Oct. 11, 1966 F. J. JANNETT 3,278,130

METHODS OF AND APPARATUS FOR WINDING STRIP MATERIAL

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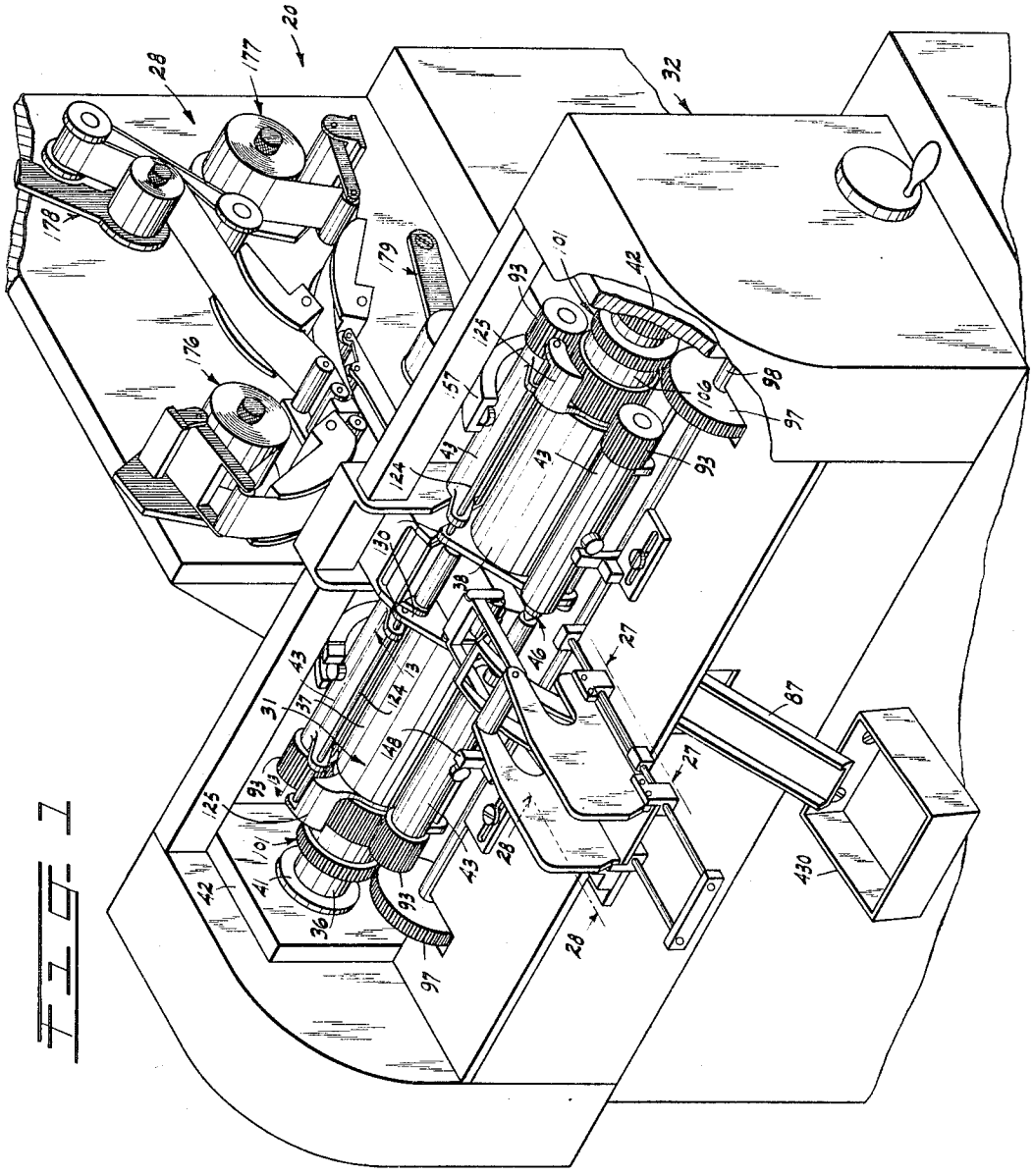


FIG. 7

INVENTOR
F. J. JANNETT
BY Don P. Bush
ATTORNEY

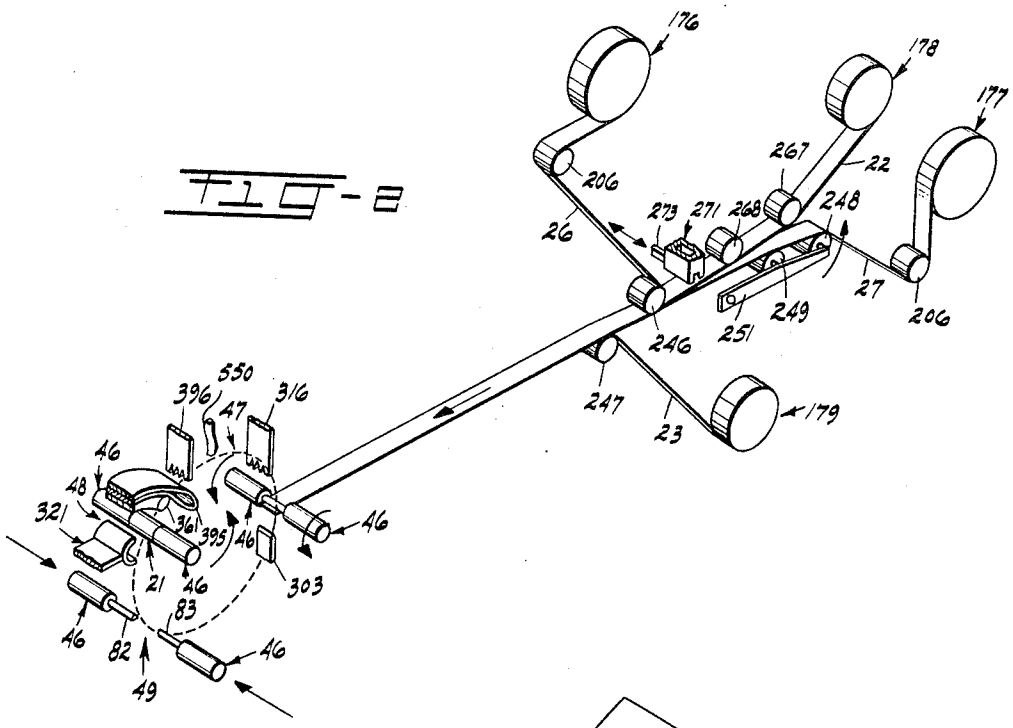
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METHODS OF AND APPARATUS FOR WINDING STRIP MATERIAL

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FIG-2



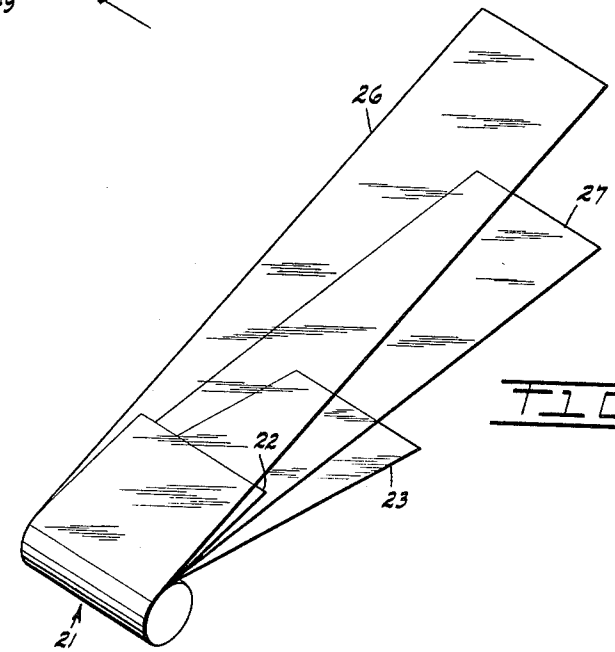


FIG-3

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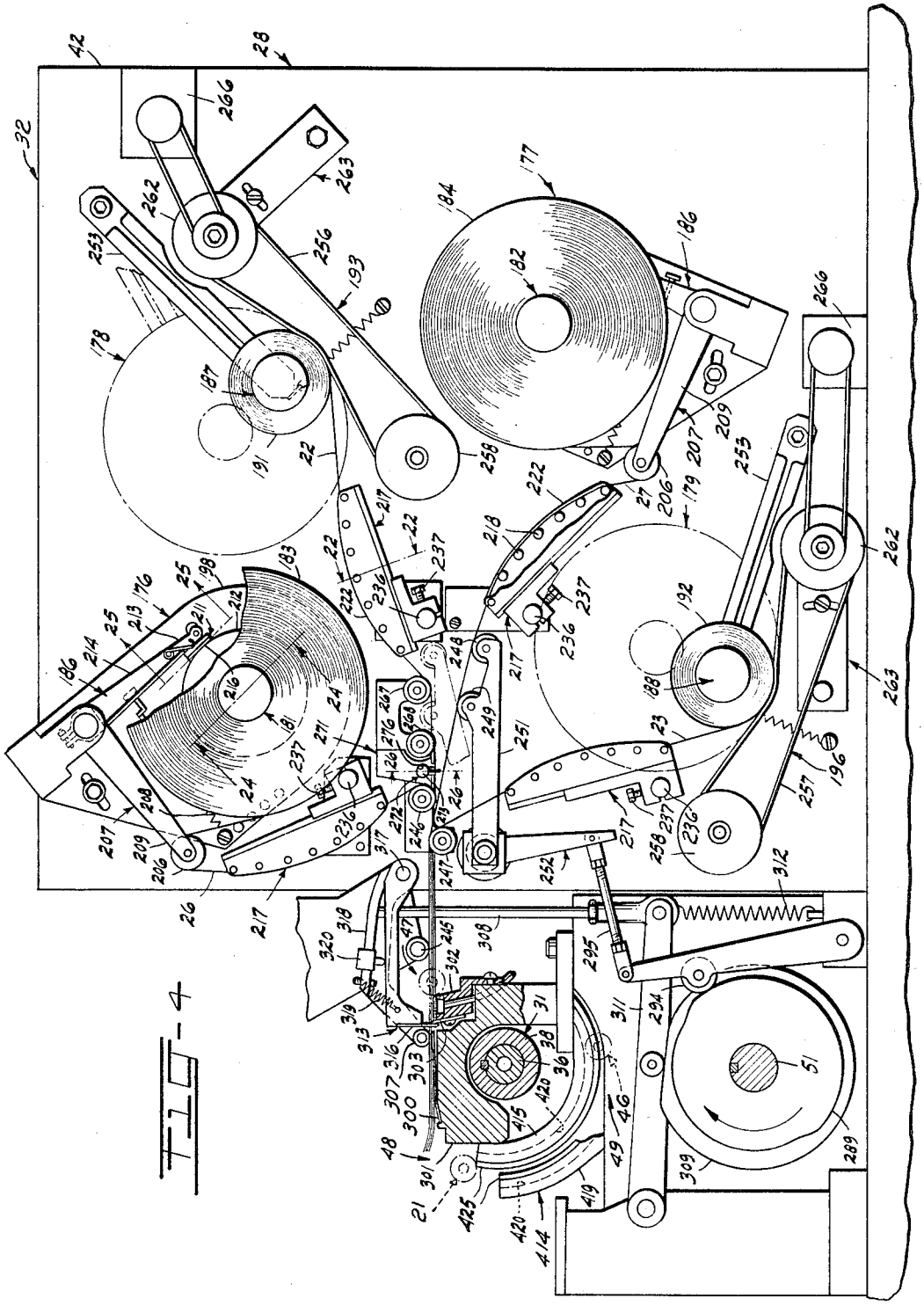


FIG-4

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METHODS OF AND APPARATUS FOR WINDING STRIP MATERIAL

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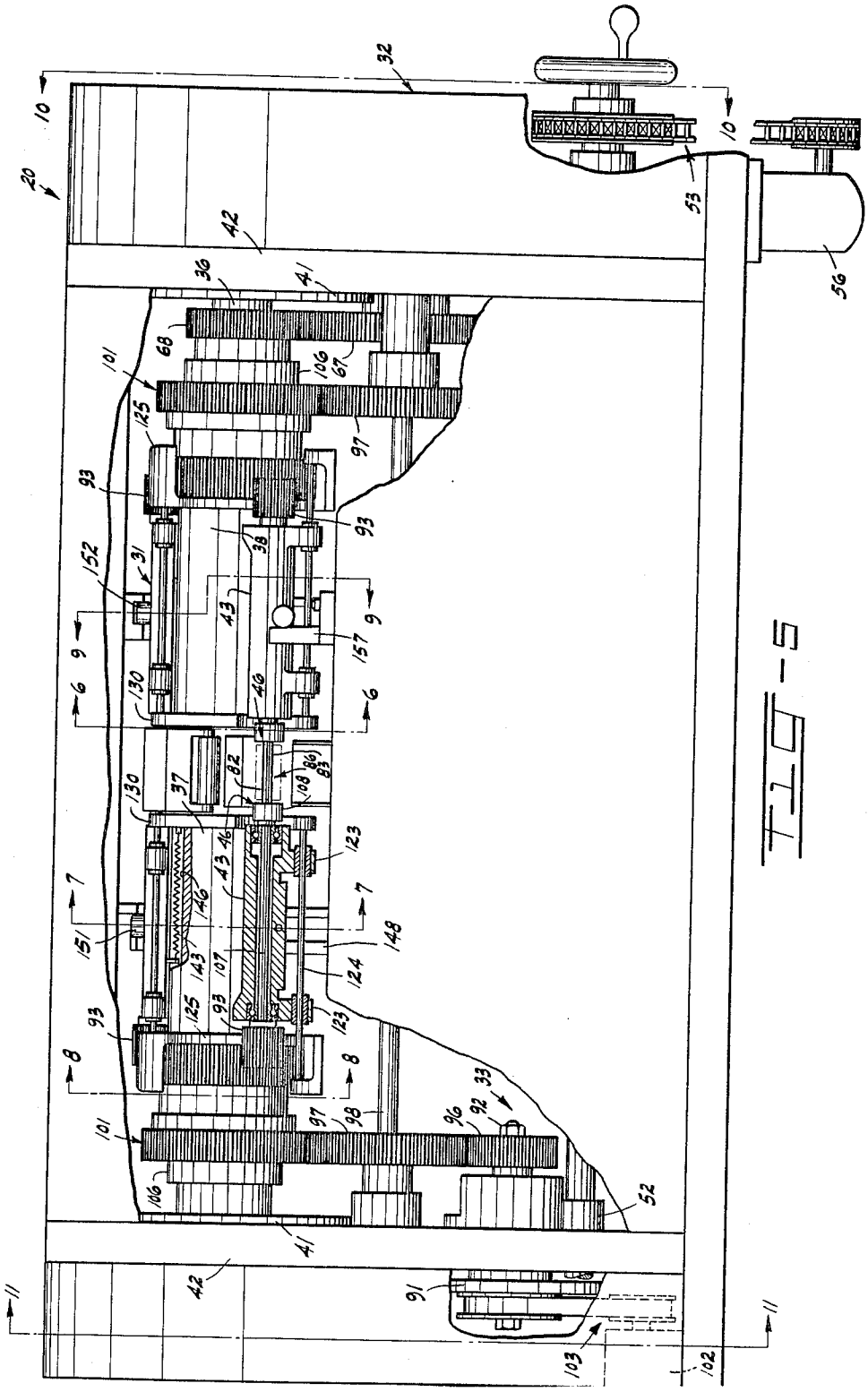


FIG-5

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METHODS OF AND APPARATUS FOR WINDING STRIP MATERIAL

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FIG-6

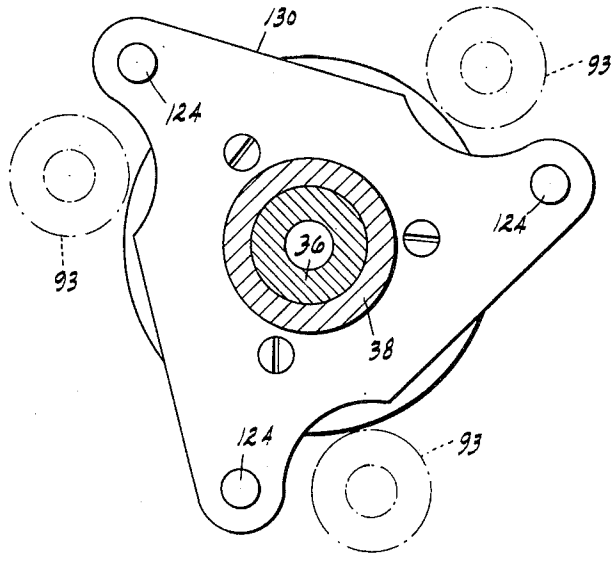
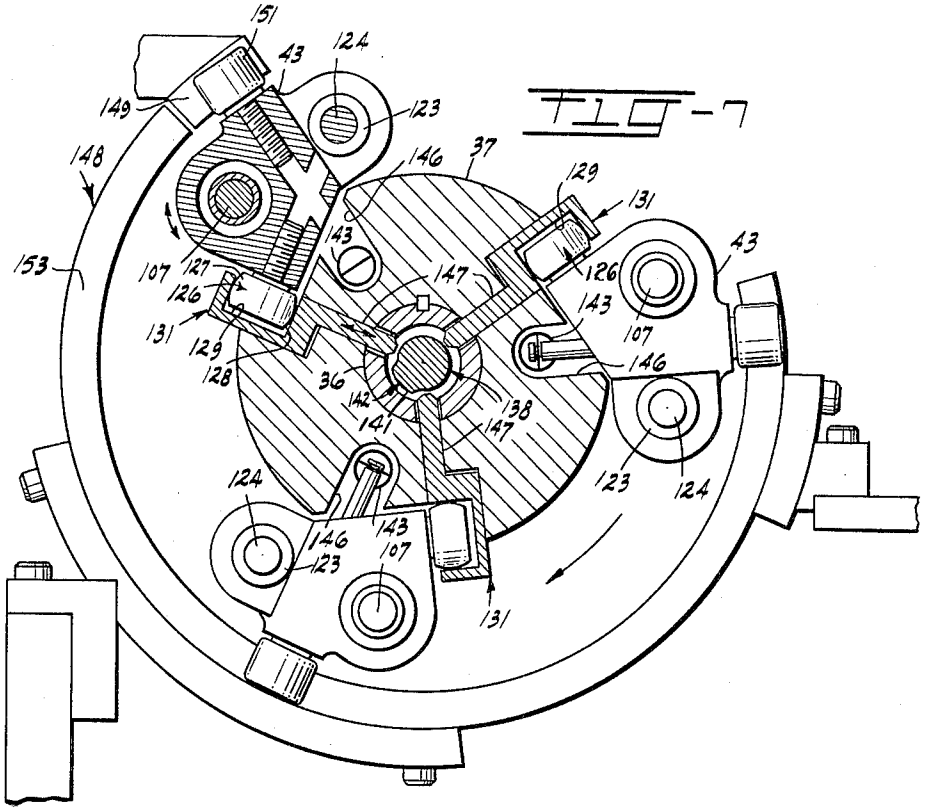


FIG-7



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METHODS OF AND APPARATUS FOR WINDING STRIP MATERIAL

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Fig-8

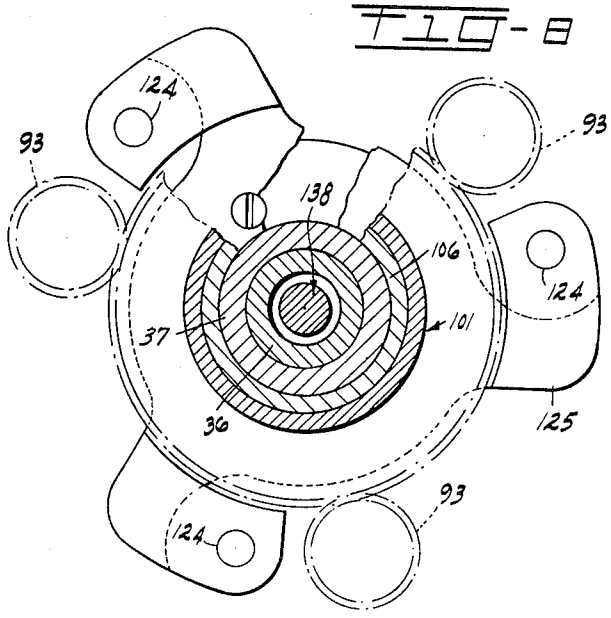
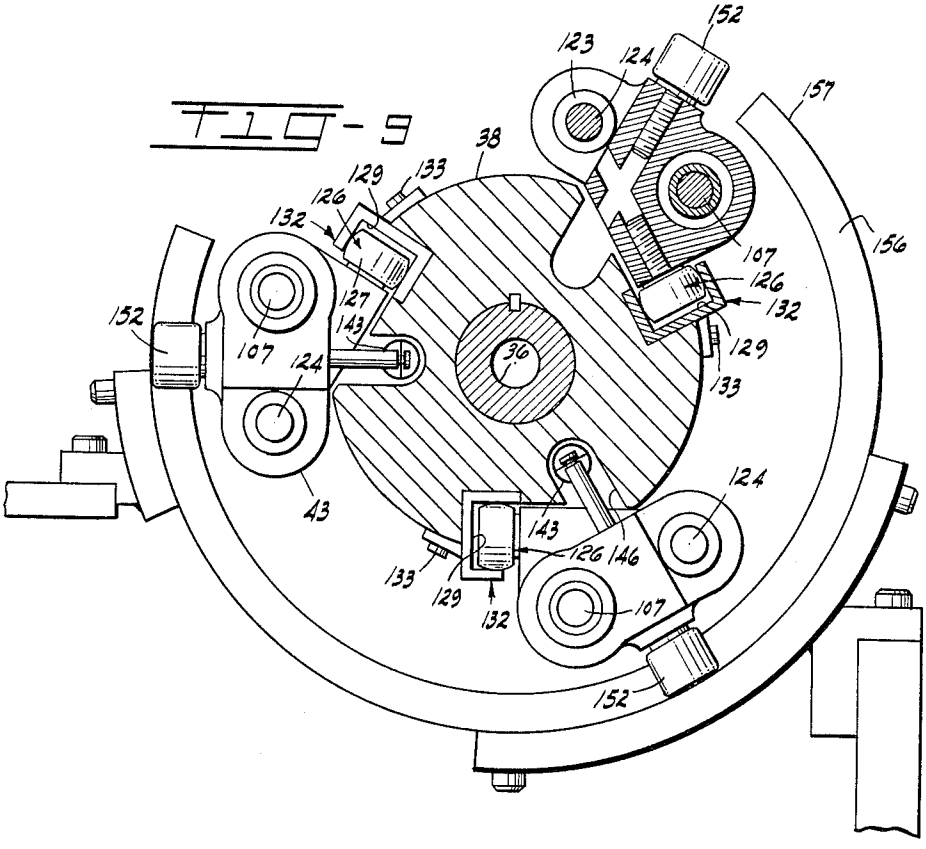


Fig-9

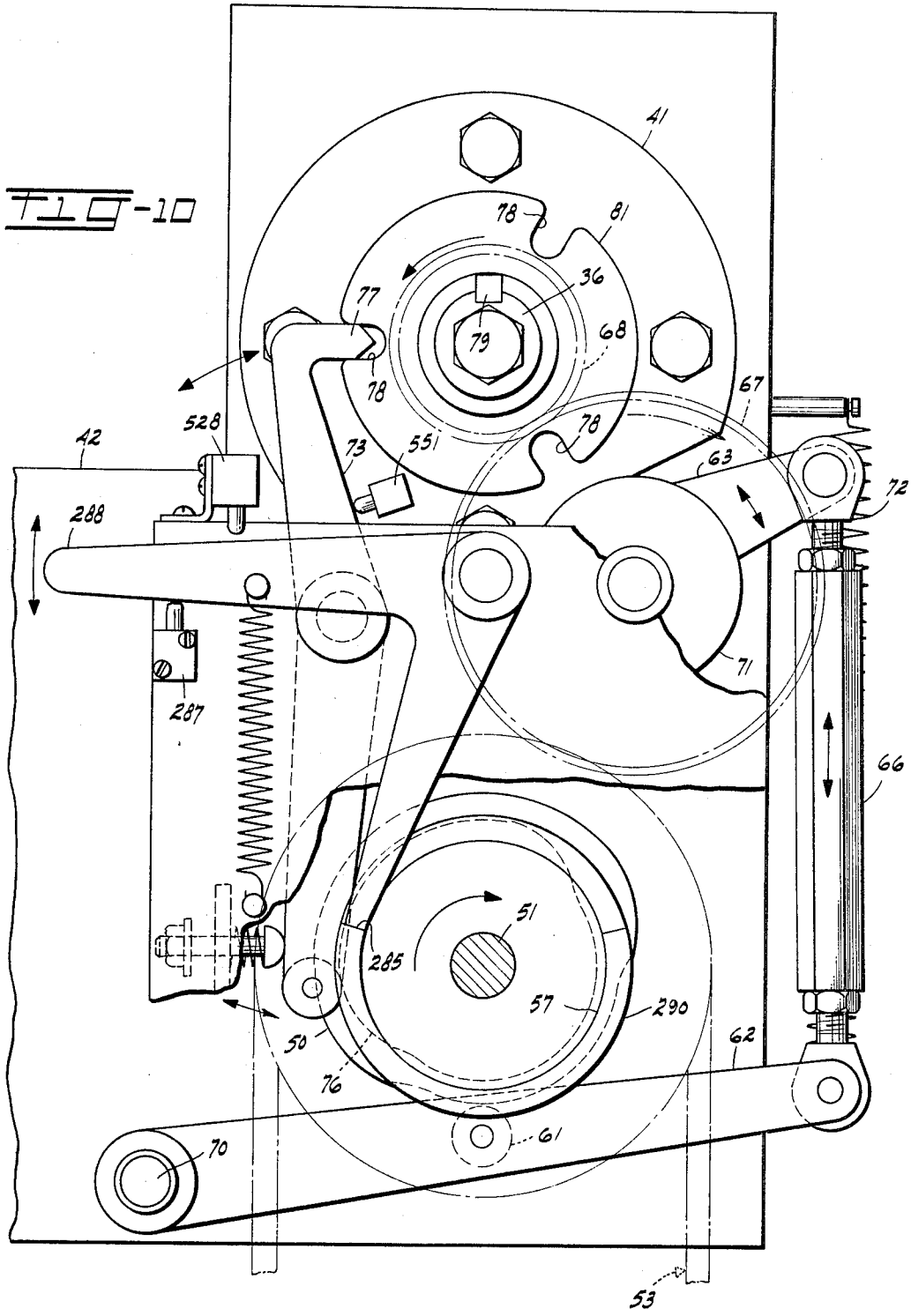


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FIG-10



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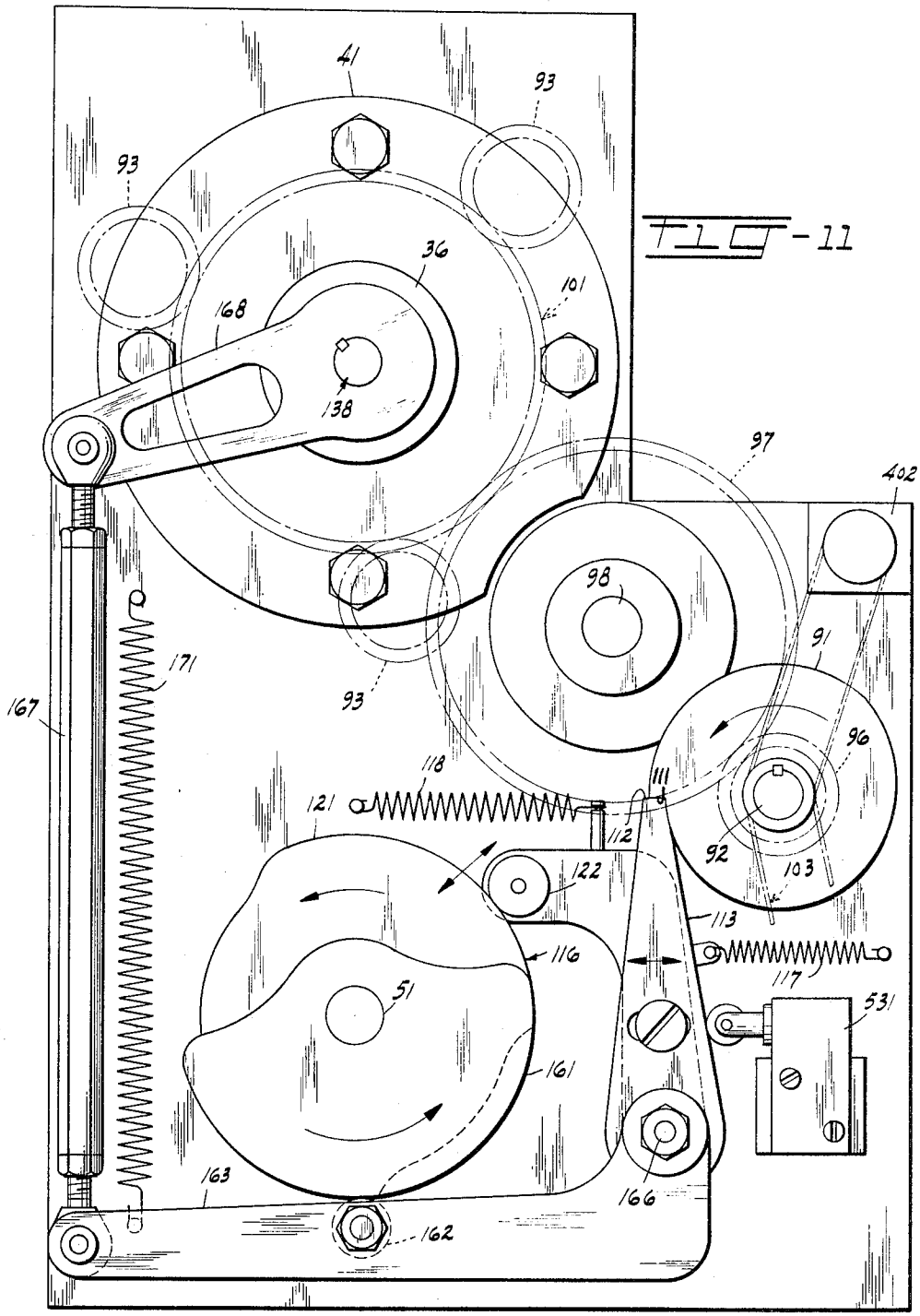
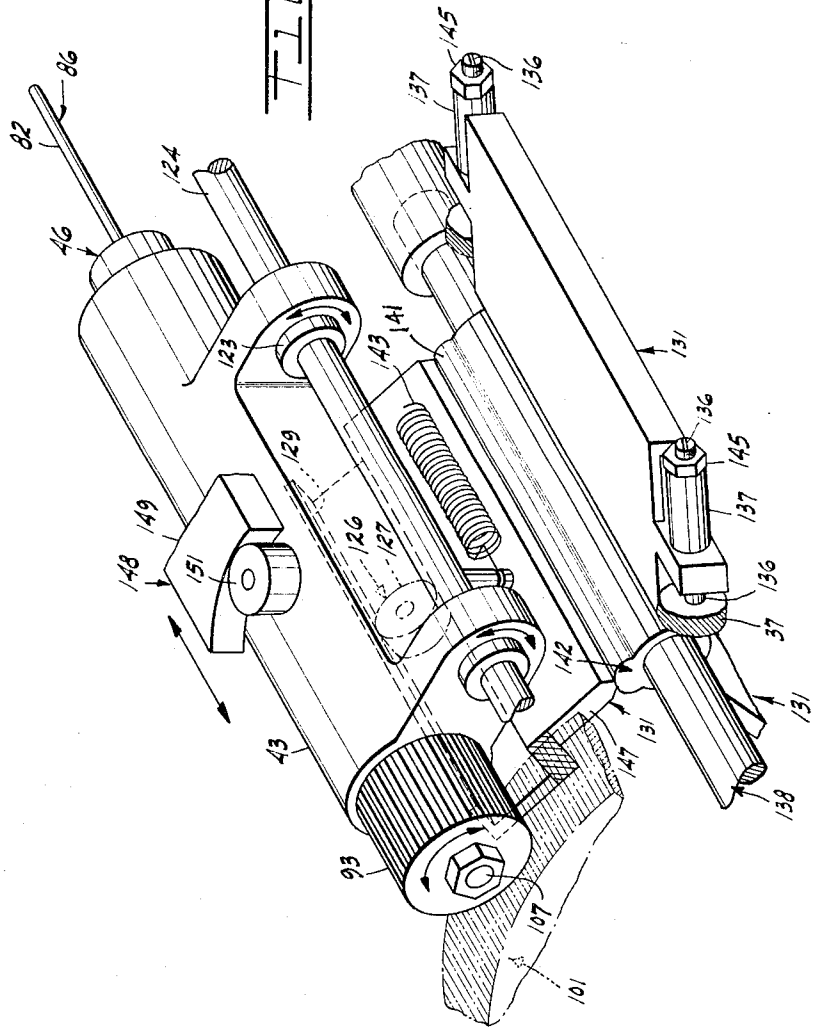


FIG-11

METHODS OF AND APPARATUS FOR WINDING STRIP MATERIAL

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FIG-12



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FIG - 22

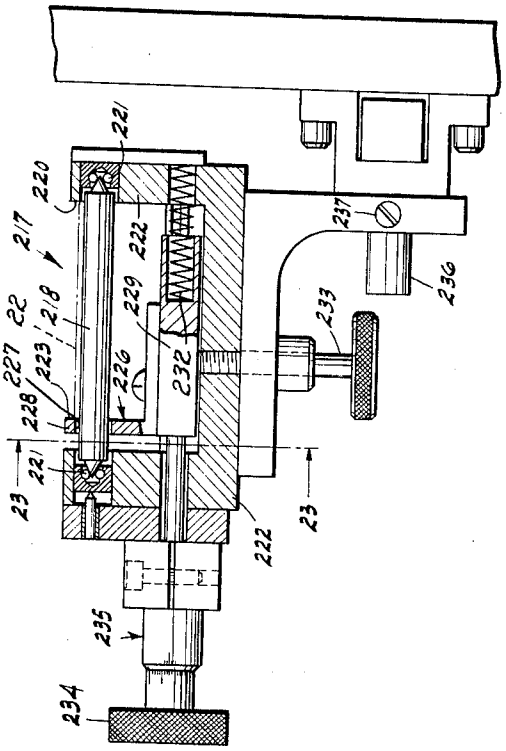


FIG - 23

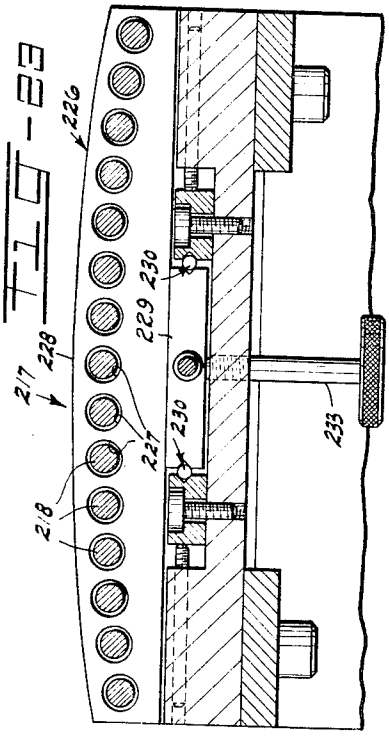
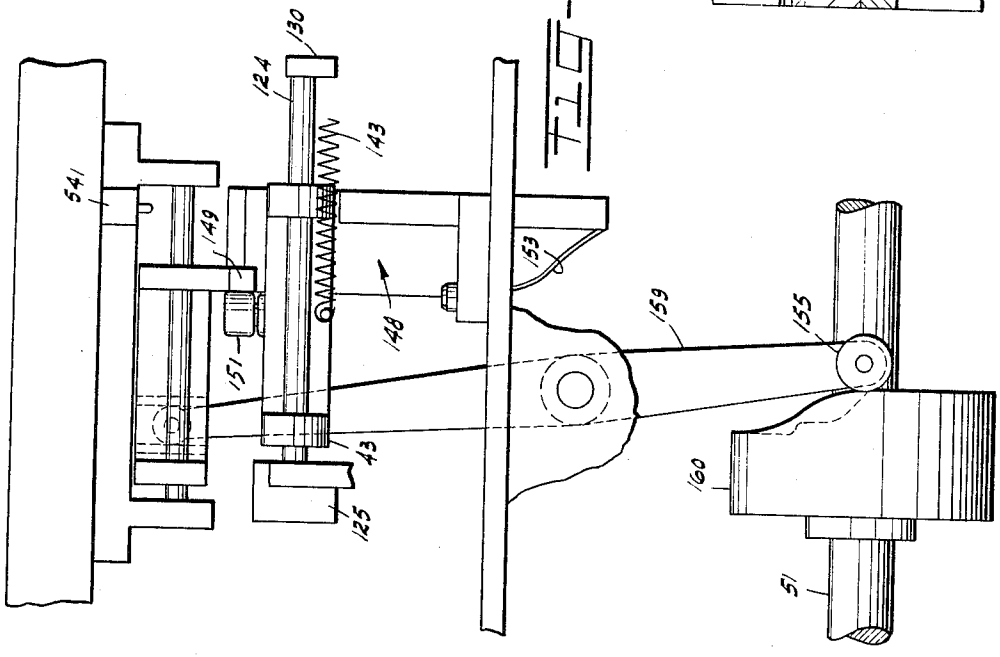


FIG - 13



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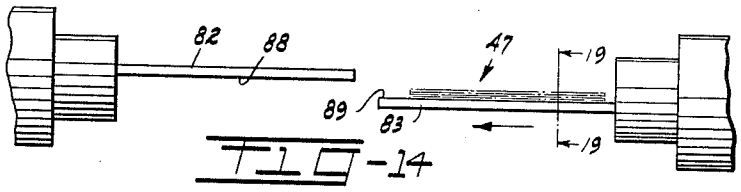


FIG-14

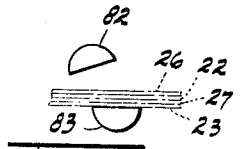


FIG-19

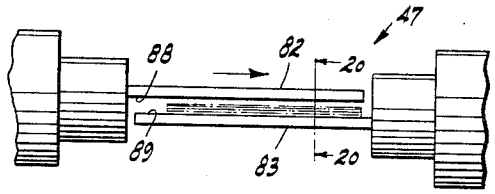


FIG-15

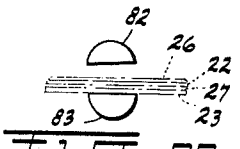


FIG-20

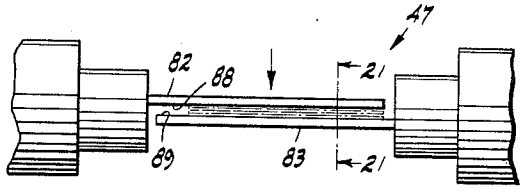


FIG-16

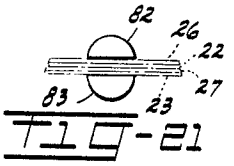


FIG-21

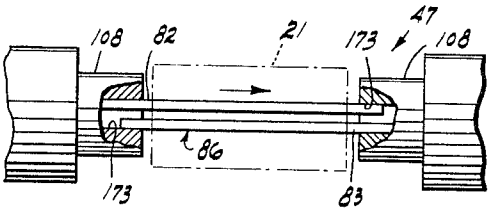


FIG-17

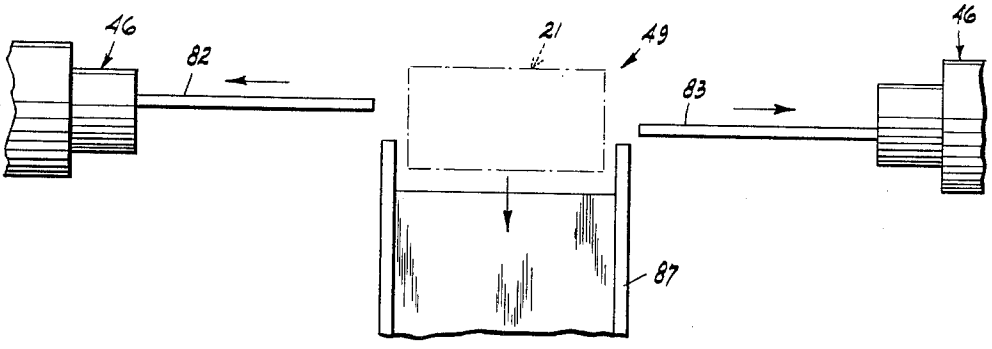


FIG-18

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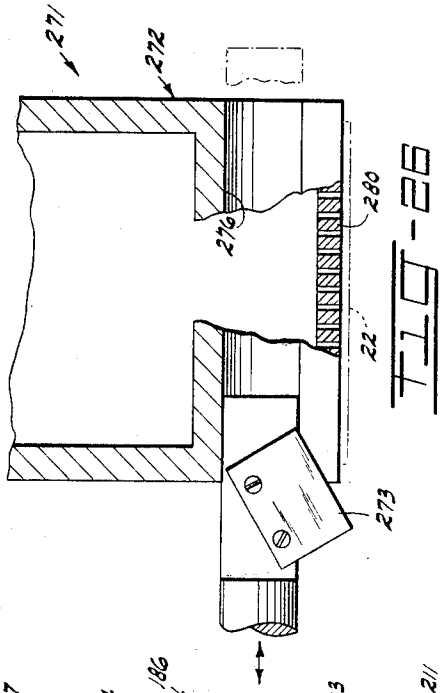


FIG-26

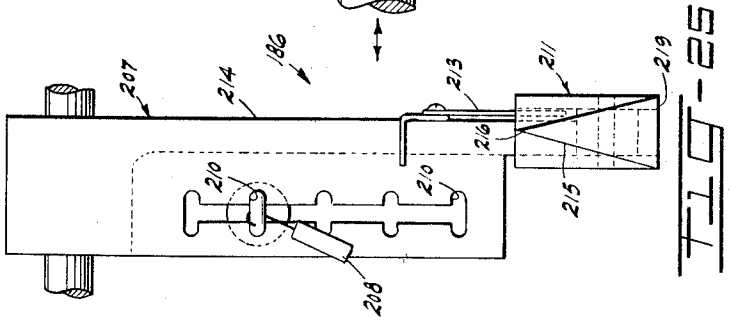


FIG-25

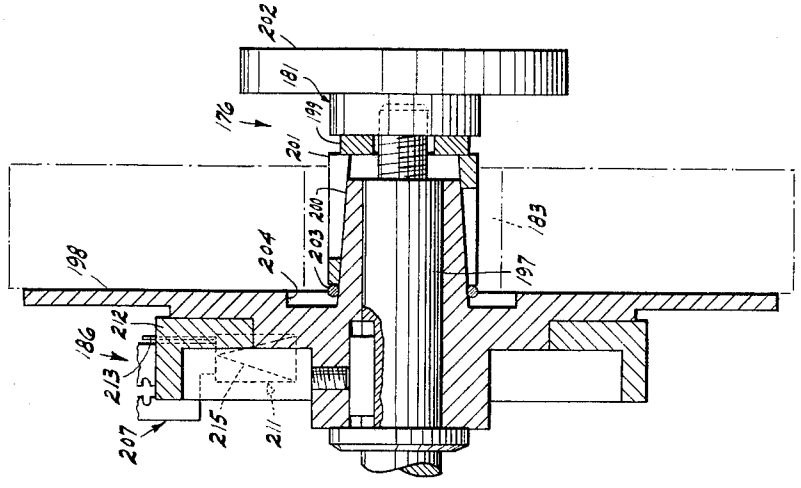


FIG-24

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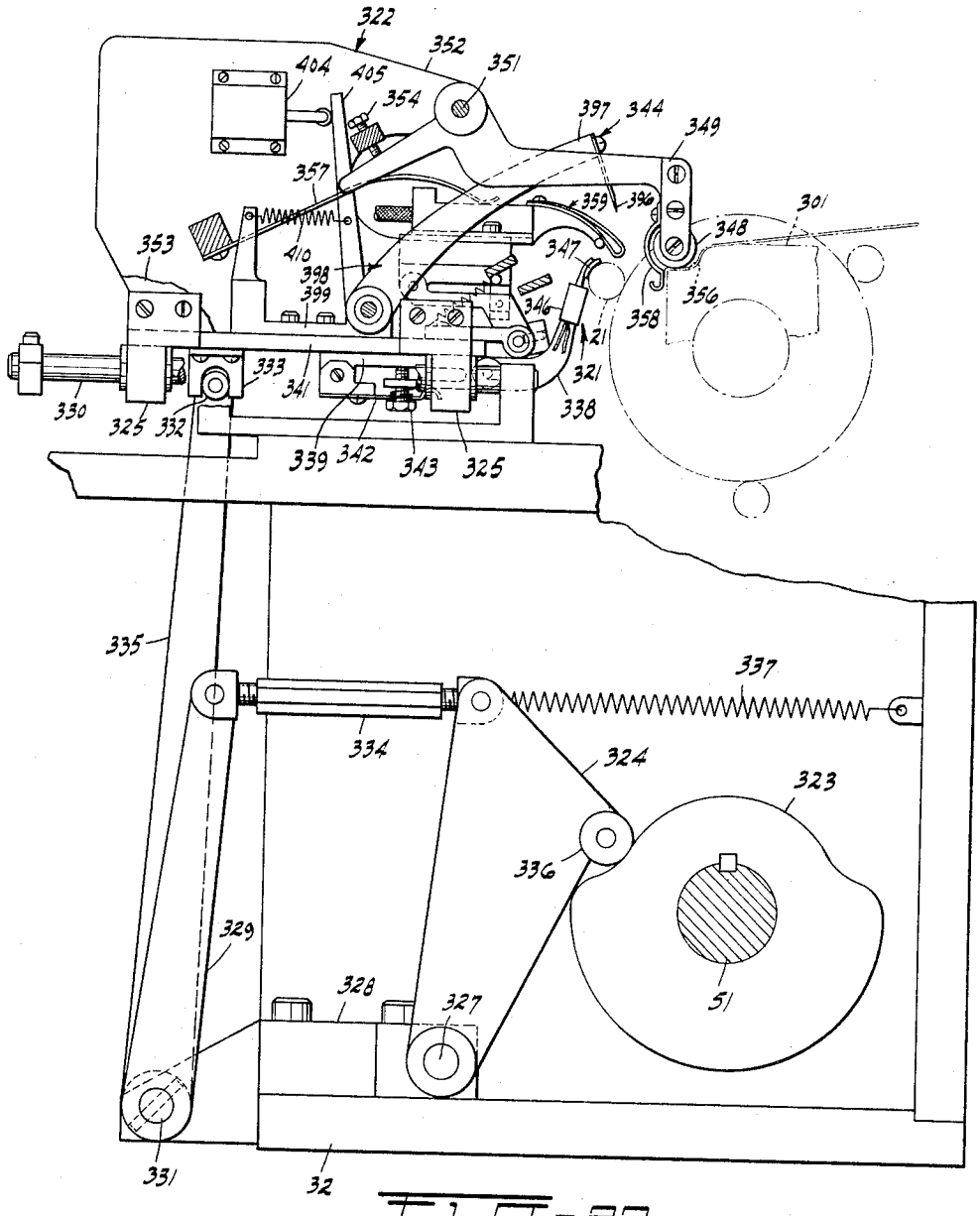


FIG-27

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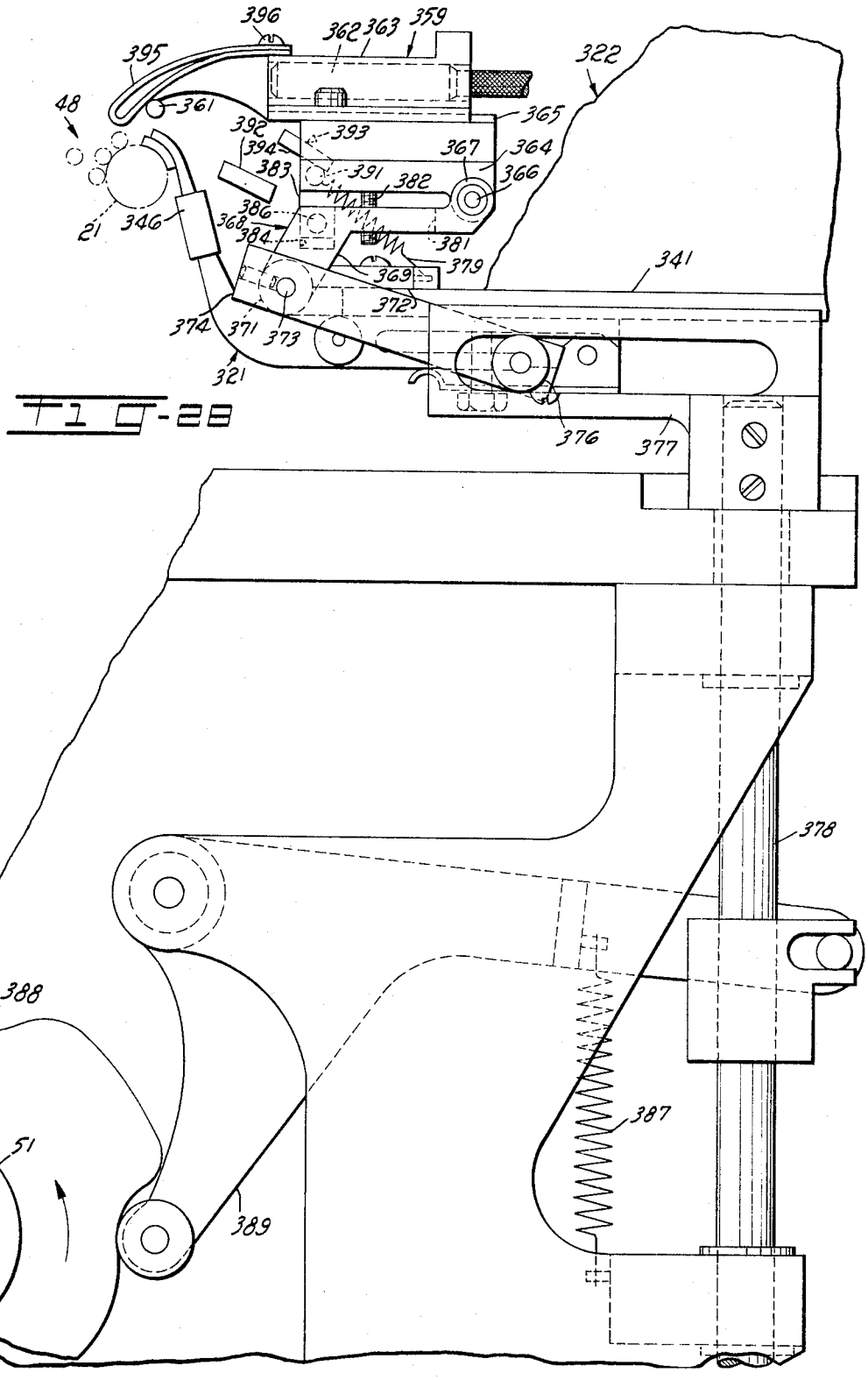
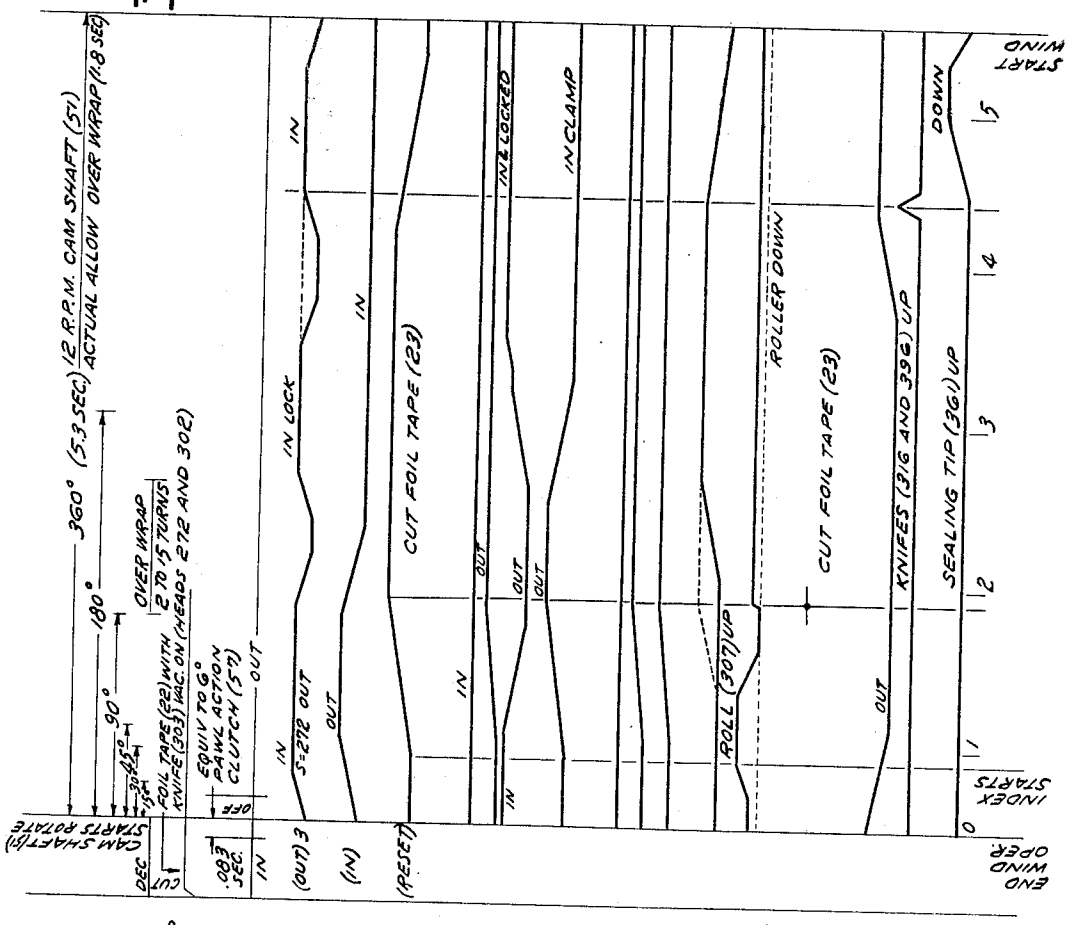


FIG-28

FIG-29

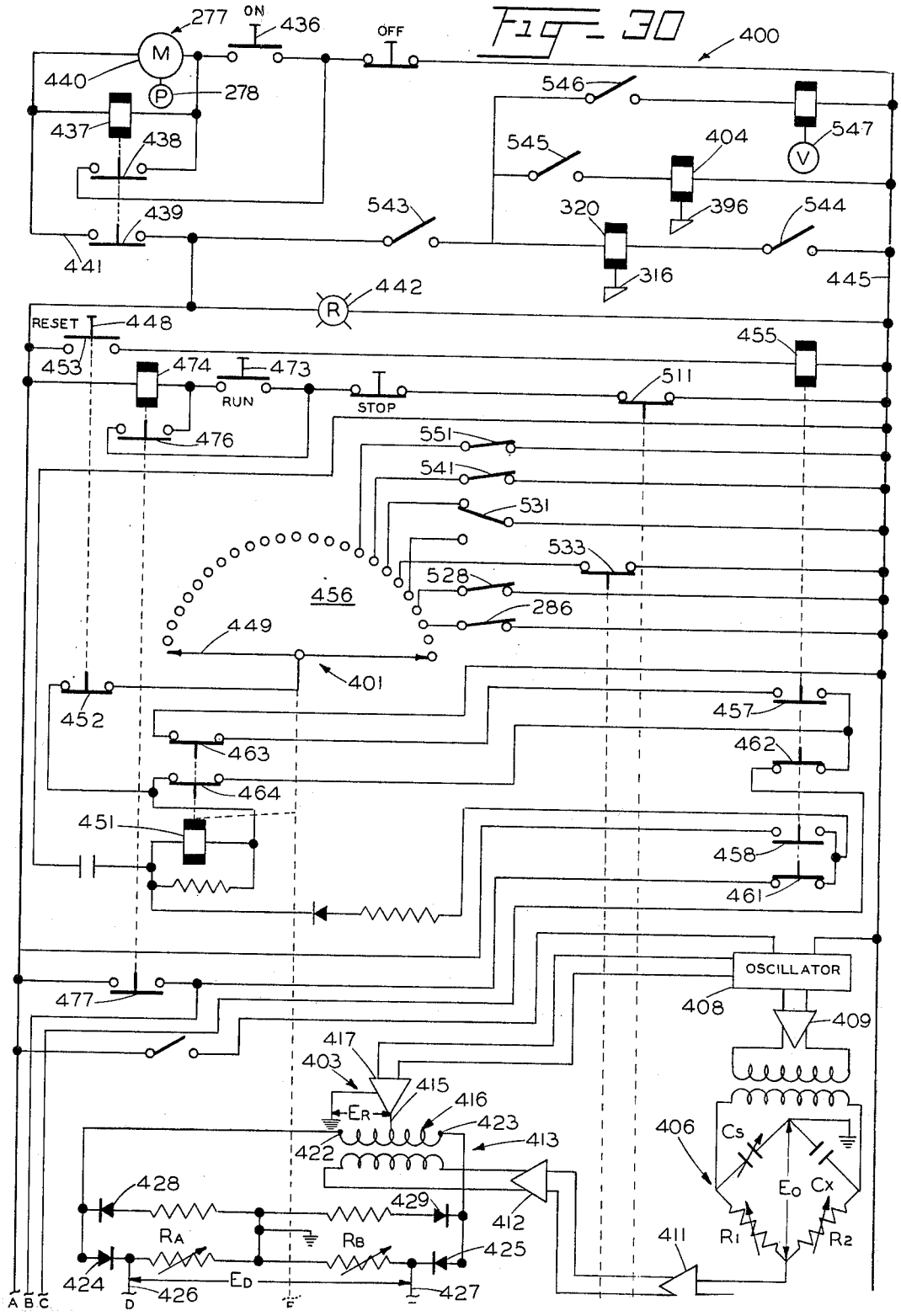


WINDING
CAP BRIDGE (403) X-OUT SOLENOID (407) DRIVEN KNIFE (273)
CAM SHAFT TRIP (288) (SOLENOID) (287)
WIND INDEX LOCK (113)
TURRET INDEX LOCK (73)
TURRET INDEX BY (50, 61, 62, 66, 63, 67 AND 68)
L. H. MANDREL HALF (82)
a) WIND TO SEAL
b) SEAL TO STRIP
c) STRIP TO WIND
L. H. MANDREL HALF PIVOT
R. H. MANDREL HALF (83)
a) WIND TO SEAL
b) SEAL TO STRIP
c) STRIP TO WIND
ACTIVE TAPE (22) REFEED ROLLERS (248 AND 249)
CLAMP ROLL (307)
GROUNDED FOIL TAPE (23) CUT BY BLADE 303
SEALING UNIT CARRIAGE 322
CLAMP ROLL (348) & UNIT (321)
SOLENOIDS (320 AND 404)
SEALING HEAD MOTION

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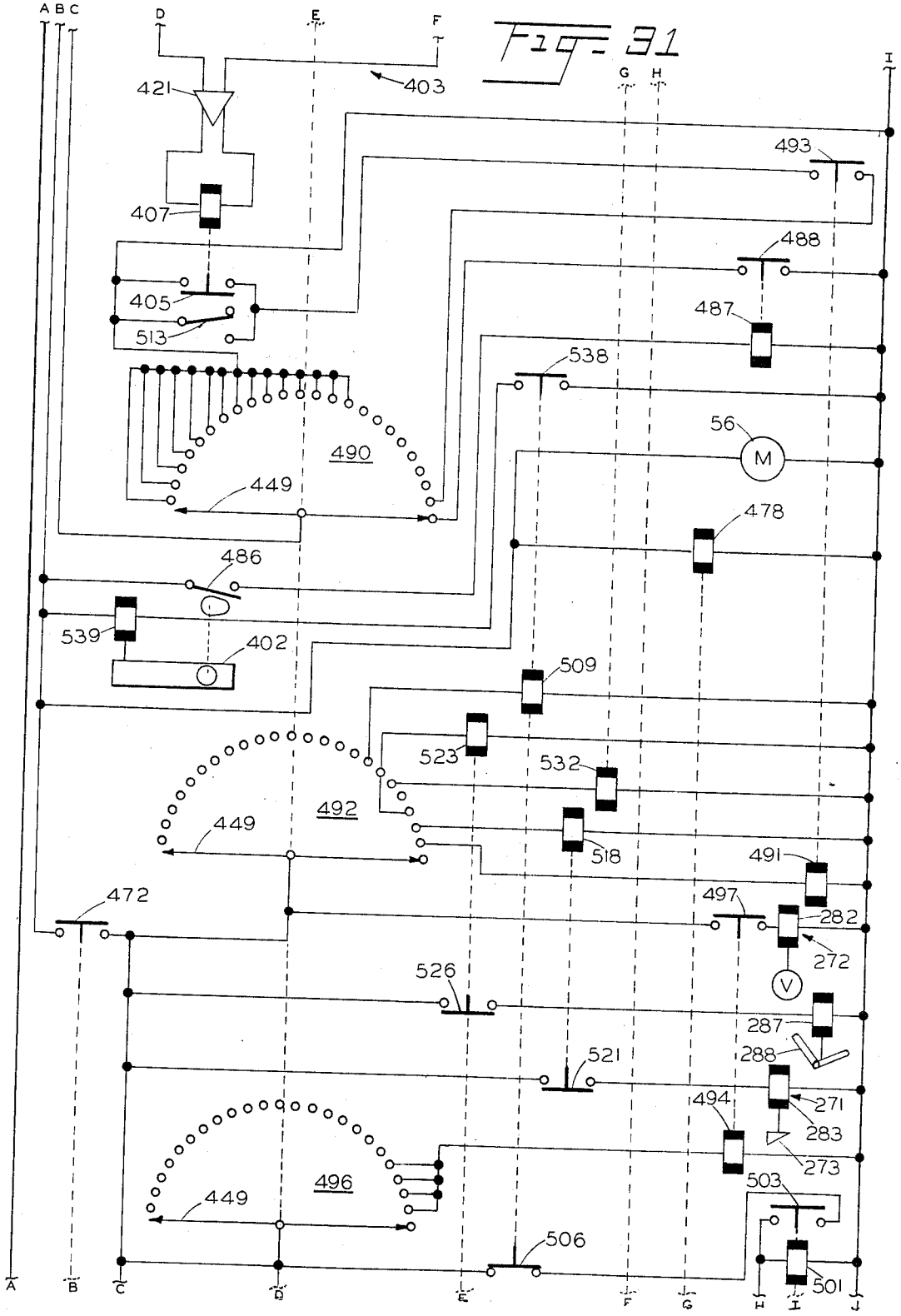
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Fig. 31



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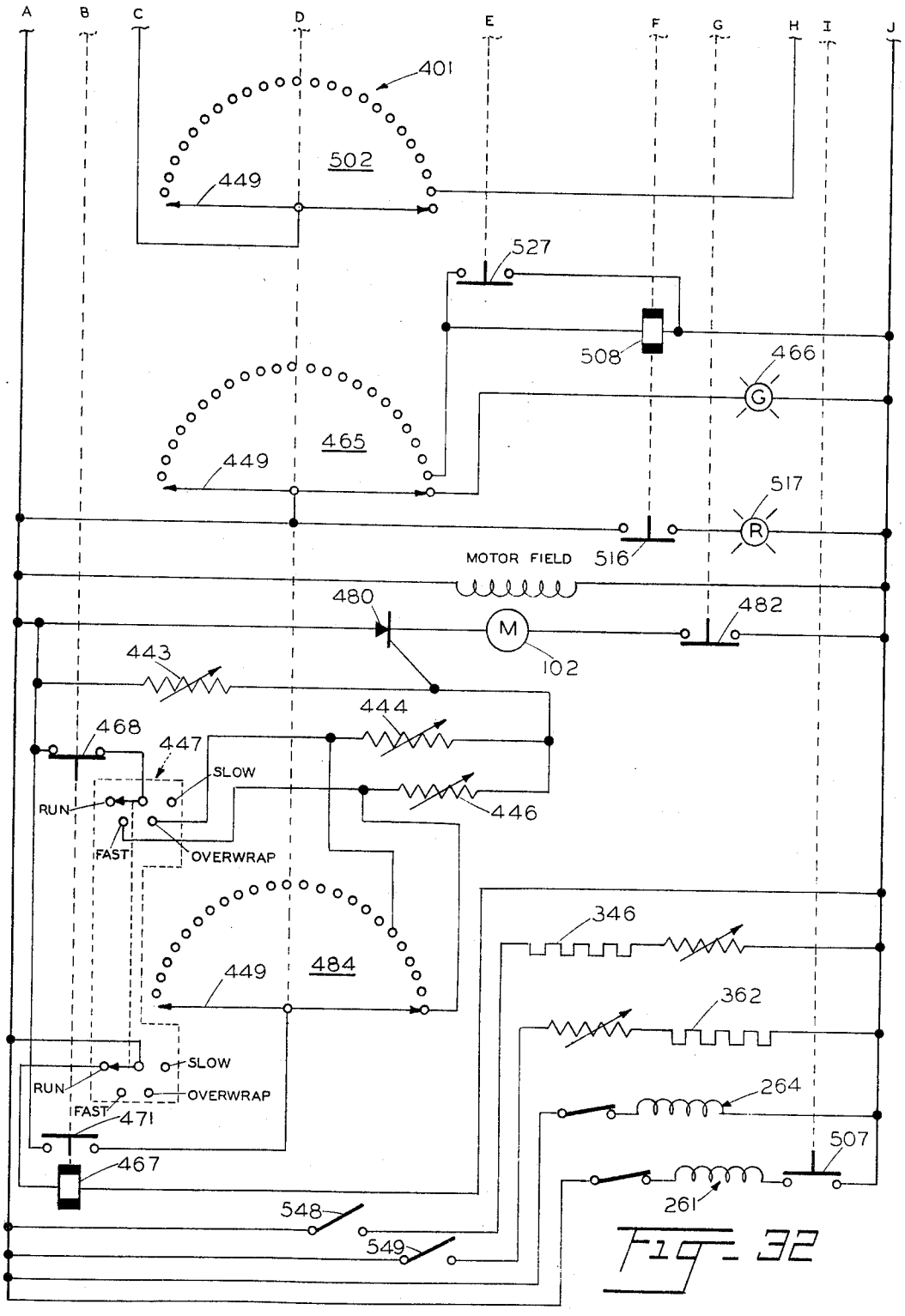


Fig. 32

United States Patent Office

3,278,130

Patented Oct. 11, 1966

3,278,130

METHODS OF AND APPARATUS FOR WINDING STRIP MATERIAL

Frederick J. Jannett, West Millington, N.J., assignor to Western Electric Company, Incorporated, New York, N.Y., a corporation of New York

Filed Feb. 19, 1964, Ser. No. 345,927

20 Claims. (Cl. 242—56.1)

The invention relates to methods of and apparatus for winding strip material. The invention relates more particularly, although not exclusively, to methods of and apparatus for winding electrical capacitors in a fully automatic operation.

The manufacture of capacitors is an old and crowded art; however, the ever increasing use of capacitors in various electrical fields, particularly the communications industry, is placing increased demands on manufacturers of electrical apparatus not only for additional quantities of capacitors, but, more important, a demand for smaller capacitors having better electrical and physical characteristics. Manufacturers of communications equipment have attempted to produce, at reduced costs, vast quantities of new, improved and more reliable miniature capacitors for use in modern telephone systems. Spirally wound capacitors have been found to be dependable for the intended use in telephone systems and are relatively inexpensive to manufacture; however, there is an ever increasing problem of providing methods and apparatus capable of high-level production of vast quantities of stable, miniature-type capacitors made from thinner and narrower tapes, having uniform properties, as required by the communications industry.

When the capacitors are used in complex communications systems having millions of different circuits which may be interconnected in millions of different ways, the uniformity of the properties of the individual capacitors and dependability of the capacitors have a significant effect on the quality of the signals or messages transmitted by such a system. It is, therefore, obvious that nonuniformity of the individual types of capacitors is undesirable in communications systems because nonuniformity introduces unreliability and instability in transmission characteristics of the circuits.

In order to provide more reliable capacitors having the desired characteristics, it was considered necessary to conceive and develop more economical and dependable equipment and processes capable of performing high-speed, low-cost methods of winding miniature-size capacitors to value from relatively thin and narrow tapes. This resulted in the conception and development of methods of and apparatus for winding circular, tubular capacitors automatically, embodying certain principles of the present invention, which permit all of the various operations necessary to wind a circular, tubular capacitor, to take place uninterruptedly in a series of automatic operations.

An object of the present invention is to provide new and improved methods of and apparatus for winding strip material.

Another object of the present invention is to provide new and improved automatic winding apparatus capable of winding strip material spirally into cylindrical packages at a relatively rapid rate and recycling from one winding operation to the other without the need of intervention by human hands.

A further object of the present invention is to provide new and improved winding apparatus capable of winding capacitors to a given value of capacitance within relatively close tolerances.

Another object of the present invention is to provide new and improved means for guiding strip material accurately to permit proper registration of the edges of the strip material being wound into a cylindrical package.

A further object of the present invention is to provide new and improved brakes capable of being used for maintaining substantially uniform tension in strips of material being fed to a capacitor-winding mandrel.

A still further object of the present invention is to provide new and improved methods of and apparatus for cutting strip material being wound into a cylindrical package, transferring and securing the leading ends of the strip material to a subsequent winding mandrel at a relatively rapid rate while preventing the strip material from wrinkling.

Another object of the present invention is to provide new and improved methods of and apparatus for clamping strip material, to be wound into a cylindrical package, between a two-piece mandrel prior to severing all of the strips of material extending from a previous package to form trailing ends on the previous package and leading ends of a package to be formed.

A further object of the present invention is to provide new and improved methods of and apparatus for rapid production of compact, precision capacitors which involve supplying relatively thin and narrow strips of conductive and nonconductive tapes to a winding head, cutting the conductive tapes prior to cutting the nonconductive tapes, sealing the capacitors to prevent unraveling of the tapes while completing the operation, removing the mandrel from the capacitor and ejecting the wound capacitors from the winding head, all automatically.

Other objects and advantages of the present invention will be more readily understood from the following detailed description of methods and apparatus forming specific embodiments of the present invention, when read in conjunction with the attached drawings in which:

FIG. 1 is a perspective view of a capacitor winding apparatus embodying certain features of the present invention;

FIG. 2 is a schematic, perspective view illustrating various cycles of the operation of the capacitor winding apparatus illustrated in FIG. 1;

FIG. 3 is an enlarged view of a partially wound capacitor of the type wound by the apparatus illustrated in FIG. 1;

FIG. 4 is an enlarged, side, elevational view of the supply units and winding station of the apparatus illustrated in FIG. 1 with portions broken away for purposes of clarity;

FIG. 5 is a partial, front, elevational view of the apparatus illustrated in FIG. 1 with portions broken away for purposes of clarity;

FIGS. 6, 7, 8 and 9 are enlarged, vertical, sectional views of the winding turret of the apparatus of FIG. 5 taken along lines 6—6, 7—7, 8—8 and 9—9, respectively, thereof;

FIG. 10 is an enlarged, vertical view of a portion of

the apparatus of FIG. 5 taken along line **10—10** thereof;

FIG. 11 is an enlarged, vertical view of a portion of the apparatus of FIG. 5 taken along line **11—11** thereof;

FIG. 12 is an enlarged fragmentary, isometric view of various elements of the apparatus of FIG. 1 for moving the winding spindles on the left side of the turret, as viewed in FIG. 5, into operating position;

FIG. 13 is an enlarged, partial, vertical view of a portion of the apparatus of FIG. 1 taken along line **13—13** thereof for moving the winding spindles on the left side of the turret into operating position;

FIGS. 14 to 18, inclusive, are enlarged, vertical views illustrating various operational positions of different portions of a winding mandrel of the apparatus illustrated in FIG. 1 during the operation thereof;

FIGS. 19 to 21, inclusive, are enlarged, sectional views of the winding mandrel illustrated in FIGS. 14, 15 and 16 taken along lines **19—19**, **20—20** and **21—21**, all respectively, thereof;

FIG. 22 is an enlarged, sectional view of a tape guide illustrated on FIG. 4 taken along line **22—22** thereof;

FIG. 23 is a sectional view of the tape guide of FIG. 22 taken along line **23—23** thereof;

FIG. 24 is an enlarged, sectional view of one of the tape-supply units illustrated on FIG. 4 taken along line **24—24** thereof;

FIG. 25 is an enlarged, fragmentary, vertical view of a braking device illustrated on FIG. 4 taken along line **25—25** thereof with portions broken away for purposes of clarity;

FIG. 26 is an enlarged, fragmentary, vertical section of a vacuum head and tape-cutting device of the apparatus of FIG. 4 taken along line **26—26** thereof;

FIGS. 27 and 28 are enlarged, fragmentary, vertical views of the heat-sealing and tape-cutting portion of the apparatus of FIG. 1 taken along lines **27—27** and **28—28**, respectively, thereof;

FIG. 29 is a timing chart illustrating the operating sequence of the various elements of the apparatus of FIG. 1; and

FIGS. 30, 31 and 32 combined, constitute a schematic representation of an electrical control circuit forming a part of the apparatus of FIG. 1.

Referring now to the drawings and more particularly to FIG. 1 thereof, there is shown a preferred embodiment of an apparatus, designated generally by the numeral **20**, for winding automatically circular, tubular capacitors, designated generally by the numerals **21—21** (FIGS. 2 and 3). The capacitors **21—21** are formed of two thin, metal-foil tapes **22** and **23**, such as aluminum or lead-tin foil, which are insulated from each other by two interleaved, dielectric tapes **26** and **27** formed of insulated material, such as Mylar, paper or polystyrene. The capacitor-winding apparatus **20** includes a tape-supply unit, designated generally by the numeral **28** (FIGS. 1 and 4), a horizontally disposed, indexable turret, designated generally by the numeral **31**, and a castered frame or carriage, designated generally by the numeral **32**. The castered frame or carriage **32** also houses a drive mechanism, designated generally by the numeral **33** (FIG. 5), and an electrical control circuit, designated generally by the numeral **400** (FIGS. 30, 31 and 32).

The winding turret **31** is mounted rotatably in the frame **32** on a hollow shaft **36** (FIGS. 4 to 10, inclusive). The turret **31** includes a left-hand barrel **37** and a right-hand barrel **38** which are both keyed to the hollow shaft **36** and are supported by flanged cartridge-type bearings **41—41** mounted in plates **42—42**. The left and right-hand barrels **37** and **38**, respectively of the turret **31** each support three pivotably mounted mandrel housings **43—43**, which cooperate to form three pairs of rotatable winding spindles, designated generally by the numerals **46—46**. Each pair of the winding spindles **46—46** is indexed, 120° at a time, to move successively through a winding station, an overwrapping and heat-sealing station, and a mandrel-removal or capacitor-stripping station, designated generally by the numerals **47**, **48** and **49**, respectively, (FIG. 2). The indexing movement is effected by an indexing cam **50** (FIG. 10) connected to a cam shaft **51**. The cam shaft **51** is supported in ball bearings **52—52** in the side plates **42—42** of the turret frame **32** and is indexed by means of a chain drive, designated generally by the numeral **53** (FIG. 5), connected to a right-angle gear motor **56** which drives a conventional single-revolution clutch **57** (FIG. 10) mounted on the cam shaft **51**.

The cam **50**, which indexes the turret **31**, is connected operatively therewith through a cam follower **61** (FIG. 10), oscillatable arms **62** and **63**, interconnected by an adjustable linkage **66**, and a set of gears **67** and **68**, connected to the oscillatable arm **63** by an unidirectional clutch **71**. The arm **62** is mounted oscillatably to one of the side plates **42—42** of thus frame **32** by a stud **70** and is biased upwardly by a tension spring **72** to hold the cam follower **61** against the surface of the cam **50**. The cam **50**, through the follower arm **62** and linkage **66**, moves the arm **63**, and the gear **67**, connected thereto by the clutch **71**, through an arc of 60° which, in turn, moves the gear **68** and attached turret **31** through an arc of 120°, because of the two-to-one ratio of the gears **67** and **68**.

In order to insure that the spindles **46—46** on the turret **31** are indexed to and remain in the desired position, the turret **31**, which is keyed to the hollow shaft **36**, is locked in position and prevented from vibrating excessively during the winding operation by a spring-biased bell crank **73** (FIG. 10), operated by a cam **76**. The end **77** of the bell crank **73** is tapered to facilitate insertion of the end **77** of the bell crank **73** into one of three notches **78—78** of a three-position, turret-indexing stop wheel **81** keyed to the hollow shaft **36** by a key **79**.

The winding spindles **46—46** (FIGS.. 2, 5 and 14 to 21, inclusive) each include a mandrel half **82** or **83** on one-half of the turret **31** which cooperates with the associated mandrel half **83** or **82** on the other half of the turret **31** to form a complete mandrel, designated generally by the numeral **86**. The individual capacitors **21—21** are wound on the individual mandrels **86—86** and held on the mandrels until the mandrel halves **82** and **83** are separated axially to remove the capacitors **21—21** from the mandrels **86—86** and permit the capacitors to drop into a discharge chute **87** at the capacitor-stripping station **49**, as illustrated in FIGS. 2 and 18.

It is desirable that the adjacent-cooperating surfaces **88** and **89** of the mandrel halves **82** and **83**, respectively, are always maintained in the same parallel orientation and are stopped when the adjacent surfaces **88** and **89** of the associated mandrel halves **82** and **83**, respectively, are oriented horizontally, as illustrated in FIGS. 14 to 21, inclusive. This is accomplished by connecting a winding-indexing lock wheel **91** (FIG. 11) rigidly to a drive shaft **92** and interconnecting the drive shaft **92** with planetary drive gears **93—93**, for driving the spindles **46—46**, by a pinion gear **96** keyed to the right-hand end of the drive shaft **92**, as viewed in FIG. 5, a pair of axially split gears **97—97** keyed to a jack shaft **98** and two turret-idler, sun-gear assemblies, designated generally by the numerals **101—101** (FIG. 5). The drive shaft **92** is driven by a shunt-wound, variable-speed, direct-current motor **102** through a timing-belt drive, designated generally by the numeral **103**, connected to the left end of the drive shaft **92**, as viewed in FIG. 5.

The pinion gear **96** on the right end of the drive shaft **92** is intermeshed with the axially split gear **97**, on the left end of the jack shaft **98**, with a three-to-one gear ratio. The split gears **97—97**, on opposite ends of the jack shaft **98**, mesh with the turret-idler gear assemblies **101—101**, mounted on bearings **106—106** (FIG. 8) on the hollow shaft **36**, and have one-to-one gear ratios. Each of the turret-idler, sun-gear assemblies **101—101** intermesh with the three associated planetary drive gears

93—93, connected to the spindles 46—46, at all times. The planetary drive gears 93—93 are each supported in the outer end of the mandrel housings 43—43 and are connected to individual mandrel halves 82 or 83 through a shaft 107 and chuck 108 (FIG. 5). The gear ratio of the turret-idler gear assemblies 101—101 and spindle-drive gears 93—93 is one-to-three, resulting in a one-to-one gear ratio of the gears interconnecting the winding-indexing lock wheel 91 and all of the individual mandrel halves 82—82 and 83—83.

A peripheral latching surface 111 (FIG. 11) is provided on the stop wheel 91 which is always parallel to the adjacent surfaces 88 and 89 of the associated mandrel halves 82 and 83 in the winding station. The latching surface 111 is engaged by a horizontal surface 112 on the free end of the cam-operated adjustable latch 113. The latch 113 is controlled by a cam, designated generally by the numeral 116, and is biased in opposite directions by coiled tension springs 117 and 118. The latch 113 is pushed into engagement with the latching surface 111 of the winding-index stop wheel 91 by a lobe 121 on the cam 116 engaging a cam follower 122, mounted on the latch 113, and is pulled away from the wheel 91, by the spring 118, just prior to the commencing of the winding operation when the lobe 121 is moved out of engagement with the cam follower 122.

In order to clamp the new leading ends of the tapes 22, 23, 26 and 27 between the mandrel halves 82–83 without damaging or wrinkling the tapes during the tape-clamping operation, the left-hand mandrel half 82 is moved axially of the associated spindle 46 (FIG. 15) and then traversely toward the right mandrel half 83 (FIG. 16) during the clamping operation. This is accomplished by mounting each of the mandrel housings 43—43, on the left-hand barrel 37 and on the right-hand barrel 38, pivotably on shafts 124—124 with bushings 123—123 (FIGS. 1, 5 to 9, inclusive, and 12). The shafts 124—124 are supported at opposite ends by plates 125—125 (FIG. 6) and 130—130 (FIG. 8) secured to opposite ends of the barrels 37 and 38.

The mandrel housings 43—43 are guided during their relative movement parallel to the axis of the turret 31 by cam followers, designated generally by the numerals 126—126 (FIGS. 7, 9 and 12). having rotatably-mounted members 127—127 provided with spherical camming surfaces 128—128 which ride in straight recesses 129—129 in camming tracks, designated generally by the numerals 131—131 and 132—132, mounted in the barrels 37 and 38, respectivey. The tracks 132—132 are secured rigidly in the right-hand barrel 38 by screws 133—133 (FIG. 9) to prevent the housings 43—43 on the right barrel from pivoting, and the tracks 131—131 are secured movably in the left-hand barrel 37 by studs 136—136 and rubber washers 137—137 (FIG. 12).

A normally stationary cam shaft, designated generally by the numeral 138 (FIGS. 7, 8, 11 and 12) extends from the left side of the turret 31 into the hollow shaft 36 (FIG. 7). A lobe 141 (FIGS. 7 and 12) of a cam 142 on the cam shaft 138 is designed to push the guide tracks 131—131, in the left mandrel barrel 37, outwardly automatically to compress the rubber washers 137—137 when the winding turret 31 is indexed into the winding station 47. The force exerted by each of the washers 137—137 can be varied by adjusting a nut 145 on the free end of the associated stud 136. Tension springs 143—143 extend between the plates 130—130 and the housings 43—43, in recesses 146—146 in the barrels 37 and 38 (FIGS. 7 and 9), and are used to urge the co-operating mandrel housings 43—43 toward each other. The spherical camming surfaces 128—128 permit the cam followers 126—126 projecting from the housings 43——43 on the left barrel to pivot with respect to the straight recesses 129—129 in the camming tracks 131—131 as the tracks 131—131 are moved transversely of the normal

path of travel of the followers 126—126 by cam-follower tails 147—147.

The cam-follower tails 147–147 project laterally from the tracks 131–131 (FIGS. 7 and 12) and ride on the normally stationary, oscillatable cam 142 as the turret 31 is indexed into the winding station 47. The compressed rubber washers 137—137 are utilized to urge the follower tails 147—147 against the cam 142 and the force exerted by the washers 137—137 is varied by adjusting the nuts 145—145. The cam-follower tails 147—147 are moved substantially in spiral paths as the turret 31 is rotated around its longitudinal axis and are moved simultaneously axially thereof, by the combined action of a movable section 149 of an arcuately shaped cam, designated generally by the numeral 148, and the associated tension springs 143—143, during the indexing of the turret 31. This action causes each of the cam followers 126—126 to slide along the recess 129 in the track 131 axially of the cam 142 and simultaneously causes the associated left mandrel half 82 to move transversely away from the associated right mandrel half 83 which, in turn, causes the rubber washers 137—137 to be compressed during the mandrel-indexing operation.

The cam 142 holds the pivotable, left mandrel housing 43 a short distance away from the normal axis of rotation of the spindle 46, which distance is less than the length of the engagement of the gear teeth on the associated sun-gear assembly 101 with the gear teeth on the planetary gears 93—93. When the particular spindle 46 is indexed, the associated left and right-hand mandrel housings 43—43 are moved axially of the turret 31 by the cam followers 151 and 152 riding on stationary, axially extending camming surfaces 153 and 156 of the cam 148 and an arcuately shaped cam 157, all respectively.

When one of the spindles 46—46 is indexed into the winding station 47, the right-hand mandrel half 83 is moved axially to the left by the cam 157, prior to the mandrel half 83 reaching the winding station 47, so that the mandrel half 83 strikes the tape 23 and supports the catenary of the tapes 22, 23, 26 and 27, extending from the supply unit 28 to the partially wound capacitor 21 supported in the preceding spindle 46. The associated left mandrel half 82 is fully retracted at this time and must stay retracted until the surface 88 of the left mandrel half 82 moves beyond the upper surface of the upper dielectric tape 26, as illustrated in FIG. 14. The left-hand mandrel half 82 is then ready to be moved axially into a position adjacent to the right-hand mandrel half 83 with the tapes 22, 23, 26 and 27 therebetween, as illustrated in FIG. 15.

At this time, the turret 31 has already indexed the particular spindle 46 into the winding station 47 and the turret 31 is stationary. Therefore, motivating means other than the cam 148 is necessary to move the left mandrel half 82 axially into operating position. This is accomplished by the use of a bell crank 159 and cam follower 155 operated by a two-step barrel cam 160 secured to the cam shaft 51 (FIG. 13). The cam 160 and bell crank 159 control the movable cam section 149 of the left cam 148 to the right and permit the tension spring 143 associated with the left mandrel housing 43 to pull the left mandrel housing 43 axially toward the associated right mandrel housing 43.

Just prior to the limit of travel of the left mandrel half 82 to the right, the axial movement of the left mandrel half 82 is interrupted and the cam 142 is rotated counterclockwise, as viewed in FIGS. 7 and 12, which is opposite to the direction the turret 31 is indexed. This moves the lobe 141 on the cam 142 out of engagement with the associated follower tail 147, which permits the compressed rubber washers 137—137 to move the associated mandrel half 82 transversely toward the then stationary right-hand mandrel half 83 to clamp the taps 22, 23, 26 and 27 therebetween, as illustrated in FIGS. 16 and 21. The cam 142 is oscillated by a cam 161 (FIG.

11), a cam follower **162**, an arm **163**, mounted pivotably on a pivot pin **166**, an adjustable linkage **167**, and an arm **168**, keyed to the cam shaft **138**. The cam follower **162** is held against the surface of the cam **161** by a tension spring **171**.

After the tapes **22**, **23**, **26** and **27** are clamped between the mandrel halves **82** and **83**, as illustrated in FIGS. 16 and 21, the cam **160** moves the section **149** of the cam **148** further to the right, to permit the associated spring **143** to move the left chuck **108** and associated left mandrel half **82** axially a short distance to the right to seat the free ends of the left mandrel half **82** and right mandrel half **83** into substantially complementary shaped recesses **173—173** in the chucks **108—108** supporting the associated mandrel halves **82** and **83**, as illustrated in FIG. 17.

The tape supply unit **28** (FIG. 4) includes a plurality of supply stands, designated generally by the numerals **176**, **177**, **178** and **179**. The supply stands **176** and **177** are provided with spool holders, designated generally by the numerals **181** and **182**, for rotatably supporting spools **183** and **184** of the dielectric tapes **26** and **27**, all respectively, and are provided with mechanical tensioning brakes, designated generally by the numerals **186—186**. The spool holders **181** and **182**, for the dielectric tapes **26** and **27**, are identical in construction except for the fact that they are of opposite hand. The supply stands **178** and **179** include two spool holders, designated generally by the numerals **187** and **188**, for rotatably supporting spools **191** and **192** of the conductive tapes **22** and **23**, and are provided with electromechanical-tensioning units, designated generally by the numerals **193** and **196**, all respectively.

The spools **183**, **184**, **191** and **192** are each held removably on arbors **197—197** (FIG. 24) of the holders **181**, **182**, **187** and **188** against the adjacent faces of accurately positioned, back-up gauge plates **198—198** by split, externally knurled, internally tapered lock bushings **201—201** and hand knobs **202—202**. Compression-spring washers **203—203** are placed in annular recesses **204—204** in the plates **198—198** behind each of the split bushings **201—201** to permit the cops on which the tapes are wound to project inwardly beyond the faces of the gauge plates **198—198** and to facilitate removal of the supply spools **183**, **184**, **191** and **192** from the supply holders **181**, **182**, **187** and **188**. The internally tapered bushings **201—201** are urged on frustoconically shaped bushings **200—200**, formed integrally with the plates **198—198** and keyed to the arbors **197—197**, by washers **199—199** and the knobs **202—202** against the actions of the spring washers **203—203**.

The arbors **197—197**, associated with the supply stands **176** and **177**, are connected to brake drums **212—212** of the friction brakes **186—186** which control the tensions in the tapes **26** and **27**. Substantially uniform tensions are maintained in the tapes **26** and **27** by passing the tapes **26** and **27** over pulleys **206—206** (FIG. 4), on free ends of arms **209—209** of bell cranks, designated generally by the numerals **207—207**, and connecting an adjustable constant-tension spring **208** (FIG. 4) in one of a series of interconnected apertures **210—210** (FIG. 25) in each of the other arms **214—214** of the bell cranks **207—207**. If the torque applied to the associate bell crank **207** by the tape **26** or **27** exceeds the torque applied to the associated bell crank **207** by the associate constant-tension spring **208**, a shoe, designated generally by the numeral **211**, of the brake **186**, is urged away from the drum **212** of the brake **186** secured to the back of the gauge plate **198**.

Brake linings **215—215** on the brake shoes **211—211** are substantially triangularly shaped and the shoes **211—211** are secured pivotably to the free ends of the associated arms **214—214** of the bell cranks **207—207**. Relatively weak springs **213—213** are secured to the bell cranks **207—207** and pivot the brake shoes **211—211** to maintain the pointed ends or the apexes **216—216** of the triangularly shaped brake linings **215—215** in engagement with the adjacent surfaces of the brake drums **212—212** to prevent the brakes **186—186** from grabbing when additional force is applied on the brake shoes **211—211** by the springs **208—208**. When the brake linings **215—215** of the brake shoes **211—211** are urged, at a uniform rate, against the drums **212—212** of the brakes **186—186** with additional force, the frictional forces are increased at a constantly increasing rate, as a result of the triangular shape of the brake linings **215—215**. The rate at which the frictional forces are increased may be varied by varying the included angle at the apex **216** of the brake lining **215**. Since the wear on the apexes **216—216** of the brake linings **215—215** will be the greatest, the brake linings **215—215** are thicker at the apexes **216—216** than at the bases **219—219** of the triangles.

Lateral registration of the tapes **22**, **23**, **26** and **27** is controlled by curved tape guides, designated generally by the numerals **217—217** (FIGS. 4, 22 and 23). Each of the tape guides **217—217** includes a plurality of idler rollers **218—218** mounted rotatably in jeweled bearings **221—221** having their axes of rotation oriented in an arcuately shaped path, in a pair of parallel plates **222—222**. A surface **220** on one of the plates **222—222** of each of the guides **217—217** is used to control the lateral position of one edge of the associated tapes **22**, **23**, **26** or **27**. The lateral position of the opposite edge of the particular tape **22**, **23**, **26** or **27** is controlled by a surface **223** of an L-shaped member, designated generally by the numeral **226**, having a series of apertures **227—227** in a leg **228** thereof positioned in an arcuate path. The L-shaped member **226** is secured to a block **229**, which is mounted on an adjustable, frictionless ball support, designated generally by the numeral **230**, on each side thereof. The block **229** is biased away from the surface **220** of the plate **222** by a spring **232** and is secured in a fixed position by a set screw **233**. The associated idler rollers **218—218** extend through the apertures **227—227** to permit the L-shaped member **226** to be moved longitudinally of the rollers **218—218**, with respect to the guiding surface **220** of the associated plate **222**, when different widths of tapes **22**, **23**, **26** or **27** are used.

Accurate adjustment of the guiding surface **223** of the L-shaped member **226** with respect to the guiding surface **220** of the plate **222** is accomplished by loosening the set screw **233** and moving the L-shaped member **226** toward or away from the surface **220** of the plate **222** by turning a knob **234** on a micropositioning device, designated generally by the numeral **235**, and then securing the block **229** in place by the set screw **233**. The positioning of the guiding surface **220** may be adjusted with respect to the associated gauge plate **198** by loosening a set screw **237**, which secures the guide **217** to a pivot pin **236**, and moving the guide **217** along the pivot pin **236**. The orientation of the arcuate paths defined by the guide rollers **218—218** may be changed by pivoting the guide **217** about the pivot pin **236**. The guides **217—217** prevent the path of travel of the tapes **22**, **23**, **26** and **27**, entering the winding station **47**, from varying as a result of variations in the diameter of the supply spools **183**, **184**, **191** and **192** during the operation of the winding apparatus **20**.

The upper dielectric tape **26** is directed from the pulley **206** over the associated, adjustable tape guide **217**, and partially around, under and in engagement with a first roller **246** of a set of guide rollers **245**, **246** and **247** and then over the second guide roller **247** and under the guide roller **245** (FIG. 4). The lower dielectric tape **27** is directed over the associated, adjustable tape guide **217**, over a pair of freely rotatable guide rollers **248** and **249**, which are mounted oscillatably on an arm **251** of a bell crank, designated generally by the numeral **252**, and then

between the two foil tapes 22 and 23 passing under the rollers 245 and 246 and over the roller 247.

The spool holders 187 and 188 for the conductive tapes 22 and 23, respectively, are secured to arms 253—253, mounted pivotably on the plates 42—42 of the frame 32, and the spools 191 and 192 rest on endless, drag belts 256 and 257. The drag belts 256 and 257 extend between pulleys 258—258 geared to drag-cup, hysteresis brakes 261 and 264, illustrated schematically on FIG. 32, and freely rotatable pulleys 262—262 mounted on belt-tensioning devices, designated generally by the numerals 263—263. The belt-tensioning devices 263—263 control the contours of the belts 256 and 257 to give the desired degree of contact with the outer peripheries of the outer convolutions of the conductive taps 22 and 23 wound on the spools 191 and 192. The lengths of conductive tapes being wound in each of the capacitors 21—21 can be measured by connecting a counter 266 to each of the pulleys 258—258 or the pulleys 262—262.

The conductive tapes 22 and 23 are directed through the separate, adjustable guides 217—217, used to adjust the lateral registration of the conductive tapes 22 and 23 with respect to each other and the dielectric tapes 26 and 27 during the winding operation. The conductive tape 22 is directed under and in engagement with a pair of spaced rollers 267 and 268, past an active, foil-cutting device, designated generally by the numeral 271, and between the two dielectric tapes 26 and 27. The conductive tape 23 is guided directly, from the associated guide 217, to and in engagement with the roller 247 so that the conductive tape 23 is positioned between the lower dielectric tape 27 and the roller 247.

The active, foil-cutting device 271, positioned along the path of travel of successive sections of the conductive tape 22 between the spool holder 187 and the winding turret 31, includes a split vacuum chuck or vacuum head, designated generally by the numeral 272 (FIGS. 4 and 26). A solenoid-operated blade 273 is mounted reciprocably in a slot 276 in the vacuum head 272. A vacuum system, illustrated schematically on FIGS. 30 and 31 and designated generally by the numeral 277, including a motor-driven vacuum pump 278, a manifold (not shown) with a regulating valve (not shown) and a solenoid-operated valve 282 (FIG. 31), is connected to the vacuum head 272 (FIGS. 4 and 26).

The vacuum system 277 causes differential air pressures to exist on opposite sides of a section of the conductive tape 22 extending past the vacuum head 272, during a predetermined interval in the winding cycle, so that a section of the conductive tape 22 is held against apertured plates 280—280 in the face of the split vacuum head 272 which extend transversely of the tape 22 of opposite sides of the slot 276 in the vacuum head 272. While a section of the conductive tape 22 is held against the apertured plates 280—280, in the split vacuum head 272, a solenoid 283 is energized to move the blade 273 through the slot 276 in the vacuum head 272 transversely of the tape 22 to cut the conductive tape 22 at a desired instant, as determined by the measured length of he conductive tape 22 in the partially wound capacitor 21, by a counted number of convolutions of the tape 22 in the capacitor 21, or by a measured capacitance of the capacitor 21.

A limit switch 286 (illustrated schematically on FIG. 30) is positioned adjacent to the blade 273 so that, upon completion of the active, foil-cutting motion, a solenoid 287 (FIGS. 10 and 31) is energized which, in turn, trips a manually operable latch 288 to remove the latch 288 from a notch 285 in a stop wheel 290. The removal of the latch 288 from the notch 285 in the stop wheel 290 permits the single-revolution clutch 57 to rotate and set all of the above-described mechanical motions into operation. As the winding operation continues, the new trailing end of the foil tape 22 is withdrawn from the left side of the vacuum head 272 (FIG. 4), but the new leading end of the foil tape 22 is secured to the right side of the vacuum head 272. The partially wound capacitor 21 is then indexed into the sealing station 48.

During the indexing of the mandrel 86 from the winding station 47 to the heat-sealing station 48 (FIGS. 2 and 4), the two cam-operated, lower rollers 248 and 249, over which the lower dielectric 27 is guided, are urged by a cam 289, a cam follower 294 and a linkage 295, intermeshedly with the two upper guide rollers 267 and 268, under which the foil tape 22 is guided, to "S" wrap the new leading end of the foil tape 22 and refeed the leading end of the foil tape 22 forward to the winding station so that when the mandrel halves 82 and 83 of an empty mandrel 86 arrive at the winding station 47 and are clamped in place at a subsequent time, the new leading ends of both of the metal-foil tapes 22 and 23 are clamped between the mandrel halves.

A deflectable plate or platform 300 (FIG. 4), made of a strip of resilient metal, is secured at one end of a rigid shoe 301, positioned between the winding station 47 and the heat-sealing station 48 (FIG. 2), so that the tapes 22, 23, 26 and 27 are drawn relatively tightly against the upper surface of the resilient platform 300 when the partially wound capacitor 21 is indexed from the winding station 47 to the heat-sealing station 48. A vacuum head 302 is secured adjustably to the shoe 301 between the free end of the platform 300 and the axis of rotation of the mandrel 86 in the winding station 47. A stationary grounded-foil cutting blade 303 is mounted below the tapes 23, 26 and 27, adjacent to the path of travel of the span of the tapes 23, 26 and 27 between the guide roller 245 and the partially wound capacitor 21 positioned in the heat-sealing station 48. The grounded-foil cutting blade 303 is secured adjustably to the vacuum head 302 on the side thereof adjacent to the shoe 301. The vacuum head 302 is connected to the vacuum system 277 so that a section of the grounded-foil tape 23 is pulled against the face of an apertured plate on the adjacent side of the vacuum head 302, during the same time a section of the active-foil tape 22 is held against the vacuum head 272.

Simultaneously, a cam 309 permits a spring 312 to pull a pivotally mounted clamping roller 307, positioned above the platform 300, downwardly into engagement with the upper surface of the upper dielectric tape 26. The spring 312, acting through a rod 308, secured to a pivotally mounted cam follower 311, pulls the roller 307 downwardly and urges the dielectric tapes 26 and 27 and the grounded-foil tape 23 against the resilient platform 300, so that the free end of the spring platform 300, secured to the shoe 301, moves downwardly a sufficient distance below the cutting edge of the cutting blade 303 to cut the grounded-foil tape 23 but not enough to permit the cutting blade 303 to cut the dielectric tapes 26 and 27.

The contour of the cam 309 is such that after the foil tape 23 is cut by the blade 303, the clamping roller 307 is raised slightly so that the platform 300 deflects upwardly above the cutting edge of the blade 303; however, the portions of the tapes 26 and 27 are held flat by the roller 307 and maintained under tension during the cutting and sealing operation. The partially wound capacitor 21 is rotated to pull the new trailing end of the metal tape 23 toward the capacitor 21 while the brakes 261 and 264 on the metal-foil-tape supply units 178 and 179 prevent the new leading ends of the tapes 22 and 23 from being fed forwardly with the dielectric tapes 26 and 27 so that a section of the dielectric tapes will be provided which do not have any metal-foil tapes therebetween or on either side thereto.

The dielectric tapes 26 and 27 must be cut adjacent to the new leading ends of the foil tapes 22 and 23, after the dielectric tapes 26 and 27 have been utilized to move the new leading end of the foil tape 22 between the mandrel halves 82 and 83 of the succeeding winding man-

drel 86. This may be accomplished by providing a dielectric-tape cutting device, designated generally by the numeral 313 (FIG. 4), adjacent to the winding mandrel 86 positioned in the winding station 47 on the opposite side thereof from the entrance of the tapes 22, 23, 26 and 27 into the winding station 47.

A serrated, dielectric-tape cutter blade 316 is mounted pivotably on a rod pin 317, on which arms 318—318 supporting the roller 307 are pivoted, and is moved downwardly adjacent to the mandrel 86 in the winding station 47 with the clamping roller 307 by the spring 312. A solenoid 320 is mounted on one of the arms 318—318, supporting the roller 307, adjacent to the dielectric-tape cutter 313 to permit selective operation of the dielectric-tape cutter 313, at the desired instance during the winding operation, against the action of a tension spring 319.

When the serrated blade 316 is used to cut the dielectric tapes 26 and 27, the blade 316 engages and cuts the dielectric tapes 26 and 27, in a space between the grounded-metal-foil cutting blade 303 and the adjacent side of the shoe 301, after the new trailing end of the metal-foil tape 23 has been pulled ahead of this section. The dielectric-tape cutter 313 is used when it is desirable to have as short tabs of the tapes 22, 23, 26 and 27 as possible on the leading ends of the tapes to eliminate wrinkling of the tapes when the winding of a new capacitor 21 commences.

Since the metal-foil tapes 22 and 23 are not present between the dielectric tapes 26 and 27, on the outer convolutions of the dielectric tape wound on the capacitor 21, the ends of the tapes 26 and 27 can be secured to each other and to the remaining portion of the capacitor 21 by utilizing a combined clamping and heat-sealing unit, designated generally by the numeral 321 (FIGS. 27 and 28), to form a smear-type seal between the outer convolutions of tapes 26 and 27 and the rest of the capacitor 21.

The combined clamping and heat-sealing unit 321 is mounted on a carriage, designated generally by the numeral 322. A cam 323 (FIG. 27) is provided on the cam shaft 51. The carriage 322 is mounted slidably by a plurality of bushings 325—325 riding on a pair of spaced, stationary rods 330—330 secured to the frame 32. A plate 324 is secured pivotally at one end thereof on a pin 327, extending through a slot in a stationary block 328 secured to the frame 32. An arm 329 is secured rigidly to a pin 331 extending transversely of a slot in the opposite side of the block 328. An elongated arm 335 is secured rigidly to the opposite end of the pin 331 and is provided with a rotatable member 332, positioned between legs of a U-shaped element 333 depending from the carriage 322, on which the heat-sealing unit 321 is mounted. An adjustable linkage 334 is used to interconnect the free end of the arm 329 and the adjacent free end of the plate 324. The opposite side of the plate 324 is provided with a freely rotatable cam follower 336.

The carriage 322 is urged forwardly into the heat-sealing station 48 by a tension spring 337 extending between the frame 32 and the plate 324. The carriage 322 is moved rearwardly out of the heat-sealing station 48 by the cam 323 acting through the cam follower 336, the linkage 334, the arms 329 and 335 and the interconnecting pin 331.

The combined clamping and heat-sealing unit 321 (FIG. 28) is secured to a free, upwardly-projecting end of an arm 338 mounted pivotably, intermediate the ends thereof, on a free end of a plate 339 secured to the bottom of a platform 341 of the carriage 322. The opposite end of the arm 338 is urged upwardly toward the lower surface of the plate 339 by an adjustable leaf spring 342. The normal position of the combined clamping and heat-sealing unit 321 is adjusted by a spring-biased screw 343, positioned in a threaded aperture adjacent to the end of the arm 338 and abutting the plate 339.

As the carriage 322 is moved toward the heat-sealing station 48, the combined clamping and heat-sealing unit 321 is moved into engagement with the wound capacitor 21, positioned on the mandrel 86 in the heat-sealing station 48, and is held against the wound capacitor 21 by the force exerted thereon by the leaf spring 342 and the spring 337. The unit 321 when used as a clamp prevents the dielectric tapes 26 and 27 from unraveling when the dielectric tapes are cut immediately adjacent to the wound capacitor 21 by a dielectric-tape cutting device, designated generally by the numeral 344. A heating element 346 is mounted on the combined clamping and heat-sealing unit 321 to permit the unit 321 to be used to perform a smear-type seal on new trailing ends of the dielectric tapes 26 and 27 when the dielectric tapes 26 and 27 are cut adjacent to the mandrel 86 in the winding station 47 by the dielectric tape cutting device 313 (FIG. 4) on a pre-selected basis. The tip 347 of the combined clamping and heat-sealing unit 321 which is held against the capacitor 21 during the sealing cycle is made of a thin strip of Inconel steel. The tip 347 has a desired curvature to fit various sizes of capacitors 21—21.

A freely rotatable clamping roller 348 (FIG. 27) is supported at a free end of an arm 349 mounted pivotably on a pin 351 extending between plates 352 and 353 projecting upwardly from opposite sides of the platform 341 of the carriage 322. The lowermost position of the clamping roller 348 is controlled by an adjustable stop 354 mounted on the plate 352. When the carriage 322 is moved forwardly by the spring 337, the clamping roller 348 rides onto a shoulder 356 on the shoe 301. A leaf spring 357 is used to urge the roller 348 downwardly against the shoe 301 to clamp the dielectric tapes 26 and 27. The clamping roller 348 is used to prevent fly back of new leading ends on the dielectric tapes 26 and 27 when the tapes 26 and 27 are cut immediately adjacent to the partially wound capacitor 21, in the heat-sealing station 48. A thin, resilient metal deflector plate 358 is secured to the free end of the arm 349 and is used to flip the new leading ends of the dielectric tapes 26 and 27 away from a heat-sealing unit, designated generally by the numeral 359, and against the front of the shoe 301.

In the event that the tapes are cut by the cutter blade 316 (FIG. 4), the clamping roller 348 is also used to hold the new trailing ends of the tapes 26 and 27 against the shoe 301 to maintain the desired tension in the tapes 26 and 27 as the winding of the tapes continues during the heat-sealing operation to form the smear-type seal over a relatively large area of tapes 26 and 27 by the use of the combined clamping and heat-sealing unit 321.

The heat-sealing unit 359 (FIG. 28) is mounted on the platform 341 of the carriage 322 and projects forwardly therefrom adjacent to the capacitor 21 in the heat-sealing station 48. A heat-sealing tip 361 on the free end of the heat-sealing unit 359 is substantially cylindrical in shape and is heated by an electric heating element 362 which is connected to the tip 361, through a metallic member 363 which forms a radiator for heat as well as a heat sink. The metallic member 363 of the heat-sealing unit 359 is mounted rigidly on an upper hinge plate 364 with a piece of heat-insulating material 365, such as asbestos, therebetween. The upper hinge plate 364 is mounted pivotably at one end thereof by a pin 366, extending between two apertured, parallel ears 367—367 projecting upwardly from a metal block, designated generally by the numeral 368. The opposite end of the block 368 is provided with a downwardly projecting, apertured portion 369 and is mounted pivotably between two downwardly projecting, apertured ears 371—371, on a lower hinge plate 372, by means of a rod 373, keyed to the downwardly projecting, apertured portion 369 of the block 368. The lower hinge plate 372 is secured adjustably to the platform 341 of the

carriage 322. The rod 373 projects beyond the edge of the lower hinge plate 372 and an arm 374 is pinned to the rod 373. The opposite end of the arm 374 is provided with a freely rotatable roller 376 which is mounted for rotating and reciprocating motion in a slotted member 377 secured adjustably to a vertically reciprocating rod 378.

A tension spring 379 is secured to the opposite end of the lower hinge plate 372, extends through a slot 381 in the center of the block 368, and is attached to the forward end of the upper hinge plate 364 to urge the front of the upper hinge plate 364 downwardly against the upper end of an adjusting threaded stop 382, projecting upwardly from the block 368. A rectangular slide member 383 is formed on the front of the upper hinge plate 364 and depends into a slot 384 in the block 368. A spring-biased ball detent 386 projects into the slot 384, from the portion of the block 368 forming a wall of the slot 384. The ball detent 386 is held in a normal retracted position by the depending slide member 383.

When the vertical rod 378 is moved upwardly against the action of a tension spring 387 by a cam 388 acting through a bell-crank cam follower 389, the end of the arm, on which the roller 376 is mounted, is moved upwardly which, in turn, pivots the back of the block 368 upwardly and causes the free end of the heating unit 359 to move downwardly and forwardly in an arc having a center of curvature which coincides with the center of the rod 373. As the free end of the heating unit 359 moves forwardly and downwardly in an arc substantially chordally of the opposite side of the capacitor 21, positioned in the heat-sealing station 48, the tip 361 of the heating unit 359 strikes the upper front side of the capacitor 21 and is held against the capacitor 21 by the tension spring 379. As the tip 361 of the heating unit 359 continues its downward and forward movement, the spring 379 is strained and the upper hinge plate 364 is pivoted slightly with respect to the block 368 so that the tip 361 of the heating unit 359 moves circumferentially of the capacitor 21 through an approximately 60° arc, as illustrated in phantom lines on FIG. 28. As the tip 361 of the heating unit 359 moves forwardly, a pin 391, projecting laterally of the upper hinge plate 364, strikes an inclining camming surface 392 of a cam, designated generally by the numeral 393, mounted on the plate 353 of the carriage 322, which causes the front of the upper hinge plate 384 and the attached slide member 383 to move upwardly with respect to the block 368.

At this time, the ball detent 386 springs into the slot 384 under the end of the slide member 383 to lock the front end of the upper hinge plate 364 in the upper position, with respect to the adjacent end of the block 368. The slotted member 377 is then lowered and the tip 361 of the heating unit 359 is raised by the pivoting action of the block 368, so that the tip 361 of the heating unit 359 is raised a sufficient distance to clear the capacitor 21 and not damage the wound capacitor 21, when the heat-sealing unit 359 is retracted subsequently by the cam 323 (FIG. 27) moving the carriage 322 out of the heat-sealing station 48. When the heating unit 359 is retracted by moving the carriage 322 rearwardly, the pin 391, projecting from the upper hinge plate 364, strikes a declining camming surface 394 of the cam 393 so that the end of the slide member 383 is forced downwardly past the ball detent 386 and the free end of the upper hinge plate 364 is pulled downwardly against the upper end of the stop 382 by the tension spring 379. A deflector member 395 (FIG. 28) made of heat-resistant material, such as a fabric formed of glass fibers, is secured adjustably to the upper surface of the heating unit 359, by a screw 396, and depends downwardly therefrom to insure that the heating unit 359 does not strike the new leading edge of the dielectric tapes 26 and 27.

An alternative dielectric-tape cutting blade 396 (FIG. 27) is secured to the free end of one arm 397 of a bell crank, designated generally by the numeral 398, mounted pivotably on a hinge plate 399 secured to the upper surface of the platform 341 of the carriage 322. The cutter blade 396 may be activated selectively by a solenoid 404 acting on the free end of the other arm 405 of the bell crank 399. The blade 396 is held in a normal retracted position by a tension spring 410 secured to the platform 341 of the carriage 322.

A stripping device, designated generally by the numeral 414 (FIG. 4), is provided to hold the wound and sealed capacitor 21 while the mandrel halves 82 and 83 are retracted from the associated ends of the capacitor 21, by the action of the cams 148 and 157, as the turret 31 is indexed to move successive winding spindles 46—46 into the winding station 47. The stripping device 414 includes two cooperating, arcuately shaped, brass channel members, designated generally by the numerals 415 and 419, which have grooves 420–420 in the adjacent convex and concave sides thereof, respectively, formed by two beveled legs 425—425 of the channel members 415 and 419. The widths of the grooves 420—420 are at least as wide as the length of the longest capacitor 21 being wound, so that the capacitors 21—21 can slide along the grooves 420—420 in the channel members 415 and 419, as the turret 31 is indexed. The mandrel halves 82 and 83 are moved simultaneously apart axially of the capacitor 21 by the stationary cams 148 and 157 (FIG. 1) to remove the mandrel halves 82 and 83 from the capacitors 21—21 (FIGS. 2 and 18) and drop the wound and sealed capacitors 21—21 down the chute 87 and into a tray 430 (FIG. 1) to remove the wound and sealed capacitors 21—21 from the capacitor winding apparatus 20.

Control circuit and operation

The various electrically operated parts on the capacitor-winding apparatus 20 must be controlled to operate at proper times during the winding cycle, illustrated on the timing chart in FIG. 29, to insure that the value of the capacitance of the capacitor 21, being wound, is the desired value within narrow limits of tolerances. A stepping switch, designated generally by the numeral 401 (FIGS. 30, 31 and 32), programs a control circuit, designated generally by the numeral 400. Various switches on the apparatus 20 program the stepping switch 401 and insure that the electrical and mechanical operations are sequenced properly. At the end of each cycle of operation, the stepping switch 401 resets itself and starts a new cycle of operation.

The capacitor 21 may be wound to a predetermined length by measuring the length of the tapes 22 and 23 being wound with the length counter 266, may be wound to a predetermined number of turns by counting the number of revolutions of the winding mandrels 86—86 with a turns counter 402 (FIGS. 11 and 31) or may be wound to a predetermined value of capacitance as determined by a capacitance monitor, designated generally by the numeral 403 (FIGS. 30 and 31). The apparatus 20 has its greatest utility when the capacitor 21 is wound to a predetermined value of capacitance as determined by measuring the capacitance of the capacitor 21 during the winding operation. This is accomplished by grounding the supply spool 192 of the foil tape 23, by the use of brushes and slip rings (not shown) connected electrically to the associated gauge plate 198 (FIGS. 4 and 24), and insulating the other foil tape 22 electrically from the remainder of the apparatus 20 by preventing the foil tape 22 from contacting any grounded elements of the apparatus 20.

The capacitance monitor 403 (FIG. 30) is connected on one side to ground and is connected on the other side

to the foil tape **22** on the supply spool **191** by brushes and slip rings (not shown) on the associated gauge plate **198**. The capacitance monitor **403** will then indicate the capacitance of the capacitor **21** being wound. The capacitance monitor **403** includes a bridge circuit, designated generally by the numeral **406**, in which the capacitance of the capacitor **21** being wound, designated C_x, is included as one arm of the bridge. The equation for the bridge circuit **406**, at balance is:

$$\frac{R_1}{\frac{1}{jC_s}}=\frac{R_2}{\frac{1}{jC_x}}$$

$$\frac{R^1}{C_x}=\frac{R_2}{C_s}$$

from which

$$C_x=\frac{R_1}{R_2}C_s$$

When the ratio arms R_1 and R_2 are equal, C_s, the standard capacitance, should be equal to the desired capacitance C_x of the finished capacitor **21**. The output voltage e_O will be determined by the ratio of C_x to C_s, and will decay to zero when C_s and C_x are equal. If C_x is allowed to become larger than C_s, the output voltage will decay to zero as C_x approaches C_s, and the change phase by 180° and increase in amplitude as C_x gets larger. By utilizing this bridge circuit **406**, the capacitance monitor circuit **403** has been designed which will energize a relay **407** (FIG. 31) when C_x is equal to C_s. The energization of the relay **407** results in the closure of a normally open contact **405** and operation of the blade **273** (FIGS. 4, 26 and 31) which cuts the active foil tape **22** and fixes the value of capacitance of the finished capacitor **21**.

It should be understood that there is an inherent increase in the capacity of the capacitor **21** being wound after the active foil **22** has been severed, because the active-foil cutting blade **273** is approximately four inches from the capacitor **21** being wound. As the additional four inches of tape **22** is wound on the capacitor **21**, the capacitance of the capacitor **21** is increased by a determinable amount. The inherent increase in the capacity of the capacitor **21** can be measured and a lump sum of capacity may be added to the arm of the bridge circuit **406** (FIG. 30) containing C_x or the value of C_s may be reduced a corresponding amount to compensate for the inherent change in the capacity of the capacitor **21**.

The capacitance-monitor circuit **403** (FIGS. 30 and 31) uses solid-state devices, hence, there is no warm-up time required for the circuit to become stabilized. A relatively small, commercially available oscillator **408** (FIG. 30) is used to generate a one kc. signal. A portion of this signal is amplified by an amplifier **409** and used as the input voltage to the bridge circuit **406**. The output voltage e_O of the bridge circuit **406** is coupled to an emitter-follower stage **411**, which has an inherently high, input impedance and has a negligible loading effect on the bridge circuit **406**. e_O is then amplified by an amplifier **412** and coupled to a demodulator stage, designated generally by the numeral **413**, by a transformer, designated generally by the numeral **416**. The emitter-follower **411** is used to match the fairly low impedance of the demodulator **413** to the amplifier **412**. A reference voltage e_R is also obtained from the oscillator **408**, is amplified by an amplifier **417** and is coupled to the center tape **415** of the secondary of the transformer **416**. The output of the demodulator **413** is used to control a magnetic amplifier **421** which will cause the relay **407** to operate when the input voltage to the demodulator **413** is of the correct polarity and magnitude.

When the instantaneous bridge output voltage e_O is zero, during the positive half cycle of the reference voltage e_R, the instantaneous voltage at points **422** and **423** at the ends of the secondary winding of the transformer **416** will be equal and positive with respect to ground. A pair of diodes **424** and **425** will conduct and there will be a positive voltage developed at points **426** and **427** with respect to ground. If R_A and R_B are equal, the voltage at point **426** will be equal to that at point **427**, and there will be zero differential voltage e_D. On the negative half cycle of the voltage e_R, a pair of diodes **428** and **429** will conduct.

When a signal is present on the primary of the transformer **416**, the instantaneous voltage induced in the secondary of the transformer **416** will be such that the voltage at point **422** will be 180° out of phase with that at point **423**. Consider the case when both the amplified voltage e_O and voltage e_R are present simultaneously. The instantaneous voltage at points **422** and **423** will be the algebraic sum of the instantaneous amplified voltage e_O and voltage e_R. Assuming the voltage e_R is greater than the amplifier voltage e_O and C_s is greater than C_x, then the voltages e_O and e_R will be in phase with each other and the direct-current voltage developed at point **426**, with respect to ground, will now be greater than that developed at point **427**, with respect to ground, and there will be a differential voltage e_D developed, with the point **426** being positive with respect to the point **427**.

Since the voltage e_O is developed by the bridge circuit **406**, it will decay to zero at a bridge balance, and change phase by 180° as C_x becomes larger than C_s. If the demodulator circuit **413** is examined for this condition, using the same reasoning as before when C_s was larger than C_x, it can be shown that the differential voltage e_D will reverse in polarity as C_x becomes greater than C_s, and point **427** will become positive with respect to point **426**.

Since the magnetic amplifier **421** requires a small voltage with point **427** being positive with respect to point **426**, it would be necessary to go through the bridge balance condition to operate the magnetic amplifier **421** and obtain a resultant operation of the relay **407**. To permit the capacitance monitor **403** to respond to a null condition of the bridge circuit **406** rather than having to go through the null condition, resistor R_A and R_B are intentionally unbalanced. The value of the resistors R_A and R_B are set so that point **427** is sufficiently positive to cause the relay **407** to operate when the amplified voltage e_O on the primary of the transformer **416** is zero.

To commence the winding operation, a normally open "on" switch **436** (FIG. 30) is pressed to energize a relay **437** which, in turn, closes a pair of normally open contacts **438** and **439**, associated therewith. The closure of the contact **438**, which is connected in parallel with the switch **436**, permits the "on" switch **436** to be released without deenergizing the relay **437**. The closure of the normally open contact **439**, which is connected to a bus **441**, causes a red light **442** to be energized, indicating that a vacuum pump motor **440**, in the vacuum system **277**, is running and power is available to the remainder of the control circuit **400** connected between the bus **441** and a bus **445**.

The desired winding speed of the direct-current shunt-wound, variable-speed winding motor **102** (FIG. 32) is regulated by three potentiometers **443**, **444** and **446**. The speed of the winding motor **102** may be controlled selectively by placing a speed-selector switch, designated generally by the numeral **447**, in either the "fast," "slow" or "overwrap" position, or the speed may be controlled automatically by the remainder of the control circuit **400** by placing the speed-selector switch **447** in the "run" position. During normal automatic operation of the apparatus **20**, the selector switch **447** is set to the "run" position and the motor **102** rotates at a relatively slow speed, unless the speed is varied by inserting the potentiometer **444** and/or the potentiometer **446** into the armature circuit of the motor **102**.

A "reset" button **448** (FIG. 30) is pressed to reset

the stepping switch 401 if the switch 401 is not already in the "homing" position with each of various wipers 449—449 thereof on the first contact on the associated bank thereof. The stepping switch 401 is of the type which cocks itself when energized and steps to the next position when a coil 451 is deenergized. By pushing the "reset" switch 448 (FIG. 30), a normally closed contact 452 is opened and a normally open contact 453 is closed. The opening of the contact 452 disconnects the coil 451 of the switch 401 from the wiper 449 of bank 456 of the switch 401. The closure of the contact 453 causes a relay 455 to be energized which, in turn, causes associated normally open contacts 457 and 458 to be closed and associated normally closed contacts 461 and 462 to be opened. The closure of the contacts 457 and 458 causes the solenoid 451 of the stepper switch 401 to be energized to open a "homing" switch 463 and a "trigger" switch 464 and then be deenergized by the opening of the switches 463 and 464, successively, until the switch 401 is reset and the normally closed contacts of the "homing" switch 463 remain open in the fully reset position. The "reset" button 448 may then be released to permit the relay 455 to be deenergized and allow the contacts 457 and 458 to reopen and the contacts 461 and 462 to reclose. The apparatus 20 is then ready for automatic cycling.

A green pilot light 466 (FIG. 32) is connected to the first contact on bank 465 of the switch 401 and is energized at this time. Since the speed-selector switch 447 is set at the "run" position, during the normal operation thereof, a relay 467 is energized. The energization of the relay 467 causes a normally closed contact 468 to be opened and a pair of normally open contacts 471 and 472 (FIG. 31) to be closed so that a "run" switch 473 may be closed to energize the winding motor 102. The closure of the "run" switch 473 causes a relay 474 to be energized which, in turn, closes a normally open contact 476, associated therewith. The now-closed contact 476 is connected in parallel with the "run" switch 473 so that the "run" switch 473 may then be released and the winding motor 102 will continue to run after the "run" switch 473 has been opened.

The energization of the relay 474 also causes a normally open contact 477, associated therewith, to be closed which, in turn, energizes a relay 478 and causes the index-drive motor 56 to be energized. The energization of the relay 478 closes a normally open contact 482 (FIG. 32), associated therewith, which, in turn, energizes the armature circuit of the winding motor 102 through a silicon controlled rectifier 480. The rectifier 480, connected in the armature circuit of the winding motor 102, is controlled by both the potentiometer 443 and the potentiometer 446 which are connected through the now-closed, normally open contact 471, associated with the relay 467, and through the first contact of bank 484 of the stepping switch 401. Accordingly, the motor 102 will run at a relatively fast speed.

When the capacitance of the capacitor 21 being wound reaches approximately 80% of the desired number of turns or convolutions, as determined by the counter 402 (FIGS. 11 and 31), a normally open contact 486, associated therewith, is closed which, in turn, causes a relay 487 to be energized. The energization of the relay 487 causes a normally open, associated contact 488, connected to the second contact in bank 490 of the switch 401, to be closed causing the solenoid 451 (FIG. 30) of the stepping switch 401 to be energized through the normally closed contacts 461 and 462 of the relay 455, the normally open contact 477 of relay 474 and the closed "trigger" switch 464. The energization of the solenoid 451, of the stepping switch 401, causes the "trigger" switch 464 to open up which, in turn, causes each of the wipers 449—449 of the stepping switch 401 to step to the second contact on the associate bank thereof. This causes the green pilot light 466 (FIG. 32) to be deenergized

When the wiper 449 on the associated bank 484 of the stepping switch 401 steps off the first contact thereof, the fast potentiometer 446 is disconnected from the armature circuit of the winding motor 102 so that the motor 102 will start to rotate at a relatively slow speed. When the wiper 449 on an associated bank 494 (FIG. 31) of the switch 401 steps to the second contact thereof, a time-delay relay 491 is energized so that a normally open contact 493, connected to the second contact of the bank 490 of the switch 401, will be closed at a subsequent time. A relay 494 is energized through a bank 496 of the stepping switch 401. Because the relay 494 is bridged across the second, third, fourth, and fifth contacts of the bank 496 of the switch 401, which are made-before-break contacts, the relay 494 also remains energized during the next three steps of the wipers 449—449 of the switch 401.

The energization of the relay 494 closes a normally open contact 497, associated therewith, which is connected in series with the now-closed contacts 472 and 477 and the coil of the solenoid valve 282, associated wtih the vacuum head 272 (FIGS. 4 and 26) for the active foil tape 22. The actuation of the solenoid valve 282 results in a section of the active-foil tape 22 being drawn against the face of the split vacuum head 272. A relay 401 (FIG. 31) is energized through the second contact on a bank 502 of the switch 401 which results in a normally open contact 503, associated therewith, being closed to hold the relay 501 energized until disconnected subsequently by the opening of a normally closed contact 506 of a relay 509, connected to the eighth contact of the bank of the switch 401. The energization of the relay 501 results in a normally closed contact 507, associated therewith, being opened to remove power from the brake 261, associated with the active-foil-tape supply unit 178 (FIG. 4), to remove substantially all tension from the active-foil tape 22. A time-delay relay 508 (FIG. 32) is energized through the second contact of the bank 465 of the switch 401 and, after a 10-second interval, opens a normally closed contact 511 (FIG. 30), associated therewith, to stop the capacitor-winding apparatus.

When the capacitors 21—21 are wound a predetermined number of turns, as determined by the counter 402, the contact 405 (FIG. 31) is shorted out by a switch 513, and the delayed closing of the contact 493 of the relay 491 causing each of the various wipers 449—449 of the stepper switch 401 to step to the third contact on the associated bank thereof. However, when the winding is controlled by the capacitance monitor 403 (FIGS. 30 and 31), the switch 513 is left open. The time-delay relay 491 is set so that the contact 493 thereof closes in approximately three seconds but must have closed before the capacitance monitor 403 has measured full capacitance to prevent indexing of the turret 31 during deceleration of the winding spindle 46, in case of a shorted capacitor 21.

The time-delay relay 508 (FIG. 32) is set at approximately ten seconds to complete the winding of the slow winding cycle and stop the apparatus 20, in the event that the bridge circuit 406 cannot measure the true capacitance of the capacitor 21 due to a break in the foil tape 22 or 23. In that event, a normally open contact 516, associated with the relay 508, would be closed to energize a red light 517 which indicates to the operator that the apparatus 20 stopped because one of the foil tapes 22 or 23 was broken.

The closure of the contact 493 (FIG. 31) energizes the coil 451 (FIG. 30) of the switch 401 causing the "trigger" switch 464 thereof to operate which, in turn, causes each of the various wipers 449—449 of switch 401 to be stepped to the third contact on the associated bank of the switch 401. The stepping of the wipers 449—449 of the switch 401 causes a relay 518 (FIG. 31) to be energized through the bank 492 of the switch 401. The energization of the relay 518 causes a normally open contact 521, associated therewith, to be closed to energize

the solenoid 283, associated with active-foil cutter device 271, to move the active-foil cutter blade 273 through the slot 276 (FIGS. 4 and 26) in the vacuum head 272, transversely of the active-foil tape 22, to cut the section of the active-foil tape 22 being held against the face of the vacuum head 272. At the end of the stroke of the active-foil cutter blade 273, the cutter blade 273 contacts the normally closed limit switch 286 (FIG. 30), connected to the third contact on the bank 456 of relay 401, and causes the switch 286 to open. The opening of the switch 286 causes each of the various wipers 449—449 of the stepping switch 401 to step to the fourth contact on the associated bank thereof. As the winding operation continues, the new trailing end of the foil tape 22 is withdrawn from the left side of the vacuum head 272 (FIG. 4); however, the new leading end of the tape 22 is secured to the right side of the vacuum head 272.

When the wiper 449 on the bank 494 (FIG. 31) of the switch 401 steps to the fourth contact thereof, a relay 523 is energized. The energization of the relay 523 closes normally open contacts 526 and 527 thereof. The closure of the contact 527 resets the time-delay relay 508, and the closure of the contact 526 energizes the solenoid 287 which, in turn, withdraws the latch 288 (FIG. 10) from the notch 285 in the stop wheel 290, associated with the clutch 57, permitting the clutch 27 to rotate and the cam shaft 51 to start to turn. At the end of the clutch-releasing cycle, a limit switch 528, tripped by the latch 288, opens and causes each of the various wipers 449—449 of the stepping switch 401 to step to the fifth contact on the associated bank of the switch 401.

As each of the various wipers 449—449 of the switch 401 steps to the fifth contact on the associated bank thereof, the cam shaft 51 continues to rotate and the relay 523 is deenergized. The deenergization of the relay 523 opens the contacts 526 and 527. The opening of the contact 527 deenergizes the solenoid 287 permitting the latch 288 to return to the stop wheel 290. The winding-stop latch 113 (FIG. 11) moves in and stops the winding mechanism. The stalled, slow-speed torque of the winding motor 102 holds the winding-index lock wheel 91 firmly against the latch 113. The end of the turret-index-locking bell crank 73 is moved out of engagement with the notch 78 in the stop wheel 81. The carriage 322 moves out of the sealing station 48 and the turret 31 is indexed to cause the grounded-foil tape 23 to be drawn across the platform 300. The winding-station-clamping roller 307 moves down to deflect the platform 300 and permit the blade 303 to cut the foil tape 23. The roller 307 moves upwardly and permits the platform to return to its normal position. The portions of the tapes 26 and 27 are held flat by the roller and maintained under tension during a subsequent tape-cutting and heat-sealing operation. The active-foil-clamping rollers 248 and 249 move up to refeed the new leading end of the foil tape 22 between the dielectric tapes 26 and 27.

Upon completion of the indexing of the turret 31 to the new position, the turret-index-locking crank 73 moves into one of the notches 78 in the wheel 81 to lock the turret 31 in the next position. The winding-stop latch 113 moves out and releases a limit switch 531 (FIG. 30), which is used to connect the fifth contact on the bank 456 of switch 401 to the bus 445. The switch 531 is then permitted to return to the normal position thereof which causes the coil 451 of the stepping switch 401 to be deenergized through the bank 456 thereof and each of the wipers 449—449 of the switch 401 to step to the sixth contact on the associated bank thereof. At the same time, the clutch 57 is stopped by the latch 288 (FIG. 10) and the cam shaft 51 stops turning.

The partially wound capacitor 21 is rotated to pull the new trailing end of the metal tape 23 toward the capacitor 21, while the brakes 261 and 264 on the metal-foil-tape supply units 178 and 179 prevent the new leading ends of the tapes 22 and 23 from being fed forwardly, to provide a section of the dielectric tapes 26 and 27 which do not have any metal-foil tape therebetween.

As the wiper 449 of the bank 496 (FIG. 31) of the stepping switch 401 steps to the sixth contact thereof, the relay 494 is deenergized to permit the contact 497 thereof to return to its normally open position. The opening of the contact 497 deenergizes the solenoid valve 282, on the vacuum heads 272 and 302, and closes the valve 282 to prevent the new leading ends of the active-foil tape 22 and the grounded-foil tape 23 from continuing to be held against the vacuum heads 272 and 302, respectively.

The potentiometer 444 (FIG. 32), connected to the control of the rectifier 480, is energized, through the sixth contact on the bank 484 of the switch 401, so that the potentiometers 443 and 444 are controlling the armature current of the drive motor 102. The mandrel 86 is then driven at an "over-wrapping" speed until a time-delay relay 532 (FIG. 31), connected to the sixth contact on the bank 492 of the switch 401, opens a normally closed contact 533 (FIG. 30), connected to the sixth contact on the bank 456 of the switch 401. This delayed opening of the contact 533 of the relay 532 causes each of the various wipers 449—449 of the stepping switch 401 to step to the seventh contact on the associated bank thereof which causes the relay 523 (FIG. 31) to be reenergized, through the bank 492 of the switch 401, to reclose the normally open contacts 526 and 527 (FIG. 32) of the relay 523. The movement of the wiper 449 from the sixth contact on the bank 484 of the switch 401 disconnects the potentiometer 444 from the armature circuit of the drive motor 102 and the motor starts running at a slow speed.

The closure of the contact 526 causes the solenoid 287 to be energized which, in turn, withdraws the latch 288 (FIG. 10) from the clutch 57 and the cam shaft 51 starts to rotate. The closure of the contact 527 resets the time-delay relay 508. The winding-stop latch 113 (FIG. 11) moves in to stop the winding mechanism and the mandrel halves 82 and 83 are indexed by the turret 31. The latch 113 strikes the limit switch 531 (FIGS. 11 and 30), connected to the seventh contact on the bank 456 of the stepping switch 401, to open and reset the switch 531 which causes each of the various wipers 449—449 on the stepper switch 401 to advance to the eighth contact on the associated bank thereof.

When the wiper 449 of the bank 494 (FIG. 31) of the stepping switch 401 steps to the eighth contact thereof, the relay 509 is energized to open the normally closed contact 506 and close a normally open contact 538. The closure of the contact 538 energizes a relay 539 which resets the turns counter 402. The opening of the contact 506 deenergizes the relay 501 which permits the contact 507 thereof to close and energize the coil of the brake 261 on the active-foil-tape supply unit 178. The relay 523 is also deenergized when the wiper 449 on the bank 492 is stepped off the seventh contact thereof to allow the normally open contact 526 to open and deenergize the turret release solenoid 287.

The various cams on the rotating cam shaft 51 cause the following actions to take place. As the turret 31 indexes a subsequent mandrel 86 into the winding station 47, the right mandrel housing 43 is returned to its normal position by the cam 157 (FIGS. 15 and 19), while the left mandrel housing 43 is held retracted by a movable section 149 of the left cam track 148 (FIGS. 1, 5, 7, 11 and 13). At this point, the cam 142 (FIGS. 7 and 12) on the shaft 138, extending into the hollow shaft 36 from the left end thereof, as viewed in FIG. 5, has pushed the left, mandrel-housing guide track 131 outward against the force of the compressed rubber washers 137—137 (FIG. 12). The left mandrel-housing spindle 46 is pivoted, on the rod 124, a small distance away from its normal axis of rotation (FIGS. 14 and 19). The split mandrel halves 82 and 83 in both mandrel housings 43—43 are phased by the winding-stop latch 113 (FIG. 11).

The cam 160 (FIG. 13) and the bell crank 159 control the movable section 149 of the left cam track 148 and permit the associated extension spring 143, in the slot 146 in the left barrel 37, to pull the left mandrel housing 43 toward the associated right mandrel housing 43. Just prior to the homing of the left mandrel half 82, in the chuck 108 of the associated right mandrel half 83, as illustrated in FIG. 15, this movement is interrupted by the dwell of the cam follower 155. Backward rotation of the cam shaft 138, by the cam 161 (FIG. 11), permits the rubber washers 137—137 to return the left mandrel half 82 to its normal axial position and the gap between the right mandrel half 83 and left mandrel half 82 is reduced to clamp the tapes 22, 23, 26 and 27 (FIGS. 16 and 21) in preparation for a subsequent winding operation. The homing movement of the left mandrel half 82 is resumed and the mandrel halves 82 and 83 of the spindles 46—46 located in the winding station 47 are each seated in a recess 173 in the chuck 108 of the associated mandrel half 82 or 83 (FIG. 17). The homing of the left mandrel half 82 opens a limit switch 541 (FIGS. 13 and 30) connected to the eighth contact on the bank 456 of the switch 401 which causes each of the various wipers 449—449 of the switch 401 to step to the ninth contact on the associated bank thereof.

With the tapes 22, 23, 26 and 27 secured in between the mandrel halves 82 and 83 in the winding station 47, the cam 323 (FIG. 27), on the cam shaft 51, causes the carriage 322 to move into the heat-sealing station 48 and close a limit switch 543 (FIGS. 27 and 30). The switch 543 may be connected selectively in series with the solenoid 320, connected to the dielectric-tape cutting blade 316, or in series with the solenoid 404, connected the blade 396, or in series with both of the solenoids 320 and 404, connected in parallel, depending in which operating position a pair of switches 544 and 545 are placed. The closure of the limit switch 543 causes the solenoid 320 and/or the solenoid 404 to be energized to oscillate the dielectric-tape cutting blade 316 and/or the blade 396 across the path of travel of successive sections of the dielectric tapes 26 and 27 extending from the supply units 176 and 177 to the substantially completely wound capacitor 21, positioned on the mandrel halves 82 and 83 which are located in the heat-sealing station 48. If both of the blades 316 and 396 are used to cut the tapes 26 and 27, the switch 546 is closed to actuate a solenoid valve 547 connected to a vacuum unit 550 (FIG. 2), which sucks the loose pieces of the tapes 26 and 27 out of the apparatus 20.

The dielectric tapes 26 and 27 are cut adjacent to the new leading ends of the foil tapes 22 and 23, after the dielectric tapes 26 and 27 have been utilized to move the new leading end of the foil tape 22 between the mandrel halves 82 and 83 of the succeeding mandrel 86 in the winding station 47. The tapes 26 and 27 may be cut adjacent to the winding mandrel 86, positioned in the winding station 47, on the opposite side thereof from the entrance of the tapes 22, 23, 26 and 27 into the winding station 47, by the blade 316 of the cutter 313 (FIG. 4) when the switch 543 is closed by the carriage 322 (FIGS. 27 and 28) moving into the heat-sealing station 48, provided that the normally open switch 544 (FIG. 30), in series with the solenoid 320, has been closed previously. The dielectric-tape cutter 313 is used when it is desirable to have as short tabs of tapes 22, 23, 26 and 27 as possible on the leading ends of the tapes to eliminate wrinkling of the tapes when the winding of a new capacitor 21 commences.

Simultaneously, with the cutting of the dielectric tapes 26 and 27, the carriage (FIGS. 27 and 28) is moved toward the heat-sealing station 48, the combined clamping and heat-sealing unit 321, mounted on the carriage 322, is moved into engagement with the capacitor 21, positioned on the mandrel 86 in the heat-sealing station, and is held against the wound capacitor 21 by the leaf

spring 342 and the spring 317. The clamp prevents the dielectric tapes 26 and 27 from unraveling when the dielectric tapes are cut immediately adjacent to the wound capacitor 21 by the dielectric-tape cutting device 344. The heating element 346 is provided, on the combined clamping and heat-sealing unit 321, to permit the unit 321 to be used selectively to form a smear-type seal between the outer convolutions of the tapes 26 and 27 and the remainder of the capacitor 21, when the tapes 26 and 27 are cut by the dielectric-tape cutter 313. This is accomplished by closing a switch 548 (FIG. 32) in series with the heating element 346.

When the carriage 322 is moved forwardly, the clamping roller 348 rides onto the shouder 356 on the shoe 301 and clamps the dielectric tapes 26 and 27 against the shoe 301 to prevent fly back of the new leading ends of the dielectric tapes 26 and 27 when the tapes are cut by the cutting unit 344. The clamping roller 348 is also used to hold the ends of the tapes 26 and 27 against the shoe 301 to maintain the desired tension in the tapes 26 and 27 as the winding of the tapes continues during the heat-sealing operation performed by the combined clamping and heat-sealing unit 321. When the tapes 26 and 27 are cut with the cutting unit 344, the metal deflector plate 358 flips the new leading ends of the dielectric tapes 26 and 27 away from the heat-sealing unit 359 and against the end of the shoe 301.

When it is desirable to use the heat-sealing unit 359, a switch 549 (FIG. 32), in series with the heating element 362, is closed. The free end of the heating unit 359 is moved downwardly and forwardly in an arc having a center of curvature which coincides with the center of the rod 373 (FIGS. 27 and 28). The deflector member 395 insures that the heat-sealing unit 359 does not strike the new leading ends of the dielectric tapes 26 and 27. As the free end of the heating unit 359 moves forwardly and downwardly in an arc substantially chordally of the opposite side of the capacitor 21, positioned in the heat-sealing station 48, the tip 361 of the heating unit 359 strikes the upper front side of the capacitor 21 and is held against the capacitor 21 by the tension spring 370. As the tip 361 of the heating unit 359 continues its downward and forward movement, the spring 379 is strained and the upper hinge plate 364 is pivoted slightly with respect to the block 368 so that the tip 361, of the heating unit 359, moves circumferentially of the capacitor 21 through an approximately 60° arc, as illustrated in phantom lines on FIG. 28, to seal the trailing ends of the dielectric tapes 26 and 27 to the body of the capacitor 21.

As the tip 361 of the heating unit 359 moves forwardly, the pin 391, projecting laterally of the upper hinge plate 364, strikes the inclining camming surface 392 of the cam 393, mounted on the plate 353 of the carriage 322, which causes the front of the upper hinge plate 384 and the attached slide member 383 to move upwardly with respect to the block 368. At this time, the ball detent 386 springs into the slot 384, under the end of the slide member 383, to lock the front end of the upper hinge plate 364 in the upper position, with respect to the adjacent end of the block 368.

When the slotted member 377 is lowered, the tip 361 of the heating unit 359 is raised by the pivoting action of the block 368. The tip 361 of the heating unit 359 is raised a sufficient distance to clear the capacitor 21 and not damage the wound capacitor 21, when the heat-sealing unit 359 is retracted subsequently by the cam 323 (FIG. 27) moving the carriage 322 out of the heat-sealing station 48. When the heating unit 359 is retracted by moving the carriage 322 rearwardly, the pin 391 projecting from the upper hinge plate 364 strikes the declining camming surface 394 of the cam 393 so that the end of the slide member 38 is forced downwardly past the ball detent 386 and the free end of the upper hinge plate 364 is pulled downwardly against the upper end of the stop 382 by the tension spring 379. In the

event that it is not desirable to use the heat-sealing unit **359**, the cam follower **389** is rendered inactive.

The active-foil-clamping rollers **248** and **249** (FIG. 4) return from the refeeding position to the normal position thereof. The latch **73** (FIG. 10) returns and trips a limit switch **551** (FIGS. 10 and 30), connected to the ninth contact on the bank **456** of the switch **401**, which causes each of the various wipers **449—449** of the switch **401** to step to the tenth contact on the associated bank thereof. Because the remaining contacts on the bank **456** of the switch **401** are not connected electrically to the remainder of the circuit **400**, the stepping switch **401** resets itself by continuing to step the various wipers **449—449** thereof until they reach the first contact on the various banks thereof.

During the automatic resetting of the switch **401**, the cam shaft **51** causes the winding-stop latch **113** (FIG. 11) to move out and the winding motor **102** starts to wind at a relatively slow speed. The rotation of the cam shaft **51** is stopped by the latch **288** (FIG. 10) engaging the notch **285** in the stop wheel **290**. The winding motor **102** (FIG. 32) continues to rotate at the relatively slow speed until the stepping switch **401** has reset its wipers **449—449** to the associated first contacts on the various banks thereof, at which time the winding motor **102** will run at a relatively fast speed and the various cycles of operation wil be repeated.

The stripping or removal of the previously wound capacitor **21** from the associated mandrel halves **82** and **83** is performed during the indexing of the turret **31**. The mandrel halves **82** and **83** being indexed to the stripping station **49** (FIG. 2) are pulled out of the capacitor **21** simultaneously as the capacitor **21** is moved through the cooperating channels. The stripped capacitor **21** slides down the chute **87** (FIG. 18) and is discharged into the tray **430** (FIG. 1).

The apparatus **20** is capable of winding extended-foil, tubular capacitors **21—21** of increased quantities, of higher reliability and of longer life, at reduced costs. For example, the capacitors **21—21** may include two strips of lead-tin-foil tapes **22** and **23** separated electrically by the two dielectric tapes **26** and **27**. One example of a capacitor wound with the apparatus **20** is formed of ¼-mil lead-tin-foil tape and ½-mil polystyrene tape. The lead-tin-foil tape extends about ⅛-inch beyond either side of the polystyrene tape. Another example of a similar capacitor is one wound with the same size ¼-mil lead-tin-foil tape and either 15-gauge, ¼-mil or 1-mil Mylar tape, with the Mylar tape being flush with the lead-tin-foil tape. The apparatus **20** is capable of winding capacitors having a controlled registration of the dielectric tapes and the lead-tin-foil tapes with either a positive or a negative extension of the foil tapes with respect to the dielectric tapes. The apparatus **20** is designed to wind capacitors of assorted dimensions. For example, capacitors from ¼ to ¾-inch diameters and ½ to 1⅜ inches long may be wound readily with the apparatus **20**. Winding speeds are adjustable within a range of approximately 700 to 2400 r.p.m.

Under normal operating conditions of the apparatus **20** and by means of the capacitor-monitoring circuit **403**, capacitors can be wound with the apparatus to ±0.05% of the desired capacitance 81% of the time, ±0.1% of the desired capacitance 96% of the time, and ±2% of the desired capacitance 100% of the time.

It should be understood that the mandrel halves **82** and **83** could be of the type which are removed from the spindles **46—46** and remain in the finished product. Accordingly, the mandrel halves **82** and **83** may be inserted into the spindles **46—46** by appropriate means (not shown), prior to the spindles **46—46** being indexed into the winding station **47**, and the spindles **46—46** would then be removed from the ends of the mandrel halves **82** and **83** in the stripping station **49**.

Although the term "tape" is employed in the specification and appended claims to define thin pieces of dielectric and metal materials, it should be understood that the term "tape" is meant to include any flexible film, strip, ribbon, strand, etc.

It is to be understood that the above-described arrangements are simply illustrative of the principles of the invention. Other arrangements may be devised by those skilled in the art which will embody the principles of the invention and fall within the spirit and scope thereof.

What is claimed is:

1. A method of winding interleaved layers of conductive and dielectric materials on successive mandrels formed of two mutually longitudinally and transversely movable, cooperating mandrel halves, which comprises:

supplying a plurality of indefinite lengths of interleaved layers of dielectric and conductive materials.

guiding the interleaved layers of conductive and dielectric materials to successive two-piece mandrels in a winding station,

indexing an empty two-piece mandrel into the winding station with one of the mandrel halves extending transversely across the path of travel of the interleaved layers while holding one of the mandrel halves retracted from its normal position extending across the normal path of travel of the interleaved layers so that the extended mandrel half strikes the interleaved layers and holds the interleaved layers in a position to be clamped between the two cooperating mandrel halves,

moving the retracted mandrel half longitudinally into an extended position across the path of travel of the interleaved layers,

causing relative transverse movement of the cooperating mandrel halves to clamp the interleaved layers therebetween,

rotating the mandrel in the winding station with the interleaved layers clamped therebetween to form a capacitor,

simultaneously monitoring the capacitance of the capacitor being wound, and

terminating the winding operation in response to the measurement of a predetermined capacitance of the capacitor being wound.

2. A method of winding interleaved layers of conductive and dielectric materials on successive mandrels formed of two mutually longitudinally and transversely movable, cooperating mandrel halves, which comprises:

supplying a plurality of indefinite lengths of dielectric and conductive tapes;

guiding the conductive tapes in interleaved relationship with the dielectric tapes to successive two-piece mandrels in a winding station;

indexing an empty two-piece mandrel into the winding station with one of the mandrel halves extending transversely across the path of travel of the tapes while holding one of the mandrel halves retracted from its normal position extending across the normal path of travel of the interleaved tapes so that the extended mandrel half strikes the interleaved types and holds the interleaved tapes in a position to be clamped between the two cooperating mandrel halves;

moving the retracted mandrel half longitudinally into an extended position across the path of travel of the interleaved tapes;

rotating the mandrel in the winding station with the interleaved layers clamped therebetween to form a capacitor;

simultaneously monitoring the capacitance of the capacitor being wound;

creating differential pressures on opposite sides of spaced, successive leading and trailing sections of one of the conductive tapes being fed to the mandrel in the winding station during a predetermined in-

terval of the winding cycle to support the spaced sections of the conductive tape;

cutting the portion of the one conductive tape extending between the supported, spaced, leading and trailing sections thereof in response to the measurement of a predetermined capacitance of the capacitor being wound;

severing the remaining tapes; and

terminating the capacitor-winding operation.

3. A method of winding interleaved layers of conductive and dielectric mateirals on successive mandrels formed of two mutually longitudinally and transversely movable, cooperating mandrel halves, which comprises:

supplying a plurality of indefinite lengths of dielectric and conductive tapes;

guiding the conductive tapes in interleaved relationship with the dielectric tapes to successive two-piece mandrels in a winding station;

indexing an empty two-piece mandrel into the winding station with one of the mandrel halves extending transversely across the path of travel of the tapes while holding one of the mandrel halves retracted from its normal position extending across the normal path of travel of the interleaved tapes so that the extended mandrel half strikes the interleaved tapes and holds the interleaved tapes in a position to be clamped between the two cooperating mandrel halves;

moving the retracted mandrel half longitudinally into an extended position across the path of travel of the interleaved tapes;

causing relative transverse movement of the cooperating mandrel halves to clamp the interleaved tapes therebetween;

rotatinng the mandrel in the winding station with the interleaved layers clamped therebetween to form a capacitor;

simultaneously monitoring the capacitance of the capacitor being wound;

creating differential pressures on opposite sides of spaced, successive leading and trailing sections of one of the conductive tapes being fed to the mandrel in the winding station during a predetermined interval of the winding cycle to support the spaced sections of the conductive tape;

cutting the portion of the one conductive tape extending between the supported, spaced, leading and trailing sections thereof in response to the measurement of a predetermined capacitance of the capacitor being wound; and

indexing the partially wound capacitor to a heat-sealing station while holding the new leading end of the one conductive tape by the differential pressure maintained on the previous trailing section thereof.

4. A method of winding interleaved layers of conductive and dielectric materials on successive mandrels formed of two mutually longitudinally and transversely movable, cooperating mandrel halves, which comprises:

supplying a plurality of indefinite lengths of dielectric and conductive tapes;

guiding the conductive tapes in interleaved relationship with the dielectric tapes to successive two-piece mandrels in a winding station;

indexing an empty two-piece mandrel into the winding station with one of the mandrel halves extending transversely across the path of travel of the tapes while holding one of the mandrel halves retracted from its normal position extending across the normal path of travel of the interleaved tapes so that the extended mandrel half strikes the interleaved tapes and holds the interleaved tapes in a position to be clamped between the two cooperating mandrel halves;

moving the retracted mandrel half longitudially into

an extended position across the path of travel of the interleaved tapes;

causing relative transverse movement of the cooperating mandrel halves to clamp the interleaved tapes therebetween;

rotating the mandrel in the station with the interleaved layers clamped therebetween;

simultaneously monitoring the capacitance of the capacitor being wound;

creating differential pressures on opposite sides of spaced, successive leading and trailing sections of one of the conductive tapes being fed to the mandrel in the winding station during a predetermined interval of the winding cycle to support the spaced sections of the conductive tape;

cutting the portion of the one conductive tape extending between the supported, spaced, leading and trailing sections thereof in response to the measurement of a predetermined capacitance of the capacitor being wound;

indexing the partially wound capacitor to a heat-sealing station while holding the new leading end of the one conductive tape by the differential pressure maintained on the previous trailing section thereof;

creating differential pressures on opposite sides of the other conductive tape to pull a section thereof against an associated cutting blade to cut the other conductive tape between the winding station and the heat-sealing station;

clamping the new leading end of the one conductive tape and an adjacent dielectric tape against each other so that the dielectric tape extending from the supply thereof to the partially wound capacitor in the heat-sealing station will pull the new leading end of the one conductive tape into the winding station;

rotating the mandrel in the heat-sealing station on which the partially wound capacitor is wound to wind the new trailing end of the other conductive tape on the body of the capacitor, to pull the new leading end of the one conductive tape into the winding station and to provide a length of the dielectric tapes which does not have a section of the conductive tapes immediately adjacent thereto;

cutting the dielectric tapes between the winding and heat-sealing stations after the dielectric tapes have been used to feed the new leading end of the one conductive tape into the winding station; and

heat-sealing the new trailing ends of the dielectric tapes to each other and to the body of the capacitor to prevent the trailing ends of the tapes in the capacitor from unraveling and to form a protective covering over the new trailing ends of the conductive tapes.

5. A method of winding interleaved layers of conductive and dielectric materials on successive mandrels formed of two mutually longitudinally and transversely movable, cooperating mandrel halves, which comprises:

supplying a plurality of indefinite lengths of dielectric and conductive tapes while controlling the tension thereof;

guiding the conductive tapes in interleaved relationship with the dielectric tapes to successive two-piece mandrels in a winding station;

indexing an empty two-piece mandrel into the winding station with one of the mandrel halves extending transversely across the path of travel of the tapes while holding one of the mandrel halves retracted from its normal position extending across the normal path of travel of the interleaved tapes so that the extended mandrel half strikes the interleaved tapes and holds the interleaved tapes in a position to be clamped between the two cooperating mandrel halves;

moving the retracted mandrel half longitudinally into an extended position across the path of travel of the interleaved tapes;

causing relative transverse movement of the cooperating mandrel halves to clamp the interleaved tapes therebetween;

severing any of the tapes extending beyond the mandrel positioned in the winding station to the body of a previously wound capacitor;

rotating the mandrel in the station with the new leading ends of the interleaved layers clamped therebetween to form a wound capacitor;

cutting a portion of the one conductive tape;

indexing the partially wound capacitor to a heat-sealing station;

cutting the other conductive tape between the winding station and the heat-sealing station;

clamping the new leading end of the one conductive tape and an adjacent dielectric tape against each other so that the dielectric tape extending from the supply thereof to the partially wound capacitor in the heat-sealing station will pull the new leading end of the one conductive tape into the winding station;

rotating the mandrel in the heat-sealing station on which the partially wound capacitor is wound to wind the new trailing end of the other conductive tape on the body of the capacitor, to pull the new leading end of the one conductive tape into the winding station and to provide a length of the dielectric tapes which does not have a section of the conductive tapes immediately adjacent thereto;

indexing an empty two-piece mandrel into the winding station with one of the mandrel halves extending transversely across the path of travel of the interleaved tapes while holding one of the mandrel halves retracted from its normal position extending across the normal path of travel of the tapes so that the extended mandrel half strikes the interleaved tapes and holds the interleaved tapes in position to be clamped between the two cooperating mandrel halves;

moving the retracted mandrel half longitudinally across the path of travel of the interleaved tapes;

causing relative transverse movement of the cooperating mandrel halves to clamp the interleaved tapes therebetween;

cutting the dielectric tapes between the winding and heat-sealing stations after the dielectric tapes have been used to feed the new leading end of the one conductive tape into the winding station;

clamping the new trailing ends of the interleaved tapes forming the capacitor against the body of the capacitor to prevent the new trailing ends of the interleaved tapes from becoming unraveled from the capacitor during a heat-sealing operation; and

heat-sealing the new trailing ends of the dielectric tapes to each other and to the body of the capacitor to prevent the trailing ends of the tapes in the capacitor from unraveling and to form a protective covering over the new trailing ends of the conductive tapes by moving a heat-sealing element substantially chordally of the body of the capacitor into engagement with the capacitor, then causing the heat-sealing element to move circumferentially of the capacitor to apply heat and pressure to a section of the capacitor and moving the heat-sealing element away from the body of the capacitor.

6. A method of winding interleaved layers of conductive and dielectric materials on successive mandrels formed of two mutually longitudinally and transversely movable, cooperating mandrel halves, which comprises:

supplying a plurality of indefinite lengths of dielectric and conductive tapes while controlling the tension thereof;

guiding the conductive tapes in interleaved relationship with the dielectric tapes to successive two-piece mandrels in a winding station;

indexing an empty two-piece mandrel into the winding station with one of the mandrel halves extending transversely across the path of travel of the tapes while holding one of the mandrel halves retracted from its normal position extending across the normal path of travel of the interleaved tapes so that the extended mandrel half strikes the interleaved tapes and holds the interleaved tapes in a position to be clamped between the two cooperating mandrel halves;

moving the retracted mandrel half longitudinally into an extended position across the path of travel of the interleaved tapes;

causing relative transverse movement of the cooperating mandrel halves to clamp the interleaved tapes therebetween;

severing any of the tapes extending beyond the mandrel positioned in the winding station to the body of a previously wound capacitor;

rotating the mandrel in the station with the new leading ends of the interleaved layers clamped therebetween to form a wound capacitor;

simultaneously monitoring the capacitance of the capacitor being wound;

creating differential pressures on opposite sides of spaced successive leading and trailing sections of one of the conductive tapes being fed to the mandrel in the winding station during a predetermined interval of the winding cycle to support the spaced sections of the conductive tape;

cutting the portion of the one conductive tape extending between the supported, spaced, leading and trailing sections thereof in response to the measurement of a predetermined capacitance of the capacitor being wound;

indexing the partially wound capacitor to a heat-sealing station while holding the new leading end of the one conductive tape by the differential pressure maintained on the previous trailing section thereof;

creating differential pressures on opposite sides of the other conductive tape to pull a section thereof against an associated cutting blade to cut the other conductive tape between the winding station and the heat-sealing station;

clamping the new leading end of the one conductive tape and an adjacent dielectric tape against each other in a tortuous path so that the dielectric tape extending from the supply thereof to the partially wound capacitor in the heat-sealing station will pull the new leading end of the one conductive tape into the winding station;

rotating the mandrel in the heat-sealing station on which the partially wound capacitor is wound to wind the new trailing end of the other conductive tape on the body of the capacitor, to pull the new leading end of the one conductive tape into the winding station and to provide a length of the dielectric tapes which does not have a section of the conductive tapes immediately adjacent thereto;

indexing an empty two-piece mandrel into the winding station with one of the mandrel halves extending transversely across the path of travel of the interleaved tapes while holding one of the mandrel halves retracted from its normal position extending across the normal path of travel of the tapes so that the extended mandrel half strikes the interleaved tapes and holds the interleaved tapes in position to be clamped between the two cooperating mandrel halves;

moving the retracted mandrel half longitudinally across the path of travel of the interleaved tapes;

causing relative transverse movement of the cooperating mandrel halves to clamp the interleaved tapes therebetween;

cutting the dielectric tapes between the winding and

heat-sealing stations after the dielectric tapes have been used to feed the new leading end of the one conductive tape into the winding station;

clamping the new trailing ends of the interleaved tapes forming the capacitor against the body of the capacitor to prevent the new trailing ends of the interleaved tapes from becoming unraveled from the capacitor during a heat-sealing operation; and

heat-sealing the new trailing ends of the dielectric tapes to each other and to the body of the capacitor to prevent the trailing ends of the tapes in the capacitor from unraveling and to form a protective covering over the new trailing ends of the conductive tapes by moving a heat-sealing element substantially chordally of the body of the capacitor to strike the capacitor, then moving the heat-sealing element circumferentially of the capacitor and moving the heat-sealing element away from the body of the capacitor.

7. A method of heat-sealing trailing ends of dielectric tapes to each other and to the body of a capacitor to prevent the trailing ends of the tapes in the capacitor from unraveling and to form a protective covering over the trailing ends of the conductive tapes, which comprises:

supporting a capacitor with dielectric tapes extending therefrom,

applying heat to the dielectric tapes and to the body of the capacitor adjacent to the ends of the dielectric tapes while simultaneously applying pressure substantially chordally of the body of the capacitor,

moving the application of heat circumferentially of the capacitor without rotating the capacitor while applying pressure radially of the body of the capacitor, and

removing the application of heat and pressure from the body of the capacitor.

8. Apparatus for winding automatically tubular capacitors formed of two or more strips of thin metal foil which are insulated from each other by two tapes of insulating material, which comprises:

means for supplying indefinite lengths of thin metal-foil tapes;

means for supply indefinite lengths of dielectric tapes;

an indexable turret including a plurality of rotatable winding mandrels, each of which is indexed successively through a winding station, a sealing station, and a capacitor-stripping station;

the mandrels each include a pair of mandrel halves which are on opposite sides of the turret, each of which cooperates with the associated mandrel half on the other side of the turret to form a complete mandrel on which the individual capacitors are wound and held until the mandrel haves are separated and the capacitors are removed therefrom in the stripping station;

means for rotating the mandrels to wind the tapes thereon to form capacitors;

means for measuring the electrical capacitance of the capacitor being wound during the winding cycle;

means for cutting one of the metal-foil tapes automatically in response to the measurement of the value of the electrical capacitance of the capacitor being wound;

means for cutting the other metal-foil tape automatically subsequent to the cutting of the one metal-foil tape;

means for cutting and heat-sealing the insulating tapes together and to the body of the capacitor as the insulating tapes are overwound on the capacitor to prevent the tapes from unwinding and to form a protective covering over the ends of the metal-foil tapes forming the plates of the capacitor;

heat-resistant means secured to the heat-sealing means for pushing the new leading ends of the insulating tapes away from the heat-sealing means; and

idler rollers for clamping the new leading end of the one metal-foil tape automatically against the adjacent dielectric tape so that the metal-foil tape is drawn by the adjacent dielectric tape attached to the newly wound capacitor, between the two mandel halves of a succeeding spindle positioned in the winding station.

9. Apparatus for winding automatically tubular capacitors formed of two or more strips of thin metal foil which are insulated from each other by two tapes of insulating material, which comprises:

means for supplying indefinite lengths of thin metal-foil tapes;

means for supplying indefinite lengths of dielectric tapes;

an indexable turret including a plurality of rotatable winding mandrels, each of which is indexed successively through a winding station, a sealing station, and a capacitor-stripping station;

the mandrels each include a pair of mandrel halves which are on opposite sides of the turret, each of which cooperates with the associated mandrel half on the other side of the turret to form a complete mandrel on which the individual capacitors are wound and held until the mandrel halves are separated and the capacitors are removed therefrom in the stripping station;

means for rotating the mandrels to wind the tapes thereon to form capacitors;

means for measuring the electrical capacitance of the capacitor being wound during the winding cycle;

means for cutting one of the metal-foil tapes automatically in response to the measurement of the value of the electrical capacitance of the capacitor being wound;

means for cutting the other metal-foil tape automatically subsequent to the cutting of the one metal-foil tape;

means for cutting and heat-sealing the insulating tapes together and to the body of the capacitor as the insulating tapes are overwound on the capacitor to prevent the tapes from unwinding and to form a protective covering over the ends of the metal-foil tapes forming the plates of the capacitor; and

a flexible resilient strip of metal to push the new leading ends of the insulating tapes away from the heat-sealing means.

10. Apparatus for winding capacitors of interleaved layers of dielectric and conductive tapes, which comprises:

means for supplying indefinite lengths of dielectric and conductive tapes;

a plurality of winding spindles;

a rotatable turret for mounting the winding spindles in spaced parallel relationship;

a plurality of mandrel halves mounted in the winding spindles, the mandrel halves being mounted mutually slidably longitudinally with respect to each other, and the mandrel halves on two adjacent spindles cooperating with each other to form a winding mandrel on which the conductive and dielectric tapes are wound to form a capacitor;

means for indexing the turret to successive positions for indexing each of the spindles successively into a capacitor-winding station, a heat-sealing station and a capacitor-stripping station and for indexing the two cooperating mandrel halves into positions on opposite sides of the path of travel of the tapes with the adjacent surface of the mandrel halves in spaced parallel relationship;

means for causing relative transverse movement of the two cooperating mandrel halves toward each other and into engagement with the tapes positioned therebetween to clamp the tapes between the mandrel halves in preparation for a winding operation;

means for rotating each of the mandrel halves at a variable speed;

spaced vacuum means for holding a section of one of

the foil tapes during a predetermined period of time;

cutting means movable between the spaced vacuum means for severing the metal-foil tape held against the spaced vacuum means when the capacitance of the capacitor being wound reaches a predetermined value;

means for cutting the insulation strips at a position between the two mandrels in the winding station and heat-sealing station immediately adjacent to the heat-sealing station;

automatic cutting means positioned along the path of travel of the tapes from the winding station to the heat-sealing station for cutting the other foil tape in advance of the cutting of the dielectric tapes so that the foil tapes wound on the mandrel are shorter than the dielectric tapes; and

means for heat-sealing the trailing ends of the dielectric tapes to the body of the capacitor.

11. Apparatus for winding capacitors of interleaved layers of dielectric and conductive tapes, which comprises:

means for supplying indefinite lengths of dielectric and conductive tapes;

a plurality of winding spindles;

a rotatable turret for mounting the winding spindles in spaced parallel relationship;

a plurality of mandrel halves mounted in the winding spindles, the mandrel halves being mounted mutually slidably longitudinally with respect to each other, and the mandrel halves on two adjacent spindles cooperating with each other to form a winding mandrel on which the conductive and dielectric tapes are wound to form a capacitor;

means for indexing the turret to successive positions for indexing each of the spindles successively into a capacitor-winding station, a heat-sealing station and a capacitor-stripping station and for indexing the two cooperating mandrel halves into positions on opposite sides of the path of travel of the tapes with the adjacent surface of the mandrel halves in spaced parallel relationship;

means for causing relative transverse movement of the two cooperating mandrel halves toward each other and into engagement with the tapes positioned therebetween to clamp the tapes between the mandrel halves in preparation for a winding operation;

means for rotating each of the mandrel halves independently at a variable speed and all of the mandrel halves in unison;

spaced vacuum means for holding a section of one of the foil tapes during a predetermined period of time interval;

cutting means movable between the spaced vacuum means for severing the metal-foil tape held against the spaced vacuum means when the capacitance of the capacitor being wound reaches a predetermined value;

means for gripping the newly formed free end of the foil tape and one of the dielectric tapes so that the new leading end of the metal tape is advanced by the dielectric tape into a predetermined position in proximity with the normal winding position;

means for cutting the insulation strips at a position between the two mandrels in the winding station and the heat-sealing station immediately adjacent to the winding station;

automatic cutting means positioned along the path of travel of the tapes from the winding station to the heat-sealing station for cutting the other foil tape in advance of the cutting of the dielectric tapes so that the foil tapes wound on the mandrel are shorter than the dielectric tapes; and

means for heat-sealing the trailing ends of the dielectric tapes to the body of the capacitor with a smear-type seal.

12. Apparatus for winding capacitors of interleaved layers of dielectric and conductive tapes with the edges of the conductive tapes extending beyond the edges of the dielectric tapes to form a mass of conductive material on each end of the capacitors to facilitate the formation of termination on the ends of the capacitors, which comprises:

means for supplying indefinite lengths of dielectric and conductive tapes;

a plurality of winding spindles;

a rotatable turret for mounting the winding spindles in spaced parallel relationship;

a plurality of mandrel halves mounted in the winding spindles, the mandrel halves being mounted mutually slidably longitudinally with respect to each other, and the mandrel halves on two adjacent spindles cooperating with each other to form a winding mandrel on which the conductive and dielectric tapes are wound to form a capacitor;

means for indexing the turret to successive positions for indexing each of the spindles successively into a capacitor-winding station, a heat-sealing station and a capacitor-stripping station;

means for guiding the conductive and dielectric tapes in interleaved relationship to one of the spindles positioned in the winding station with one edge of each of the conductive tapes extending beyond the edges of the dielectric tapes on each side of the composite strip;

means for indexing the two cooperating mandrel halves into positions on opposite sides of the path of travel of the tapes with the adjacent surface of the mandrel halves in spaced parallel relationship;

means for causing relative transverse movement of the two cooperating mandrel halves toward each other and into engagement with the tapes positioned therebetween to clamp the tapes between the mandrel halves in preparation for a winding operation;

means for rotating each of the mandrel halves independently at a variable speed and all of the mandrel halves in unison;

means connected electrically to said foil tapes for measuring the instantaneous, electrical capacitance of the capacitor being wound on each of the mandrels;

spaced vacuum means for holding a section of one of the foil tapes during a predetermined period of time;

cutting means movable between the spaced vacuum means for severing the metal-foil tape held against the spaced vacuum means when the capacitance of the capacitor being wound reaches a predetermined value;

means for gripping the newly formed free end of the foil tape and one of the dielectric tapes so that the new leading end of the metal tape is advanced by the dielectric tape into a predetermined position in proximity with the normal winding position;

means for cutting the insulation strips at a position between the two mandrels in the winding station and the heat-sealing station;

automatic cutting means positioned along the path of travel of the tapes from the winding station to the heat-sealing station for cutting the other foil tape in advance of the cutting of the dielectric tapes so that the foil tapes wound on the mandrel are shorter than the dielectric tapes; and

means for heat-sealing the trailing ends of the dielectric tapes to the body of the capacitor.

13. Apparatus for winding interleaved layers of conductive and dielectric materials on successive mandrels formed of two mutually longitudinally and transversely movable, cooperating mandrel halves, which comprises:

a plurality of winding mandrels, indexable individually into a winding station;

means for supplying a plurality of indefinite lengths

of dielectric and conductive tapes to the winding mandrels;

means for guiding the conductive tapes in interleaved relationship with the dielectric tapes to successive two-piece mandrels in a winding station;

means for controlling the tension in the tapes being supplied to the winding mandrels;

means for indexing an empty two-piece mandrel into the winding station with one of the mandrel halves extending transversely across the path of travel of the tapes while holding the other cooperating mandrel half retracted from its normal position extending across the normal path of travel of the interleaved tapes so that the extended mandrel half strikes the interleaved tapes and holds the interleaved tapes in a position to be clamped between the two cooperating mandrel halves;

means for moving the retracted mandrel half longitudinally into an extended position across the path of travel of the interleaved tapes and for causing relative transverse movement of the cooperating mandrel halves to clamp the interleaved tapes therebetween;

means for rotating the mandrel in the winding station with the new leading ends of the interleaved layers clamped therebetween to form a wound capacitor;

means for simultaneously monitoring the capacitance of the capacitor being wound;

means for creating differential pressures on opposite sides of spaced successive leading and trailing section of one of the conductive tapes being fed to the mandrel in the winding station during a predetermined interval of the winding cycle to support the spaced sections of the conductive tape;

means for cutting the portion of the one conductive tape extending between the supported, spaced, leading and trailing sections thereof in response to the measurement of a predetermined capacitance of the capacitor being wound;

a cutting blade;

means for creating differential pressures on opposite sides of the other conductive tape to pull a section thereof against the cutting blade to cut the other conductive tape between the winding station and the heat-sealing station;

means for clamping the new leading end of the one conductive tape and an adjacent dielectric tape against each other in a tortuous path so that the dielectric tape extending from the supply thereof to the partially wound capacitor in the heat-sealing station will pull the new leading end of the one conductive tape into the winding station;

means for rotating the mandrel in the heat-sealing station on which the partially wound capacitor is wound to wind the new trailing end of the other conductive tape on the body of the capacitor, to pull the new leading end of the one conductive tape into the winding station and to provide a length of the dielectric tapes which does not have a section of the conductive tapes immediately adjacent thereto;

means for cutting the dielectric tapes between the winding and heat-sealing station after the dielectric tapes have been used to feed the new leading end of the one conductive tape into the winding station; and

means for moving a heat-sealing element substantially chordally of the body of the capacitor to strike the capacitor, then moving the heat-sealing element circumferentially of the body of the capacitor to heat-seal the new trailing ends of the dielectric tapes to each other and to the body of the capacitor to prevent the trailing ends of the tapes in the capacitor from unraveling and to form a protective covering over the new trailing ends of the conductive tapes.

14. Apparatus for winding capacitors, which comprises:

a hollow shaft;

an indexable winding turret mounted rotatably on the hollow shaft;

a plurality of mandrel housings mounted pivotally and slidably in spaced parallel relationship on one side of the turret;

a plurality of mandrel housings mounted slidably in spaced, parallel relationship on the other side of the turret;

a plurality of mandrel halves mounted rotatably in the mandrel housings, each of the mandrel halves mounted rotatably in a mandrel housing mounted on one side of the turret cooperating with another one of the mandrel halves mounted rotatably in a corresponding one of the mandrel housings on the other side of the turret to form a mandrel on which a capacitor is wound;

a cam follower secured to the outer periphery of each of the mandrel housings;

a cam positioned adjacent to the path of travel of the cam follower for causing the mandrel housings to slide axially of the turret away from the cooperating mandrel housings;

a cam follower channel mounted in the turret adjacent to each of the mandrel housings on one side of the turret for reciprocation radially of the turret;

a second cam follower projecting from each of the mandrel housings on the one side of the turret into a camming groove formed in the associated camming channel;

a normally stationary, oscillatable cam mounted in the hollow shaft in the center of the turret and having a cam lobe projecting radially thereof in a predetermined section of the turret;

adjustable resilient means for securing each of the cam-follower channels in the turret;

cam-follower tails projecting from the cam-follower channels radially of the turret and being urged against the oscillatable cam by the adjustable resilient means;

means for indexing the turret to move successive mandrels with a wound capacitor thereon from a winding station and successive mandrels from which the capacitors have been removed into the capacitor-winding station;

resilient means for urging the cooperating mandrel housings toward each other so that as the empty mandrels are indexed into the winding station the slidable mandrel housing is moved axially into a winding position and after the mandrel is indexed into the winding station the pivotally and slidably mounted mandrel housing is moved axially into winding position;

the indexing of the turret causes the cam-follower tail associated with the pivotable and slidable mandrel housing being indexed into the winding station to ride upon the lobe of the stationary cam to urge the cam channel radially outwardly of the turret and cause the associated mandrel half to move transversely outwardly of the cooperating mandrel half; and

means for oscillating the cam to cause the mandrel half in the pivotable and slidable mandrel housing in the winding station to move transversely toward the cooperating mandrel half and clamp the tapes therebetween in preparation for a subsequent capacitor-winding operation.

15. Apparatus for winding capacitors, which comprises:

a rotatable winding turret;

a plurality of mandrel housings mounted pivotally and slidably in spaced parallel relationship on one side of the turret;

a plurality of mandrel housings mounted slidably in spaced parallel relationship on the other side of the turret;

a plurality of mandrel halves mounted rotatably in the mandrel housings, each of the mandrel halves mounted rotatably in the mandrel housings mounted on one side of the turret cooperating with one of the mandrel halves mounted rotatably in one of the mandrel housings on the other side of the turret to form a mandrel on which a capacitor is wound;

means positioned adjacent to the path of travel of the mandrel housing for causing the mandrel housings to slide axially of the turret away from the cooperating housings;

a cam follower channel mounted in the turret adjacent to each of the mandrel housings on one side of the turret for movement transversely of the turret;

a cam follower projecting from each of the mandrel housings on the one side of the turret into a camming groove formed in the associated camming channel;

a normally stationary cam mounted in the turret and having a cam lobe projecting radially thereof in a predetermined section of the turret;

means for urging the pivotably mounted mandrel housing laterally into a normal winding position;

means for indexing the turret to move successive mandrels with a wound capacitor thereon from a winding station and successive mandrels from which the capacitors have been removed into the capacitor winding station;

means for urging the cooperating mandrel housings toward each other so that as the empty mandrels are indexed into the winding station the slidable mandrel housing is moved axially into a winding position and after the mandrel is indexed into the winding station the pivotably and slidably mounted mandrel housing is moved axially into winding position;

the indexing of the turret causes the cam follower channel associated with one of the mandrel housings being indexed into the winding station to move outwardly of the turret by the lobe of the normally stationary cam and cause the associated mandrel half to move transversely outwardly of the cooperating mandrel half; and

means for moving the cam to cause the mandrel half in the pivotable and slidable mandrel housing in the winding station to move transversely toward the cooperating mandrel half and clamp the tapes therebetween in preparation for a subsequent capacitor winding operation.

16. Apparatus for winding capacitors, which comprises:

a rotatable winding turret;

a plurality of mandrel housings mounted pivotably and slidably in spaced parallel relationship on one side of the turret;

a plurality of mandrel housings mounted slidably in spaced parallel relationship on the other side of the turret;

a plurality of mandrel halves mounted rotatably in the mandrel housings, each of the mandrel halves mounted rotatably in the mandrel housings mounted on one side of the turret cooperating with one of the mandrel halves mounted rotatably in one of the mandrel housings on the other side of the turret to form a mandrel on which a capacitor is wound;

means positioned adjacent to the path of travel of the mandrel housing for causing the mandrel housings to slide axially of the turret away from the cooperating mandrel housings;

means for indexing the turret to move successive mandrels with a partially wound capacitor thereon from a winding station to a heat-sealing station, successive wound capacitors from the heat-sealing station to a capacitor stripping station, and successive mandrels from which the capacitors have been removed into the winding station;

means for urging the cooperating mandrel housings toward each other so that as the empty mandrels are indexed into the winding station the slidable mandrel housing is moved axially into a winding position and after the mandrel is indexed into the winding station the pivotably and slidably mounted mandrel housing is moved axially into winding position;

means for causing the mandrel half in the pivotable and slidable mandrel to move transversely outwardly of the cooperating mandrel half as the particular mandrel housing is indexed into the winding station by the turret; and

means for causing the mandrel half in the pivotable and slidable mandrel housing in the winding station to move transversely toward the cooperating mandrel half and clamp the tapes therebetween in preparation for a subsequent capacitor winding operation.

17. Apparatus for winding capacitors, which comprises:

a rotatable winding turret;

a plurality of mandrel housings mounted pivotably and slidably in spaced parallel relationship on one side of the turret;

a plurality of mandrel housings mounted slidably in spaced parallel relationship on the other side of the turret;

a plurality of mandrel halves mounted rotatably in the mandrel housings, each of the mandrel halves mounted rotatably in the mandrel housings mounted on one side of the turret cooperating with one of the mandrel halves mounted rotatably in one of the mandrel housings on the other side of the turret to form a mandrel on which a capacitor is wound;

a cam follower secured to the outer periphery of each of the mandrel housings;

a cam positioned adjacent to the path of travel of the cam follower for causing the mandrel housings to slide axially of the turret away from the cooperating mandrel housings;

cam follower means mounted in the turret and connected to each of the mandrel housings on one side of the turret for movement transversely of the turret;

a normally stationary, oscillatable cam mounted in the center of the turret and having a cam lobe projecting radially thereof in a predetermined section of the turret;

adjacent resilient means for securing each of the cam follower means in the turret to urge the cam follower means against the oscillatable cam;

means for indexing the turret to move successive mandrels with a capacitor wound thereon from a winding station and successive mandrels from which the capacitors have been removed into the winding station;

resilient means for urging the cooperating mandrel housings toward each other so that as the empty mandrels are indexed into the winding station the slidable mandrel housing is moved axially into a winding position and after the mandrel is indexed into the winding station the pivotably and slidably mounted mandrel housing is moved axially into winding position;

the indexing of the turret causes the cam follower means associated with one of the mandrel housings being indexed into the winding station to ride upon the lobe of the stationary cam to cause the associated mandrel half to move transversely outwardly of the cooperating mandrel half; and

means for oscillating the cam to cause the mandrel half in the pivotable and slidable mandrel housing in the winding station to move transversely toward the cooperating mandrel half and clamp the tapes therebetween in preparation for a subsequent capacitor-winding operation.

18. A device for heat-sealing trailing ends of dielectric tapes to a body of a capacitor, which comprises:

a carriage;

a pivot secured to the carriage;

means for mounting a capacitor adjacent to the pivot with the axis thereof parallel to the pivotal axis of the pivot;

a pivotable member secured pivotably at one end thereof to the pivot and projecting in a general direction away from the capacitor;

a pivotable plate secured pivotably at one end thereof to the other projecting end of the pivotable member, said pivotable plate projecting in a general direction toward the capacitor;

a heat-sealing unit secured to the pivotable plate and having an elongated heat-sealing tip mounted with its longitudinal axis parallel to the longitudinal axis of the capacitor, of the pivot and of the pivotal connection between the member and the plate, the tip projecting beyond the end of the pivotable plate generally toward and above the capacitor;

resilient means for urging the free end of the pivotable plate toward the carriage;

a cam follower element connected to and projecting from the free end of the pivotable plate;

cam means haivng inclining and declining camming surfaces positioned in the path of travel of the cam follower element;

means for oscillating the pivotable member about the pivot to move the heat-sealing tip out of its normal position, in an arcuate path extending substantially chordally of the upper and opposite side of the capacitor, and into engagment with the upper and opposite side of the capacitor, further movement of the heat-sealing tip by the oscillating means causing the resilient means to be strained to permit the free end of the pivotable plate to pivot away from the pivotable member and the heat-sealing tip to slide circumferentially along the opposite side of the capacitor in an arcuate path to heat-seal the trailing ends of dielectric tapes against the body of the capacitor, the cam follower element engaging the inclining camming surface to cause further pivoting movement of the free end of the pivotable plate with respect to the pivotable member against the action of the resillent means for moving the heat-sealing tip out of engagement with the capacitor;

means for locking the pivotable plate in the pivoted position until the cam follower element strikes the declining camming surface when the heat-sealing tip is retracted by the carriage so that the heat-sealing element will clear the capacitor as the tip is moved into its normally retracted position; and

means for retracting the carrriage from the capacitor so that the cam-follower element strikes the declining camming surface, to release the locking means, and forces the free end of the pivotable plate toward the pivotable member.

19. A device for heat-sealing trailing ends of dielectirc tapes to a body of a capacitor, which comprises:

a carriage;

a pivot secured to the carriage;

means for mounting a capacitor adjacent to the pivot with the axis thereof parallel to the pivotal axis of the pivot;

a heat-sealing unit secured pivotably to the pivot on the carriage and having an elongated heat-sealing tip mounted with its longitudinal axis parallel to the longitudinal axis of the capacitor, the tip projecting beyond the end of the carriage generally toward and above the capacitor;

resilient means for urging the free end of the heat-sealing unit toward the carriage;

means for oscillating the heat-sealing tip out of its normal position, in an arcuate path extending substantially chordally of the upper and opposite side of the capacitor and into engagement with the upper and opposite side of the capacitor, further movement of the heat-sealing tip by the oscillating means causing the resilient means to be strained to permit the free end of the heat-sealing unit to pivot away from the carriage and the heat-sealing tip to slide circumferentially along the opposite side of the capacitor in an arcuate path to heat-seal dielectric tapes against the body of the capacitor;

means responsive to further movement of the tip to pivot the heat-sealing unit further with respect to the carriage against the action of the resilient means for moving the heat-sealing tip out of engagement with the capacitor; and

means for locking the heat-sealing element in the pivoted position until the heat-sealing tip is retracted by the carriage so that the heat-sealing element will clear the capacitor as the tip is moved into its normally retracted position.

20. A device for heat-sealing trailing ends of dielectric tapes to a body of a capacitor, which comprises:

a frame;

a heat-sealing unit secured pivotably to the frame and having an alongated heat-sealing tip mounted with its longitudinal axis parallel to the longitudinal axis of the pivotal connection between the heat-sealing unit and the frame;

means for mounting a capacitor adjacent to the heat-sealing unit with the axis of the capacitor parallel to the pivotal axis of the heat-sealing unit so that the tip of the heat-sealing unit projecting generally toward and above the capacitor;

means for oscillating the heat-sealing tip out of its normal position, in an arcuate path extending substantially chordally of the upper and opposite side of the capicator and into engagement with the upper and opposite side of the capacitor, and for causing the heat-sealing tip to slide circumferentially along the opposite side of the capacitor in an arcuate path to heat-seal the dielectric tapes against the body of the capacitor; and

means for moving the heat-sealing tip out of engagement with the capicator so that the heat-sealing element will clear the capacitor as the tip is moved into its normally retracted position.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,278,130 October 11, 1966

Frederick J. Jannett

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

Column 4, line 18, for "thus" read -- the --; column 5, line 44, for "(FIGS. 7, 9 and 12)." read -- (FIGS. 7, 9 and 12), --; line 49, for "respectivey" read -- respectively --; column 6, line 73, and column 9, line 15, for "taps", each occurrence, read -- tapes --; column 10, line 47, and column 11, line 44, for "pivotally", each occurrence, read -- pivotably --; column 15, line 15, for "R^1" read -- R_1 --; line 27, for "the" read -- then --; column 16, line 60, after "direct-current" insert a comma; column 17, line 74, for "associate" read -- associated --; column 21, line 33, after "connected" insert -- to --; column 22, line 14, for "shouder" read -- shoulder --; line 72, for "38" read -- 383 --; column 25, line 11, for "mateirals" read -- materials --; line 35, for "rotatinng" read -- rotating --; line 75, for "longitudially" read -- longitudinally --; column 29, line 41, for "supply" read -- supplying --; column 33, lines 30 and 31, for "section" read -- sections --; column 34, lines 6, 53 and 73, for "pivotally", each occurrence, read -- pivotably --; column 36, line 49, for "adjacent" read -- adjustable --; column 37, line 26, for "haivng" read -- having --; line 33, for "engagment" read -- engagement --; lines 45 and 46, for "resillent" read -- resilient --; line 55, for "carrriage" read -- carriage --; column 38, line 29, for "alongated" read -- elongated --; line 48, for "capicator" read -- capacitor --; between lines 52 and 53, insert

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Signed and sealed this 5th day of September 1967.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

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Commissioner of Patents