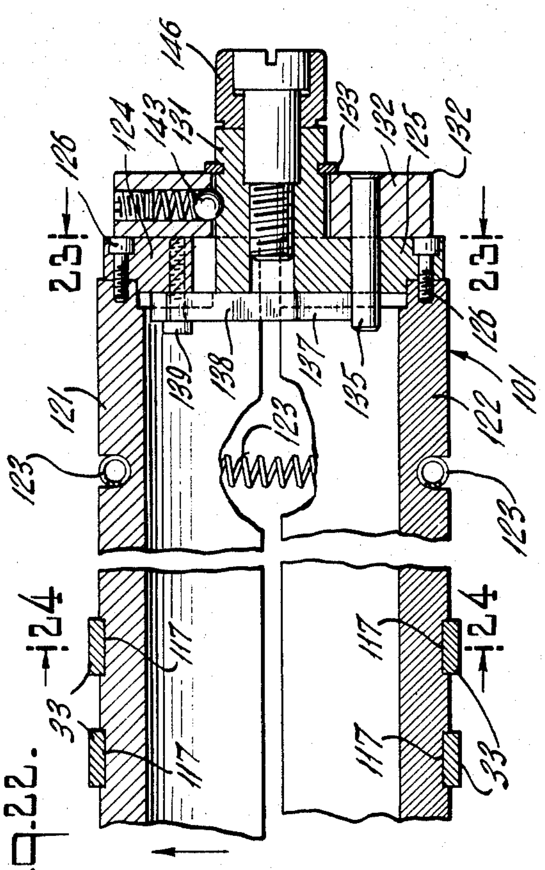


Fig. 22.



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United States Patent Office

3,702,687
Patented Nov. 14, 1972

3,702,687
WINDING DEVICE

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Continuation-in-part of application Ser. No. 701,196, Jan. 29, 1968. This application July 2, 1970, Ser. No. 51,901
Int. Cl. B65h 19/04
U.S. Cl. 242—56.9 25 Claims

ABSTRACT OF THE DISCLOSURE

A differential surface winding device for winding a number of rolls of pressure-sensitive adhesive tape upon cores mounted in axially spaced relation from one another upon the same mandrel, which comprises a mandrel on which the tape cores are rotatably mounted, means associated with the mandrel for maintaining the cores and the tape rolls wound thereon in definite positions axially spaced from one another on the mandrel, a driving roll presenting a relatively compressible and resilient peripheral surface portion adapted to contact all of the cores and/or tape rolls on said mandrel, and means for urging the mandrel and the driving roll toward one another with sufficient force to provide intimate driving contact between the driving roll and the tape rolls. The resilient peripheral surface portion of the driving roll is sufficiently resilient and compressible to allow a tape roll which acquires a somewhat larger diameter to sink further into the driving roll than the tape rolls of smaller diameter while maintaining driving contact with each of the tape rolls on the mandrel. In addition, the resilient driving roll contacts all of the tape rolls at the points where the tapes being wound on the rolls first contact their respective rolls or cores in such a way as to express the air from between the convolutions of the rolls as the tapes are being wound.

This application is a continuation-in-part of my copending U.S. patent application, Ser. No. 701,196, filed Jan. 29, 1968, now abandoned.

The present invention relates to devices and methods for winding pressure-sensitive adhesive tape upon itself around a cylindrical core with the adhesive side of the tape facing inwardly or toward the core, and more particularly to such devices wherein a multiplicity of tapes are cut from the same sheet and then wound into rolls utilizing two or more winding mandrels, each of which supports a plurality of rolls.

Conventionally, a large number of such pressure-sensitive adhesive tapes are slit from a relatively wide sheet having one of its surfaces coated with a layer of adhesive. For instance, approximately 60 tapes one-half inch wide may be slit from an adhesive coated sheet approximately 30 inches wide; and then wound alternately, 30 rolls each, upon a pair of winding mandrels. At least two mandrels are used in this manner to avoid the difficulties which would arise in attempting to wind all 60 tapes upon a single mandrel. Basically the problem would be in attempting to prevent contiguous or adjacent rolls from sticking to one another, or from becoming fouled on one another and thereby causing machine down time.

Many difficulties have been encountered in the operation of this type of device, both from the standpoint of efficient operation with minimum waste, and from the standpoint of consistently producing a high-quality products. For instance, in producing film-backed tapes, problems have developed in both of these areas due to variations in the thickness of the films supplied by film manufacturers. These variations commonly occur not only lengthwise of a relatively long roll of film but widthwise, or from edge

to edge, of the film. In addition, variations in the thickness of the adhesive layer also occur widthwise and lengthwise of the film, particularly if the amount of adhesive deposited depends to some extent upon the thickness of the backing. Variations in thickness cause variations in the size of the rolls being wound on the same mandrel and this creates variations in winding tension and roll tightness. As a result, tape rolls are produced which are unsatisfactory both in function and appearance.

Rolls which are wound too tight tend to collapse sidewise to relieve the tension built into the roll structure, especially when subjected to heat or high humidity conditions. This type of failure is called dishing or telescoping of the rolls and may render the tape completely unusable. Certainly, the appearance of the rolls is entirely unsatisfactory. Rolls which are wound too loosely, lose their shape and become humped, or out of round, and develop gaps between the various convolutions of the tape. This, not only is unacceptable from the standpoint of appearance, but it causes the tape to function poorly in dispensing and may be the cause of tape deterioration. Loose winding also creates rough side surfaces on the roll since the tape is somewhat free to wander axially during winding.

It has been determined that there is an acceptable range of tightness within which the tape, not only appears tightly wound in cylindrical roll form with staright side surfaces, but does not telescope, hump or otherwise lose its shape or ability to function. Roll tightness for this purpose normally is evaluated by a hardness test in which the resistance of the roll to penetration by an instrument is measured. Hardness standards then are established for determining acceptable roll tightness for each type of tape.

In order to achieve optimum appearance even within the range of acceptable roll hardness for a given type of tape, it also is important to express out the air bubbles which tend to form between the tape convolutions as the tape is being wound on the roll. This is particularly important for clear tapes having backing films of polypropylene, polyethylene terephthalate, and the like.

I have invented a differential surface winder for simultaneously winding a large number of rolls of pressure-sensitive adhesive tape slit from the same sheet upon a single mandrel in a way which will insure that virtually all of the rolls will have a tightness falling within the acceptable range and, in addition, will be free of air bubbles which detract from the clarity and general overall appearance of the tape rolls and a method to accomplish this. In my device, the tapes are wound at a substantially constant linear speed on each of the rolls along the mandrel, with the result that winding tension is maintained substantially constant from tape to tape extending widthwise of the original sheet or lengthwise of the mandrel. In order to accomplish this, means are provided for allowing for or absorbing variations in the thickness of the sheet with consequent variations in the angular speed of the tape rolls, without substantially affecting linear speed or winding tension. Thus, the tape rolls normally are wound under substantially constant tension from beginning to end of the roll, although this tension can be zero or even slightly negative since the tape is under control of the driving roll which is in contact with the peripheries of the tape rolls, themselves, and the linear speed of the surface of the driving roll can be lowered to the point where tension is negative. In addition, the tapes are wound on each roll in such a way that air is pressed out from between the convolutions of the roll as the tape is being wound.

The differential surface winder of my invention comprises a mandrel on which the tape cores are rotatably mounted. It is important that the mandrel possesses an outer diameter small enough to allow the tape cores to turn freely thereon. As a result, the individual tape rolls are free to assume different angular speeds and allow the linear speeds of the tapes being wound on each of the rolls to be governed by the linear speed of the surface of the driving roll and thereby maintained substantially constant from tape to tape extending widthwise of the original sheet from which the tapes are slit. Preferably, to maintain maximum control over winding conditions, the tapes are wrapped around a substantial portion of the periphery of the driving roll with the non-adhesive side of the tapes in contact with the resilient surface of the driving roll prior to any contact between the adhesive side of the tape and the tape rolls. The area of contact between the wrapped tapes and the surface of the driving roll, and the relative coefficients of friction of the non-adhesive surfaces of the tapes and the surface of the driving roll, are such as to normally prevent slippage between the tape and the driving roll during winding of the tape, so that the tapes are advanced at the linear speed of the surface of the driving roll.

Preferably, the mandrel is mounted in such a way as to be freely rotatable and is driven through the tape by direct pressure from the driving roll. Normally, the mandrel is urged toward the driving roll for this purpose. An effective device for accomplishing this is a pressure roll or set of pressure rolls disposed above the mandrel, and in axial parallelism therewith, in such a way that pressure normally is applied directly to the tape rolls themselves and through the tape rolls urges the mandrel towards the driving roll. Preferably, the resilient peripheral surface portion of the driving roll is formed of rubber and possesses a Short-A durometer hardness of about 25–35. The resilient portion of the driving roll may be in the form of a hollow cylinder of rubber surrounding a central cylindrical hub portion of the driving roll, and normally is at least about one-quarter inch thick. However, any other resilient roll structure capable of performing this function may be employed.

Preferably, also, the pressure means for urging the tape rolls toward the driving roll is a set of resilient pressure wheels mounted for rotation independently of one another in axial parallelism with respect to the mandrel on the opposite side of the mandrel from the driving roll. The pressure wheels are arranged so that no one wheel will contact more than one of the tape rolls. This is assured when the axial width of the pressure wheels is less than the axial distance between the tape rolls. With the pressure being applied independently to each of the tape rolls through independently rotating pressure wheels, the tape rolls are completely free to adjust with respect to one another on the mandrel to compensate for variations in the thickness of the tape being wound, and the like. Furthermore, complete control of the tape windings is assured by the fact that the resilient pressure wheels will compensate for the larger roll diameters and allow pressure to be applied directly to rolls of smaller diameter and thereby assure that the smaller rolls are pressed into the resilient peripheral portion of the driving roll to surface-wind the tape while expressing the air from between its convolutions in accordance with this invention.

In a preferred form of this invention the mandrel includes a series of members which are completely retractable into the mandrel to allow free axial movement of the tape cores onto the mandrel, and extensible with respect to the mandrel to position the tape rolls and prevent their further axial movement while allowing free rotation of the cores on the mandrel. Preferably these spacing members are adapted to be moved inwardly and outwardly of the mandrel as a set so that the tape cores and rolls may be easily positioned on and removed from the mandrel. In a preferred structure for this purpose the spacing members are in the form of spaced teeth or flanges extending outwardly from a pair of opposed comb-like spacing bars. In another form of this invention the mandrel may be in the form of expandable halves transversely slotted to position the tape rolls axially.

It is an important feature of the preferred embodiment of this invention that the resilient peripheral surface portion of the driving roll contacts all of the tape rolls at the points where the tapes being wound on the rolls first contact their respective tape rolls or cores. This makes it possible to wind the tape on the rolls in such a way as to express the air from between the convolutions of the rolls as the tape is being wound. The tape is led into the nip, formed between the driving roll and its respective core or tape roll and wound on the tape roll by the motion imparted to the tape by virtue of its contact with the resilient peripheral surface portion of the driving roll. As stated above, the mandrel and the driving roll are urged together with sufficient force that the tape rolls being wound on the mandrel sink at least slightly into the resilient portion of the driving roll. Larger rolls occasioned by thicker sections of the film or tape being wound are adapted to sink further into the resilient portion of the driving roll. However, regardless of the size of the tape rolls the peripheral speed of the tapes being wound is governed by the peripheral speed of the surface of the driving roll and thereby is maintained substantially constant since the tape rolls are freely rotatable on the mandrel and are caused to rotate only by virtue of their contact with the driving roll through the tapes being wound thereon. As explained hereinbefore, this allows individual tape rolls to assume different angular speeds to compensate for variations in their diameter. The method of winding tape in accordance to this invention and the apparatus employed for this purpose will be described more fully hereafter.

Other and further objects and advantages of this invention will appear to one skilled in that art from the following description and claims taken together with the drawings wherein.

FIG. 1 is a schematic view partly in section and partly in side elevation of differential surface winding apparatus according to one embodiment of this invention.

FIG. 2 is a fragmental end elevational view of the foregoing apparatus taken from the line **2—2** of FIG. 1, with parts broken away and omitted for the sake of clarity.

FIG. 3 is an enlarged schematic sectional view of a portion of the apparatus of FIG. 1 showing the contact between the resilient peripheral portion of the driving roll and the tape rolls during winding.

FIG. 4 is an enlarged schematic sectional view similar to that of FIG. 3 and showing greater distortion of the resilient portion of the driving roll due to an enlarged tape roll.

FIG. 5 is a view in perspective of mandrel according to a preferred embodiment of this invention and showing the spacing members retracted.

FIG. 6 is a perspective view similar to that of FIG. 5 of a portion of the mandrel of FIG. 5 but showing the spacing members extended in such a way as to position the tape rolls or cores axially on the mandrel.

FIG. 7 is an exploded perspective view of an end portion of the mandrel of FIG. 6 showing the relationship between the mandrel and the comb-like spacing bars which present the spacing members.

FIG. 8 is an elevational view of a portion of one end of the mandrel of FIG. 5.

FIG. 9 is an enlarged sectional view taken along the line **9—9** of FIG. 8.

FIG. 10 is a similar enlarged sectional view taken along the line **10—10** of FIG. 13.

FIG. 11 is another enlarged sectional view taken along the line **11—11** of FIG. 13.

FIG. 12 is a similar enlarged sectional view taken along line **12—12** of FIG. 13.

FIG. 13 is an enlarged view partly in longitudinal section and partly in elevation showing the assembled parts at one end of the mandrel of FIG. 5 with the spacing bars retracted to allow the tape cores to be positioned on the mandrel.

FIG. 14 is an enlarged view similar to FIG. 13 but showing the spacing bars extended to position the tape cores.

FIG. 15 is an enlarged view partly in section and partly in elevation of a mandrel according to a somewhat different embodiment of this invention.

FIG. 16 is a partially broken away sectional view taken along the line **16—16** of FIG. 15.

FIG. 17 is an end elevational view of a differential surface winder according to still a different embodiment of this invention.

FIG. 18 is an enlarged view in perspective of an end portion of the positioning comb of the apparatus of FIG. 17.

FIG. 19 is a fragmental end elevation view partly in section similar to FIG. 2 and showing apparatus according to a somewhat different embodiment of this invention.

FIG. 20 is a somewhat schematic end view, partly in section, similar to the left hand part of FIG. 1 and partly broken away to show the guide track for the pressure applying head.

FIG. 21 is an enlarged front elevation view, partly in section, showing the arrangement of the pressure wheels on their control shaft and the way in which they contact the tape rolls mounted on the mandrel.

FIG. 22 is an enlarged broken away sectional view of one end of the mandrel of the embodiment of FIG. 19.

FIG. 23 is an end view partly in section and partly in elevation, taken along the line **23—23** of FIG. 22.

FIG. 24 is a sectional view taken along the line **24—24** of FIG. 22 and showing the mandrel expanded to prevent the tape rolls from moving axially with respect thereto.

FIG. 25 is a sectional view similar to FIG. 24 showing the mandrel with its halves retracted to allow the tape rolls to move axially.

FIG. 26 is an exploded view of the parts at one end of the mandrel of FIG. 22.

Referring to FIGS. 1–14 of the drawings and in particular FIGS. 1–4 thereof, there is shown differential surface winding apparatus according to a preferred embodiment of this invention. The apparatus, shown most clearly in FIG. 1, includes a pair of mandrels **21** each of which is associated with a differential surface winding device according to this invention which comprises the mandrel **21** itself, a driving roll **22** below the mandrel, and a weighted roll **23** above the mandrel. Similarly, only one end portion of the lower winding device is fully shown in FIG. 2 since the other end is identical and the central portion thereof merely is a continuation of that which is shown.

A relatively wide adhesive coated sheet **24** is drawn from a supply roll thereof, not shown, over a pair of freely rotating rubber covered pull rolls **25** and **26** and thence over a pair of spaced rotatably mounted support rolls **27** and **28** with the adhesive side of the sheet facing the support rolls. A set of slitting knives **29** are positioned above the support rolls **27** and **28** in such a way that the knives can be moved into contact with the top surface of the adhesive sheet to slit the sheet into relatively narrow tapes. For instance, as indicated hereinbefore, the original sheet may be about 30 inches wide or wider, and may be slit into approximately 60 tapes **30**, one-half inch wide by a set of 59 slitting knives. The resulting tapes are drawn from the knives **29** and around a relatively large driven platen roll **31**. As the tapes pass around the platen roll **31** alternate tapes are separated to form two sets of tapes each consisting of one-half of the total number slit from the sheet with adjacent tapes spaced from one another by a distance approximately equal to the width of each of the tapes. One set of these tapes is led around the driving roll **22** of the lower winding device to the left of the platen roll, and the other set is led around the driving roll **22** of the upper winding device above the platen roll. Thereafter, each of the sets is wound into individual tape rolls **32** as will be described in detail for the lower winding device.

The set of tapes **30** is drawn around the driving roll **22** in such a way that each of the tapes in the set is wrapped around a substantial portion of the outer surface of the roll with the non-adhesive side of the tape facing the driving roll **22**. Then the tapes are led into the nip between the driving roll **22** and the mandrel **21**, while still in contact with the driving roll, and thence wound on conventional cylindrical cores **33** mounted in the desired spaced relation on the mandrel **21**. During this process the mandrel **21** is urged toward the driving roll by the weighted roll **23** mounted above the mandrel which, in turn, is urged downwardly at each of its ends, in such a way as to exert a constant downward force applied relatively evenly from end to end of the mandrel. This force is applied to the mandrel **21** through the tape rolls **32** or cores **33**, themselves, which are in contact with the weighted roll **23**.

The driving roll **22** is mounted on a shaft **35** which is driven from a conventional source of power such as an adjustable electric motor, not shown. The shaft **35** is mounted for rotation in frames **36** at each end of the device. The driving roll **22** comprises a central cylindrical hub portion **37** of a rigid material such as steel, and a resilient peripheral surface portion **38** in the form of a hollow cylinder of rubber, or the like, possessing a Shore-A durometer hardness of about 25–35. The resilient cylinder **38** should be thick enough to allow the desired deformation during winding as will be described more fully hereafter. A rubber cylinder of this hardness and approximately one-quarter inch thick is useful for this purpose although greater thicknesses in the neighborhood of one-half inch or more may be more desirable. The mandrel **21** is mounted in such a way as to be freely rotatable through a pair of opposed cam follower rolls **39**, one threaded into each end of the mandrel. Each of the follower rolls **39** rides in a vertical guide track **41** secured to the inside of its corresponding end frame **36**. The weighted roller **23**, which may be a conventional steel idler roll, is mounted for rotation on a shaft **42** which is rotatively supported at its ends in a pair of slides **43**, each of which is guided for vertical movement in a vertical guide **44** attached to the outside of each of the end frames **36**. In order to assure that the weighted roller **23** applies a constant and relatively even force downwardly upon the tape rolls **32** being wound on the mandrel, each of the slides **43** is pulled downwardly by a chain **45** attached to the arm of an eddy current clutch, not shown, which is controlled so as to deliver a balanced pulling force on each of the chains **45**. Therefore, the weighted roll **23** exerts a downward force upon the tape rolls **32** which is, not only due to its weight, but complemented and regulated by the eddy current clutch arrangement just described.

A preferred form of mandrel **21** in accordance with this invention is shown in more detail in FIGS. 5–14. This mandrel comprises an elongated barrel **46** having two halves almost separated, by a pair of opposed longitudinal slots **47** designed to hold a corresponding pair of top and bottom guide bars **48**, which in turn, present a multiplicity of spacing members in the form of teeth or flanges **49**. The halves of the barrel **46** of the mandrel are connected by a central rib **51** which remains between the slots **47**. When the top and bottom guide bars **48** are positioned in the longitudinal slots **47** in such a way that they are both in contact with the rib **51** the spacing teeth **49** are retracted within the normal outer diameter of the mandrel. This allows a full set of conventional cylindrical tape cores **33** to be slid onto the mandrel from one end thereof and into the desired spaced relationship with one another thereon. The spacing between adjacent teeth **49** on the spacing bars **48** is such as to freely accommodate one of the cylindrical cores **33**. Each of the spacing bars **48** defines a recess **52** adjacent each of its ends in which a compression spring **53** is located which presses inwardly against the rib **51**. The springs **53** are so designed that they normally urge the bars **48** outwardly away from the rib. The maximum outward extension of the bars **48** and their spacing teeth or flanges **49** is controlled by pairs of positioning pins **54** as shown most clearly in FIGS. 12–14 which extend through holes **54***a* in the barrel **46** and through a corresponding pair of vertical slots **55** in each of the spacing bars **48**. In the position shown in FIG. 14, these pins **54** are shown limiting the outward movement of the spacing bars **48**.

The extension and retraction of the spacing bars **48** is controlled by a pair of cam plates **56** at each end of the mandrel. Each of these cam plates **56**, in turn, defines upper and lower inclined cam shoulders **57** adapted to cooperate with a corresponding inclined shoulder **58** at the end of each of the spacing bars **48**. The cam plates **56** are mounted for axial movement in the mandrel **21** in a slot **59**, provided for this purpose, in such a way that when the cam plates **56** are moved inwardly both of the spacing bars **48** are caused to move inwardly against the force of the compression springs **53** and therefore to assume their retracted position, shown most clearly in FIGS. 5 and 13, in which the tape cores **33** are free to move axially over the mandrel. When the cam plates **56** are moved outwardly to the position most clearly shown in FIGS. 6 and 14, the two spacing bars **48** are able to move radially outwardly under the force of the compression springs **53** to their extended position where the spacing teeth or flanges **49** protrude between the tape cores **33** and thereby prevent their axial movement with respect to the mandrel. However, in this position of the spacing bars the diametric distance between the lands or flat portions **61** between the teeth **49** is at least slightly less than the inner diameters of the cores **33** so that the cores are free to rotate with respect to the mandrel **21**. Of course, it also is necessary for this purpose that the outer diameter of the barrel portion **46** of the mandrel allow the cores **33** to rotate thereon and that the distance between the spacing teeth **49** be such that the teeth do not bind the cores or otherwise prevent them from rotating freely on the mandrel. To assure that the cam plates **56** assume the proper position axially inwardly and outwardly with respect to the positioning bars **48**, their movement in each direction is limited by a set of stop pins **62** extending through holes **62***a* provided for this purpose in the barrel **46** of the mandrel and thence through horizontal slots **63** in the cam plates which are designated to limit the movement of the cams when they are operated as described above. The exposed outermost surfaces of the cam plates **56** present a series of small transverse serrations **64** for gripping the plates to move them axially for this purpose.

FIG. 15 shows a mandrel according to a somewhat different embodiment of the invention which is very much the same as that described hereinbefore with the basic difference that it comprises a hollow barrel **65**. This construction is best adapted for winding larger diameter tape rolls on cores in the order of 3 inches in diameter or larger. In this mandrel the longitudinal grooves **47** only extend partially through the cylindrical barrel **65** in such a way that there are two shelf-like portions **66** of the barrel below each of the grooves **47** corresponding to the single rib **51** of the embodiment of FIGS. 1–14. It also will be seen that, due to the large size of the cam plates **56** in this device, two more positioning pins **62** are included at each end of the mandrel for controlling the axial movement of the cam plates.

In the embodiment shown in FIG. 17, each of the tape rolls **32** is mounted on a cylindrical core which is free to rotate on a mandrel **67**, as described hereinbefore, but instead of using spacing members which retract into the mandrel **67**, a separate spacing comb **68** is provided. This

comb **68** presents a series of teeth **69** which correspond to the teeth **49** of the spacing bars **48** in the foregoing embodiments, and which position the tape rolls axially between them in the same manner. However, the comb **68** is mounted at its ends on a pair of pins **71**, only one of which is shown at one end of the comb in FIG. 18, in such a way that it may be pivoted downwardly into the position shown in FIG. 17 to position the rolls (or cores) axially of the mandrel, or pivoted upwardly to retract or move the teeth **69** out of the way of the cores or rolls **32** to allow them to be positioned on, or removed from, the mandrel. Otherwise the device of this embodiment operates in the same manner as those of the foregoing figures.

In operation, the cam plates **56** are moved inwardly; i.e., towards the center of the mandrel **21** to cam the spacing bars **48** inwardly to their retracted position, shown in FIG. 13, and the required number of cylindrical tape cores **33** are slid axially over the mandrel to their proper location thereon. Then, the cam plates **56** are moved outwardly to release the spacing bars **48** so that they can move outwardly under the urging of the compression springs **53** to their extended position, shown in FIG. 14, where the flanges **49** on the bars **48** separate the cores **33** and retain them in position axially of the mandrel while leaving them freely rotatable thereon. After the mandrel **21** is placed in position between the driving roll **22** and the weighted roll **23**, the adhesive sheet **24** is slit into tapes **30** by drawing it under the bank of slitting knives **29**, the tapes **30** are let around the platen roll **31** and then separated into alternate sets as described hereinbefore. One of these sets is led around the driving roll **22** of the lower winding device, whereas the other is let upwardly around the driving roll **22** of the upper winding device, after which both sets are wound in the same manner.

The tapes **30** are led into the nip between the driving roll **22** and their respective cores **33** on the mandrel **21** with the adhesive side of the tape in contact with the peripheries of the cores **33** and then wound around the cores to form the tape rolls **32**. Since the cores **33** are free to rotate on the mandrel, their rotation is controlled directly by the rotation of the driving roll **22** in contact therewith through the tapes being wound on the cores as best shown in FIGS. 1–4. The cores **33** and then the tape rolls **32** are urged into compressive contact with the resilient surface portion **38** of the driving roll **22** by the downward pressure exerted upon the cores from the weighted roll **23**. This pressure is applied by the weighted roll to the tape rolls **32**, themselves, and through the tape rolls to the mandrel **21**. Thus, if any of the tape rolls **32** are not contacted directly by the weighted roll **23**, due to the fact that they have become smaller in diameter during winding, they nevertheless are urged downwardly by the weighted roll through the mandrel. As explained hereinbefore, the resilient surface portion **38** of the driving roll is sufficiently thick and compressible that it absorbs any variations which may occur in the diameter of the tape rolls 32 being wound on the mandrel **21** due to variations in the thickness of the tape backing or the tape itself or any other cause. This is illustrated in FIGS. 3 and 4 where a roll of larger diameter is shown in FIG. 4 than FIG. 3, with the roll of FIG. 4 consequently sinking further into the resilient portion 38 of the driving roll. However, in both cases intimate driving contact is maintained between the driving roll **22** and the tape roll **32**.

It also should be noted that the tapes **30** are wrapped around a substantial portion of the periphery of the driving roll **22** and the tape rolls **32**, and prior to any contact between the adhesive side of the tapes and the tape rolls. This amount of contact area between the non-adhesive surfaces of the wrapped tapes **30** and the periphery of the resilient portion 38 of the driving roll is sufficient to assure that there normally is no slippage between the tapes **30** and the driving roll **22**, in view of the relative coefficients of friction of the materials in contact with one another. Thus, each of the tapes 30 moves into the nip between the driving roll 22 and its respective tape roll 32 at the linear speed of the periphery of the driving roll 22 and is wound upon the tape roll substantially at this linear speed. This assures that the tape rolls 32 are wound at relatively constant tension well within the acceptable range of roll tightness as measured by the normal hardness standards established for this purpose and explained hereinbefore.

When the tape rolls 32 are wound in this manner with the resilient peripheral surface portion 38 of the driving roll 22 contacting all of the tape rolls through the tapes being wound thereon at the points where these tapes first contact their respective rolls in such a way that the tape rolls 32 sink into the resilient portion 38 of the driving roll at least to the extent illustrated schematically in FIGS. 3 and 4; air is expressed sufficiently from between the tape convolutions being wound on the roll to produce a brilliantly clear roll of tape when all of the tape components are normally transparent. While the exact mechanism by which this is accomplished is not known, it is believed that it is attributable to the relative forces created by the distortion of the resilient portion 38 of the driving roll as the tape is being wound on the freely rotating tape cores. It also is important that the amount of pressure exerted between the driving roll 22 and the tape rolls 32 is controlled relatively evenly along the mandrel 21, with only slight variations occurring between tape rolls of somewhat different size. Thus, with the close control obtainable in winding tape rolls in accordance with this invention, whole sets of transparent tape rolls may be wound on the same mandrel with virtually the same hardness and clarity.

Referring to FIGS. 19–26, a preferred embodiment of apparatus according to this invention is shown, wherein the tape rolls 32 are rotatably mounted on an improved expandable mandrel 101, and the tape rolls and the mandrel are pressed into contact with the resilient peripheral portion of the driving roll 22 by a set of resilient pressure wheels 102 rotatably mounted on a control shaft 103, laterally on the opposite side of the mandrel from the driving roll 22. Each end of the control shaft 103 is journaled in a ball bearing 104 fitted in opposed end blocks 105 each of which is fixed to a nonrotatable support shaft 106. As is the case for FIG. 2, only one end of the unit of FIGS. 19–26 is shown in FIG. 19 for the sake of simplicity since the other end is identical. The ends of the support shaft are connected to a pair of square end slides 107 which are guided for vertical movement towards and away from the driving roll 22 by corresponding vertical tracks 108 shown on the outside of the end frame 36 which rotatably supports the drive shaft 35 for the driving roll 22. The control shaft 103, the pressure wheels 102 rotatably mounted thereon, the support shaft 106 and the end blocks 105, together provide a pressure applying unit which presses the tape rolls 32 and the mandrel 101 into intimate contact with the resilient portion of the driving roll 22 through direct contact between the pressure wheels 102 and the tape rolls 32. As explained in connection with the embodiment of FIGS. 1–14, each of the slides 107 is pulled downwardly by a chain 109 attached to the arm of an eddy current clutch, not shown, which is adjustable to deliver a balanced pulling force on each end of the unit and to control the amount of pressure which the pressure wheels 102 exert upon the tape rolls 32 in urging them into contact with the driving roll 22. The control shaft 103 is guided for this purpose by a pair of cam follower rolls 110 which ride in vertical guide tracks 110*a* secured to the end frame 36. The follower rolls 110 are threaded into the ends of the shaft 103.

The pressure wheels 102, themselves, each comprise an annular mounting rim 111 having a flat peripheral mounting portion 112 and opposed projecting flanges 113, and a compressible and resilient annular ring 114 which fits between the flanges 113 of the rim 111 and grips the flat mounting portion 112 thereof so that the ring 114 rotates as a unit with the rim 111. The rims 111 and, correspondingly, the pressure wheels 102 are mounted to rotate freely on the control shaft 103 independently of one another, but are positioned axially on the shaft as a set by collars 115 secured to the shaft 103 with a set screw 116. The outside annular surfaces of the rims 111 and the flanges 113 are curved convexly so that only a very limited circular portion of one rim contacts a corresponding portion of the next adjacent rim on each side of each pressure wheel 102, thereby minimizing frictional drag between adjacent wheels.

It will be seen most clearly from FIGS. 21 and 22 that the tape rolls 32 are positioned axially on the mandrel 101 by circumferentially extending annular spacing recesses 117 which the tape cores 33 fit into when the mandrel is expanded. The axial spacing between the recesses 117 and therefore the cores 33 and the tape rolls 32, is greater than the axial width of the resilient rings 114 at their periphery, thereby assuring that a given pressure wheel 102 can not contact more than one tape roll 32 simultaneously. Thus, with the dimensional relationships shown in FIG. 21, each tape roll 32 normally is being pressed towards the driving roll 22 by two of the resilient pressure wheels 102 but under no circumstances can a single pressure wheel 102 bridge the gap between two tape rolls 32. This assures that the pressure wheels 102 will not exert any appreciable drag on the tape rolls 32 and that the tape rolls will remain capable of turning at different angular speeds with respect to one another even though their surface linear speeds are constant across the driving roll 22. This relationship is very important since, in this embodiment of the invention, the peripheries of the tape rolls 32 enter into strong frictional engagement with the resilient and compressible rings 114 of the pressure wheels 102 and would not be able to turn independently of one another if the rings bridged the distance between tape rolls.

The rings 114 preferably are quite resilient and may be molded from pure gum rubber whereas the rims 111 preferably are formed of brass or another material possessing good bearing characteristics. Thus, the pressure wheels 102 are capable of exerting continuing downward pressure on each of the tape rolls 32 directly through the rings 114 to press them into the resilient surface portion of the driving roll 22 and thereby establish the desired surface winding relationship described hereinbefore. In fact, the very resilient nature of the individual rings 114 allows this relationship to be established even though there is considerable clearance between the inner diameters of the tape cores 33 and the outer diameters of the circumferential recesses 117 in the mandrel 101.

FIGS. 21–25 show the expandable mandrel 101 of this invention in more detail. Again only one end of the mandrel is shown for simplicity since both of its ends are identical. This mandrel is particularly suited for handling tape rolls wound on relatively large diameter cores. The mandrel 101 comprises a pair of semi-cylindrical halves, i.e., a top shell 121 and a bottom shell 122 normally urged into contact with one another to form a full cylinder by a pair of girth springs 123, located one at each end beyond the tape rolls 32. This position of the shells 121 and 123 is shown in FIG. 25 and is the one wherein the mandrel is radially retracted to allow the tape cores 33 to be slid axially into position aligned with their respective annular spacing recesses 117.

A semi-cylindrical top end cap 124 is fitted into and over each end of the top shell 121, and a corresponding bottom end cap 125 is fitted into and over each end of the bottom shell 122, with the two end caps fitting together at each end to close the cylinder. Each end cap 124 and 125 is secured to the end of its respective cylinder by bolts 126 and presents a semi-cylindrical inwardly extending shelf, 128 on the top caps 124, and 129 on the bottom caps

125, which fit into the shells and structurally supports them. The bottom end caps 125 includes an integral outwardly extending cylindrical boss 131 and the top end caps 124 are relieved to receive the bosses 131 when the two end caps are brought together at each end of the mandrel.

A knurled cam control wheel 132 is rotatably fitted over the boss 131 at each end of the mandrel where it is held in position axially by a C-spring 133 which snaps into an annular groove 134 in the boss. A camming rod 135 extends inwardly from each of the control wheels 132 through a curved arcuate slot 136 in its respective bottom end cap 125. The rod 135 is moved from the top of the slot 136, where it is shown in FIG. 25, towards the bottom of the slot, where it is shown in FIGS. 23 and 24, simply by rotating the control wheel 132 clockwise, referring to FIGS. 23–25. Movement of the rod 135 in this direction brings it into contact with the inclined camming surface 137 of a cam follower plate 138 secured to the top end plate 124 by bolts 139. The cam plate 138 rests in a vertical slot 141 in the shelf 129 of the bottom end plate 125 for vertical movement therein. Thus, the cam follower 138 is driven upwardly as the camming rod 135 is turned beyond point 142 in FIG. 25 and thence moved towards the bottom of the slot 136. When the rod 135 reaches the bottom of the slot, it assumes a position under the cam follower 138, as shown in FIG. 24, and holds the mandrel in its expanded position shown in FIGS. 22–24. A spring loaded ball detent 143 is provided in the control wheel 132 to fit into a recess 144 in the boss 131 to prevent the rod 135 from being accidentally misplaced from the position shown in FIG. 24 during operation of the unit. Of course, as soon as the detent 143 is displaced from the recess 144 and the camming rod 135 is moved to the right in FIG. 24 (out from under the cam follower 138) the springs 123 will pull the two halves of the mandrel together to return all parts to the position shown in FIG. 25.

In the retracted position of the mandrel 101, shown in FIG. 25, the tape cores 33 will be slightly larger in inner diameter than the maximum outer diameter of the mandrel 101 taken between the annular recesses 117, thereby assuring that the cores 33 can be properly positioned axially on the mandrel as explained hereinbefore. The recesses 117 preferably are cut to a depth which will result in the expanded mandrel outer diameter across the bottoms of the recesses approximately being equal to the maximum retracted outer diameter of the mandrel. Thus the recesses 117 may vary from a negligible depth at the side edges of the shells to their full depth at the top of the shell 121 and the bottom of the bottom shell 122 in the positions shown in the drawings.

The mandrel 101 is mounted for rotation on cylindrical cam followers 146 threaded into the bosses 131 and the followers 146 ride in the guide tracks 110*a* for guiding the mandrel as it is urged toward and away from the driving roll 22.

Having now described the invention in specific detail and exemplified the manner in which it may be carried into practice, it will be readily apparent to those skilled in the art that innumerable variations, modifications, aplications and extension of the basic principles involved may be made without departing from its spirit or scope.

What is claimed is:

1. A differential surface winder for simultaneously winding a plurality of pressure-sensitive adhesive tapes slit from the same sheet into a corresponding number of tape rolls wherein the tapes are wound upon themselves on cylindrical cores with the adhesive side of the tapes facing inwardly, which comprises a mandrel having circumferential portions adapted to receive said cores and mount them rotatably with respect to said mandrel, spacing means associated with said mandrel for maintaining said rolls in definite positions axially spaced from one another on said mandrel but without interfering with their rotation with respect thereto, said spacing means being movable laterally with respect to the axis of the mandrel in a direction perpendicular to said axis from a first position wherein the spacing means does not interfere with the axial sliding movement of the tape cores on or off the mandrel to a winding position wherein the tape cores are retained in position axially on the mandrel by the spacing means while being allowed to rotate freely thereon during winding, means for retaining said spacing means in the aforesaid operating relation with respect to the axis of the mandrel during winding, a driving roll disposed in axial parallelism with respect to said mandrel and presenting a relatively compressible and resilient peripheral surface portion adapted to contact all of the tape rolls on said mandrel, and means for urging said mandrel and said driving roll towards one another with sufficient force that the peripheries of said tape rolls sink at least slightly into the peripheral surface portion of said driving roll to provide intimate driving contact between the driving roll and the tape rolls, said peripheral surface portion being sufficiently compressible to allow a tape roll which acquires a somewhat larger diameter to sink further into said driving roll than tape rolls of smaller diameter while maintaining driving contact with each of the tape rolls on said mandrel.

2. A differential surface winder according to claim 1, wherein the resilient peripheral surface portion of said driving roll is adapted to contact all of said tape rolls through said tapes at the points where said tapes first contact their respective tape rolls.

3. A differential surface winder according to claim 2, which further comprises means for wrapping the tapes around a substantial portion of the periphery of the driving roll with the non-adhesive side of the tape in contact with the surface of the driving roll prior to any contact between the adhesive side of the tape and the tape rolls.

4. A differential surface winder according to claim 3, wherein the area of contact between the wrapped tapes and the periphery of the driving roll and the coefficient of friction between the non-adhesive surfaces of the tapes and the resilient outer surface of the driving roll are such as to normally prevent slippage between the tapes and the driving roll during winding of the tape.

5. A differential surface winder according to claim 1, wherein the mandrel is mounted in such a way as to be freely rotatable.

6. A differential surface winder according to claim 2, wherein the means for urging said mandrel towards the driving roll is a pressure roll disposed on the opposite side of said mandrel from said driving roll and in axial parallelism therewith in such a way that said pressure roll normally rests on the tape rolls themselves and through the tape rolls urges the mandrel towards the driving roll.

7. A differential surface winder according to claim 6, wherein said pressure roll is urged towards said mandrel by control means at each end of said pressure roll.

8. A differential surface winder according to claim 6, wherein said pressure roll is a weighted roll.

9. A differential surface winder according to claim 1, wherein the resilient peripheral surface portion of said driving roll possesses a Shore-A durometer hardness of about 25–35.

10. A differential surface winder according to claim 9, wherein said resilient peripheral surface portion is in the form of a hollow cylinder surrounding a central cylindrical portion of said driving roll and said hollow cylinder is at least about one quarter inch thick.

11. A differential surface winder according to claim 1, wherein said mandrel includes a series of spacing members which are adapted to be retracted radially with respect to the axis of the mandrel to allow free movement of the tape cores axially on the mandrel, and ex-

tended radially with respect to the axis of the mandrel to position the tape rolls axially of the mandrel and prevent their further movement in this direction while allowing free rotation of the cores on the mandrel.

12. A differential surface winder according to claim **11**, wherein said spacing members are completely retractable into said mandrel to allow axial movement of the tape cores on the mandrel.

13. A differential surface winder according to claim **12**, wherein said spacing members are adapted to be moved inwardly and outwardly of the mandrel as a set and are spring loaded in one direction and cam controlled in the other direction.

14. A differential surface winder for simultaneously winding a plurality of pressure-sensitive adhesive tapes slit from the same sheet into a corresponding number of tape rolls wherein the tapes are wound upon themselves on cylindrical cores with the adhesive side of the tapes facing inwardly, which comprises a mandrel having circumferential portions adapted to receive said cores and mount them rotatably with respect to said mandrel, spacing means associated with said mandrel for maintaining said rolls in definite positions axially spaced from one another on said mandrel but without interfering with their rotation with respect thereto, means for retracting said spacing means transversely with respect to the axis of the mandrel to allow free movement of the tape cores axially on the mandrel and for extending said spacing means transversely with respect to the axis of the mandrel to position the tape rolls axially on the mandrel while allowing them to rotate freely thereon as aforesaid, a driving roll disposed in axial parallelism with respect to said mandrel and presenting a relatively compressible and resilient peripheral surface portion adapted to contact all of the tape rolls on said mandrel and means for urging said mandrel and said driving roll towards one another with sufficient force that the peripheries of said tape rolls sink at least slightly into the peripheral surface portion of said driving roll to provide intimate driving contact between the driving roll and the tape rolls, said peripheral surface portion being sufficiently compressible to allow a tape roll which acquires a somewhat larger diameter to sink further into said driving roll than tape rolls of smaller diameter while maintaining driving contact with each of the tape rolls on said mandrel, and said tape rolls being rotatably driven only through the aforesaid contact with said driving roll.

15. A differential surface winder for simultaneously winding a plurality of pressure-sensitive adhesive tapes slit from the same sheet into a corresponding number of tape rolls wherein the tapes are wound upon themselves on cylindrical cores with adhesive side of the tapes facing inwardly, which comprises a mandrel adapted to receive said cores and mount them rotatably with respect to said mandrel, spacing means associated with said mandrel for maintaining said rolls in definite positions axially spaced from one another on said mandrel but without interfering with their rotation with respect thereto, a driving roll disposed in axial parallelism with respect to said mandrel and presenting a relatively compressible and resilient peripheral surface portion adapted to contact all of the tape rolls on said mandrel, a plurality of pressure wheels mounted for rotation independently of one another in a set disposed in axial parallelism with respect to said mandrel and laterally on the opposite side of said mandrel from said driving roll, said pressure wheels being adapted to contact radially opposite portions of said tape rolls from those portions contacted by said driving roll and being arranged axially with respect to the tape rolls on said mandrel so that no one of said wheels will contact more than one of said tape rolls, and means for urging said pressure wheels and said driving roll towards one another with suffiicent force that the pressure wheels press said tape rolls against said driving roll and the peripheries of said tape rolls sink at least slightly into the peripheral surface portion of said driving roll to provide intimate driving contact between the driving roll and the tape rolls, said peripheral surface portion being sufficiently compressible to allow a tape roll which acquires a somewhat larger diameter to sink further into said driving roll than tape rolls of smaller diameter while maintaining driving contact with each of the tape rolls on said mandrel.

16. A differential surface winder according to claim **15**, wherein the axial width of the individual pressure wheels at their periphery is less than the axial distance between adjacent tape rolls on said mandrel.

17. A differential surface winder according to claim **15**, wherein said pressure wheels are compressible and resilient and thereby adapted to accommodate tape rolls of slightly different diameters.

18. A differential surface winder according to claim **15**, which comprises a control shaft on which said pressure wheels are rotatably mounted.

19. A differential surface winder according to claim **18**, wherein said control shaft is urged towards said mandrel by control means at each of its ends and said control means is adjustable to regulate the force by which said pressure wheels press the tape rolls against said driving roll.

20. A differential surface winder according to claim **19**, wherein said pressure wheels comprise compressible and resilient peripheral portions for contacting said tape rolls.

21. The method of manufacturing a roll of clear-to-the-core pressure-sensitive adhesive tape from a length of normally clear and transparent tape comprising a transparent film backing and a layer of a transparent pressure-sensitive adhesive on one side of said backing whereby the tape has an adhesive side and a non-adhesive side, wherein the tape length is wound upon itself about a core with the adhesive side of the tape facing inwardly toward the axis of the roll and the non-adhesive side of the tape facing outwardly away from the axis of the roll; which comprises mounting said core on a winding mandrel, freely rotating said core (with respect to) on said mandrel and winding the tape by rotating the tape roll only by contact between the outer non-adhesive surface of the tape roll and the surface of a compressible and resilient peripheral portion of a driving roll, and urging the tape roll and the driving roll against one another with sufficient force to cause a circumferential portion of the tape roll to sink into the resilient portion of the driving roll during said winding and press the adhesive layer in the newly formed outermost convolution of the tape roll smooth and into intimate contact with the outer non-adhesive surface of the adjacent inner convolution of said tape roll and thereby express the air from between said convolutions as the adhesive layer of the newly formed outermost convolution of said tape becomes adhered to the non-adhesive outer surface of the said adjacent inner convolution, the tape first contacting said tape roll at one edge of the sunk-in-circumferential portion of the tape roll.

22. The method of manufacturing a roll of tape according to claim **21**, wherein the tape is wrapped around a substantial portion of the driving roll in contact with the surface of the compressible and resilient portion of said driving roll prior to any contact between the adhesive layer of the tape and the tape roll, the said contact between the tape and the driving roll being such as to normally prevent slippage between the tape and the driving roll.

23. The method of manufacturing a roll of tape according to claim **21**, wherein a plurality of cores are mounted on said mandrel in such a way as to remain freely rotatable while being retained in axially spaced relation from one another and a corresponding plurality of tape rolls are wound thereon, said tape rolls being urged as a set against said driving roll and the peripheral portion of the driving roll is sufficiently resilient to maintain driving contact with each of the tape rolls on said mandrel despite slight differences in the outer diameters of said tape rolls.

24. The method of manufacturing a roll of tape according to claim **23**, wherein said tape rolls are urged against said driving roll by applying pressure to the peripheral surface of each tape roll on the side of the tape rolls radially opposite to that contacting said driving roll.

25. A dimensionally stable and clear-to-the-core roll of pressure-sensitive adhesive tape made in accordance with the method of claim **21**.

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