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Karlson et al.

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[54] **COMPOSITE-TAPE PLACEMENT HEAD**

[75] Inventors: **Harald E. Karlson**, Santa Monica; **Ethridge E. Hardesty**, Pine Valley, both of Calif.

[73] Assignee: **Goldsworthy Engineering Inc.**, Torrance, Calif.

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[21] Appl. No.: **131,191**

[52] **U.S. Cl.** **156/363**, 156/353, 156/526

[51] **Int. Cl.** **B32b 31/00**

[58] **Field of Search** 156/353, 355, 523, 156/526, 527, 363, 522

[56] **References Cited**

UNITED STATES PATENTS

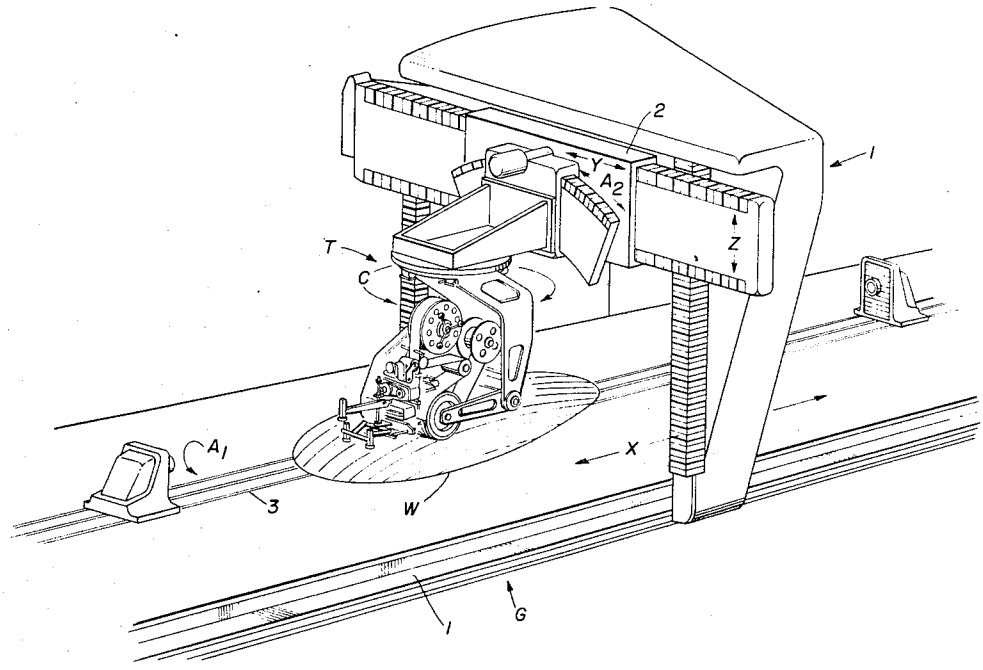
3,212,950	10/1965	Philippi	156/353
3,652,363	3/1972	Kinslow	156/355
3,523,053	8/1970	Zbinden et al.	156/523
3,625,799	12/1971	Way	156/523
3,404,060	10/1968	Taylor	156/526
3,577,303	5/1971	Buck	156/526
3,677,865	7/1972	Wagner	156/526
3,058,869	10/1962	Cohen et al.	156/527
3,573,135	3/1971	Cooper et al.	156/353

Primary Examiner—Norman G. Torchin
Assistant Examiner—Edward C. Kimlin
Attorney—Robert J. Schaap, Neal E. Willis and John D. Upham

[57] **ABSTRACT**

An integrally complete composite-tape placement head for direct attachment to a host gantry type of machine, which tape placement head is designed to precisely apply preimpregnated fiber reinforced tape to a work piece. The tape is initially supplied in the form of a roll with a suitable backing. The tape is automatically peeled from the backing by a separator mechanism and thereafter applied to the work piece. A powered cut-off device is actuated by a photoelectric mechanism to sever the tape at a proper location and at a preestablished angle. The determination of the pre-established angle is accomplished by a photoelectric edge sensing mechanism.

22 Claims, 11 Drawing Figures



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SHEET 1 OF 6

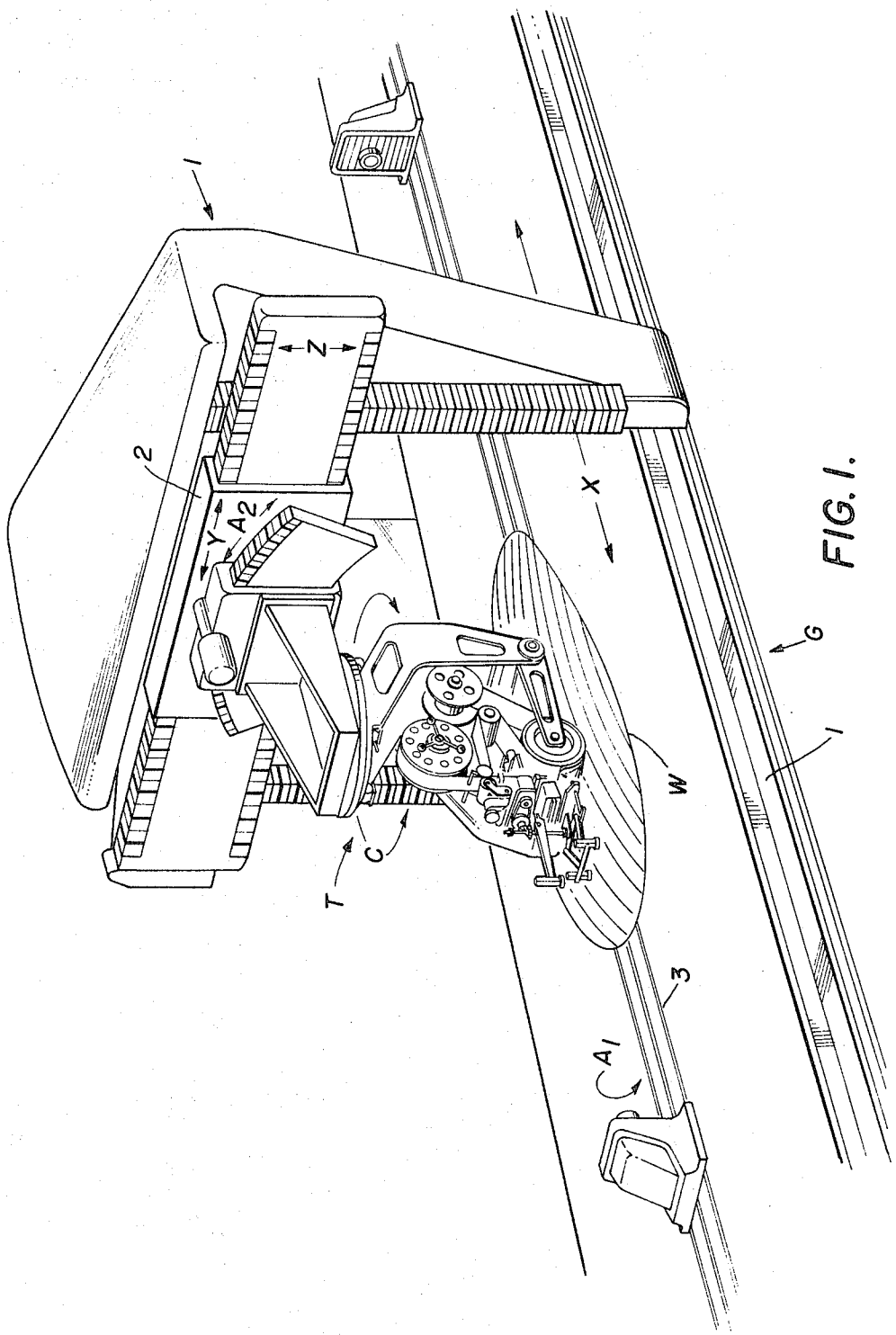


FIG. 1.

INVENTORS
HARALD E. KARLSON
ETHRIDGE E. HARDESTY

BY Robert J. Schaap

ATTORNEY

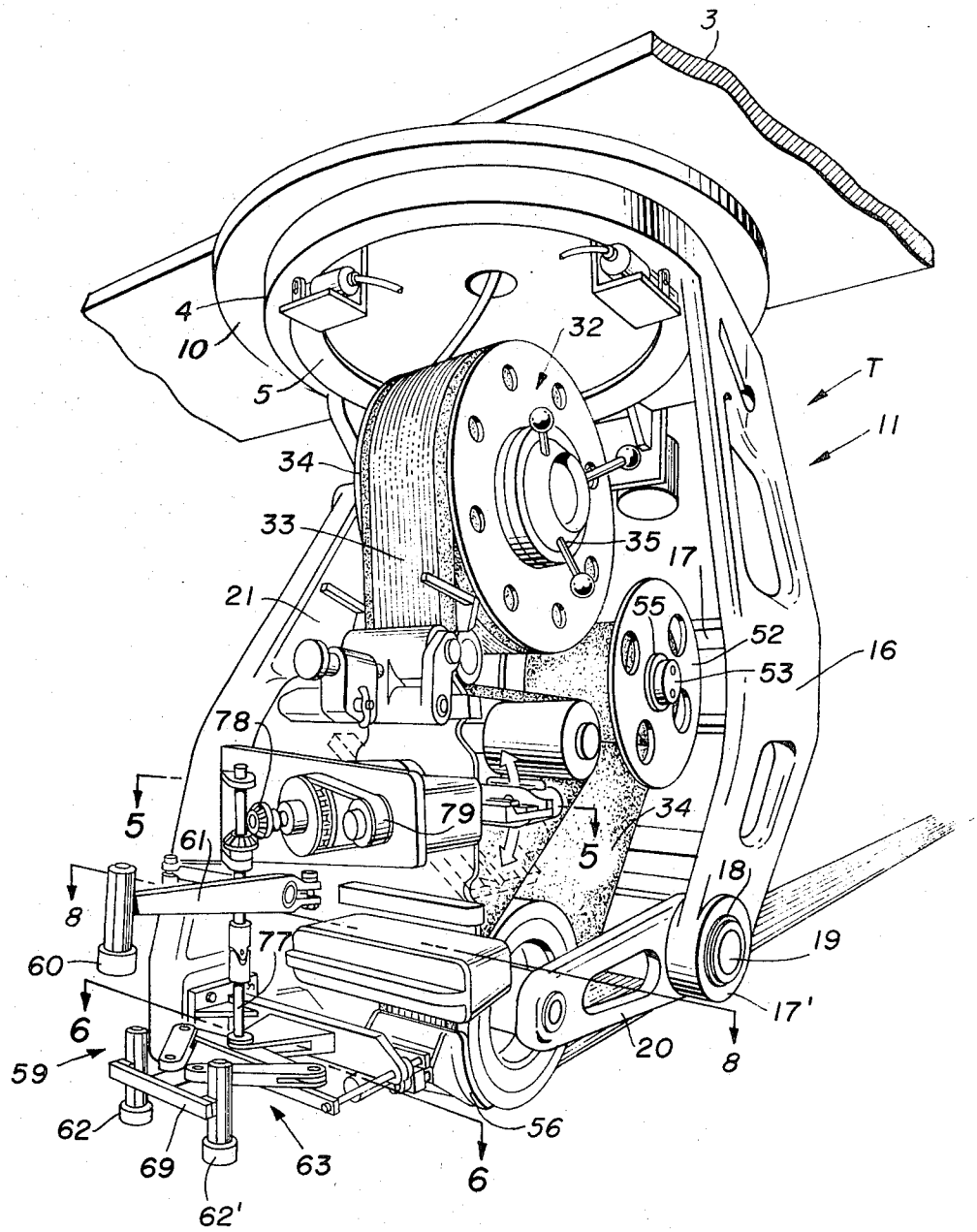


FIG. 2.

INVENTORS
HARALD E. KARLSON
ETHRIDGE E. HARDESTY
BY
Robert J. Schaap
ATTORNEY

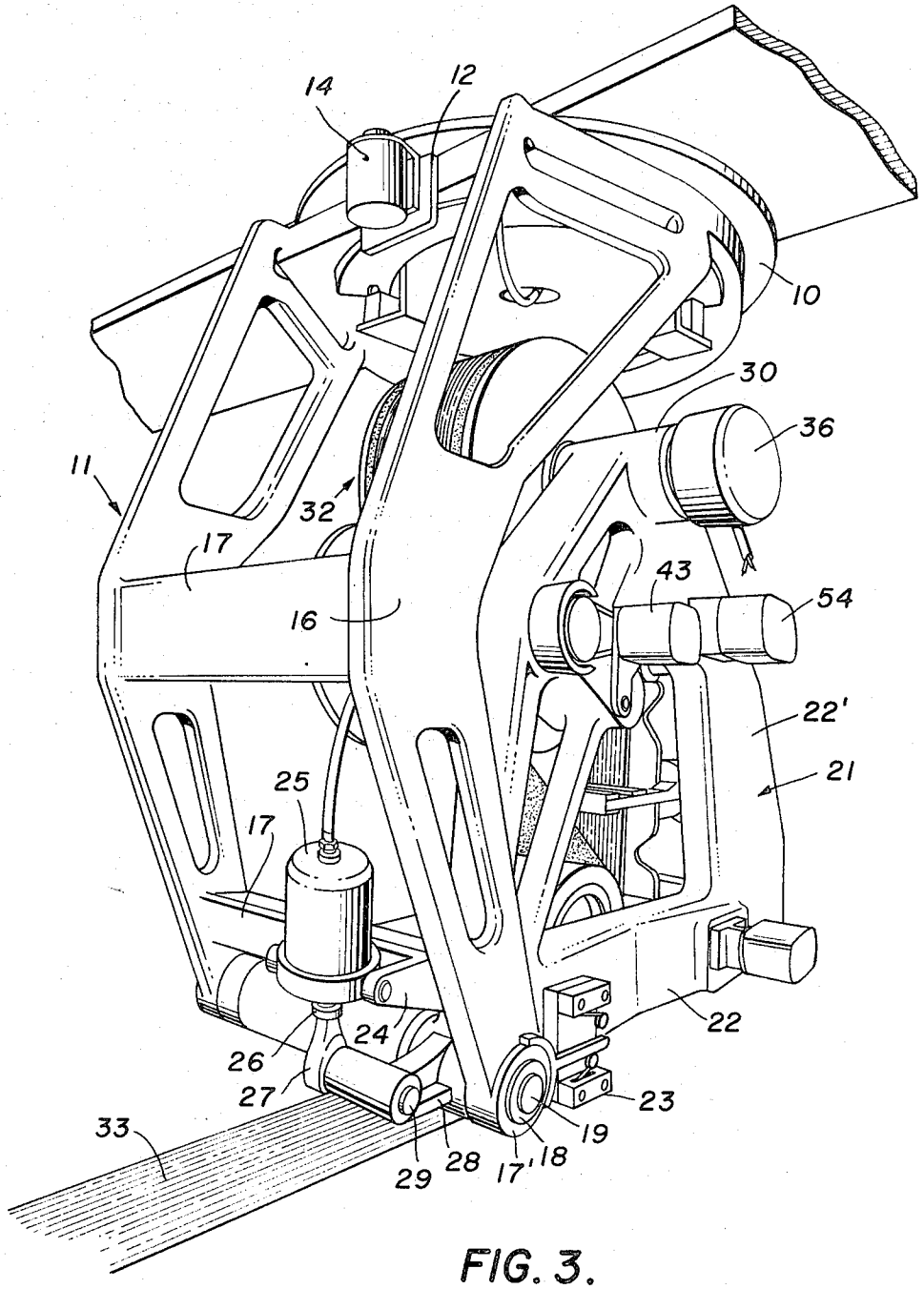


FIG. 3.

INVENTORS
HARALD E. KARLSON
ETHRIDGE E. HARDESTY
BY
Robert J. Schaap
ATTORNEY

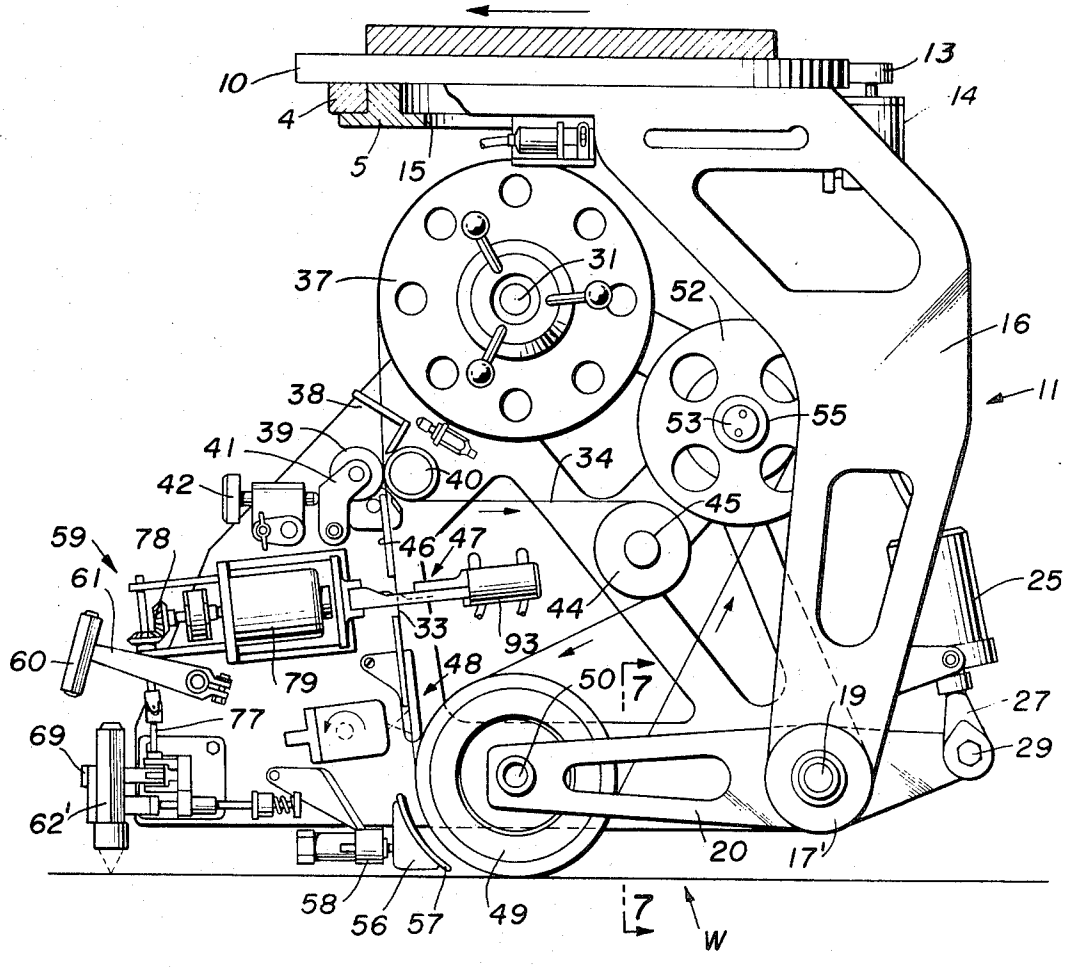


FIG. 4.

INVENTORS
HARALD E. KARLSON
ETHRIDGE E. HARDESTY

BY Robert J. Schaap

ATTORNEY

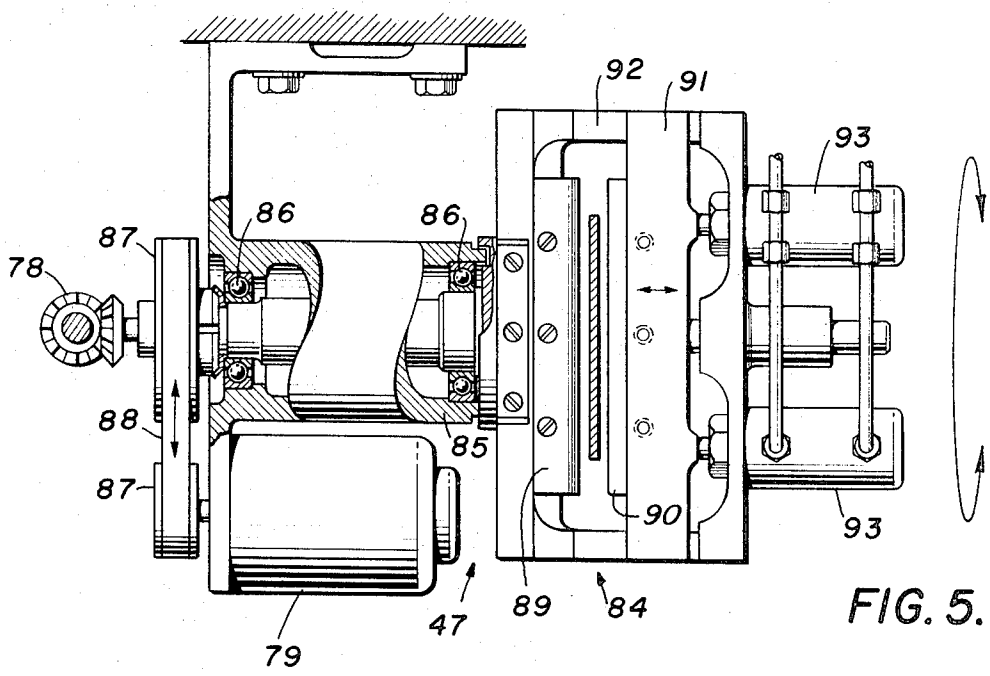


FIG. 5.

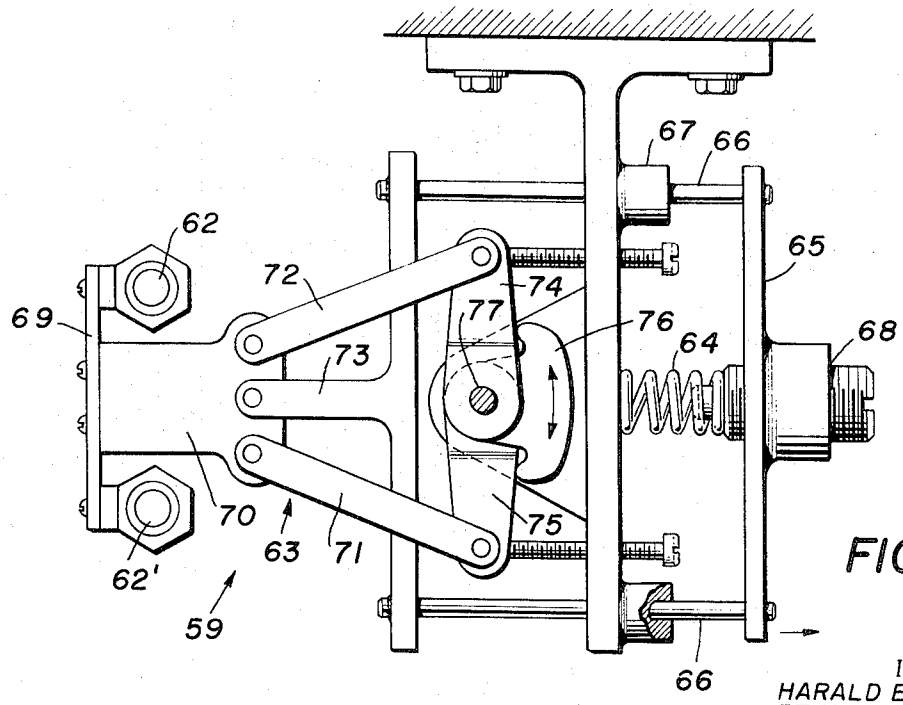


FIG. 6.

INVENTORS
HARALD E. KARLSON
ETHRIDGE E. HARDESTY
BY
Robert J. Schaap
ATTORNEY

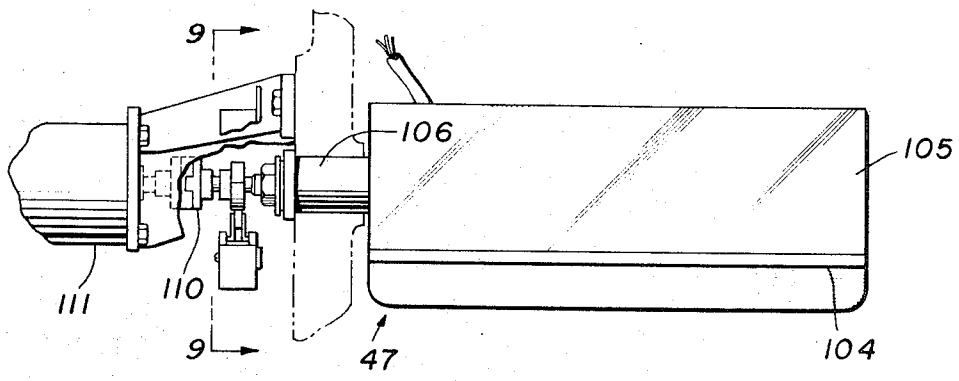


FIG. 8.

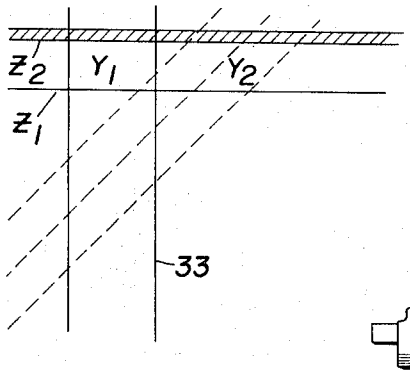


FIG. 10.

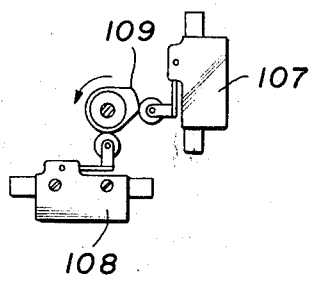


FIG. 9.

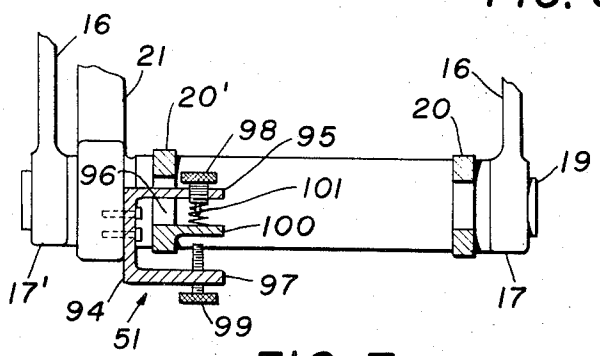


FIG. 7.

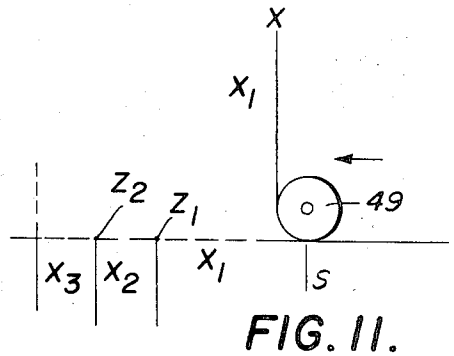


FIG. 11.

INVENTORS
HARALD E. KARLSON
ETHRIDGE E. HARDESTY

BY

Robert J. Schaap

ATTORNEY

COMPOSITE-TAPE PLACEMENT HEAD

BACKGROUND OF THE INVENTION

This invention relates in general to certain new and useful improvements in composite-tape placement heads, and more particularly, to composite-tape placement heads for direct attachment to actuating equipment.

In recent years, reinforced plastic composite materials have achieved increased prominence and have been used in the manufacture of a variety of products which are normally formed of heavy metals and other counterpart materials. For example, pipe, motor casings and various other types of structural members which were formerly fabricated from the heavy metals are now being produced in the form of reinforced plastics.

Many of the structural members used in the air frame industry are presently formed of aluminum and other light weight metals. However, there has also been a recent transition to the employment of reinforced plastic components. Conventional filament winding systems have been employed in the fabrication of these reinforced plastic components. In order to increase productivity in the manufacture of these components, resort has been made to the use of tape application equipment.

However, the extant tape laying equipment is ineffective in many cases because the filament reinforced tapes are often difficult to effectively handle due to their modulous of induced rigidity. Accordingly, the unspooling of a three inch tape, for example, presents considerable problems in maintaining proper tension on the tape as it is applied to the work surface. The convolute windings of the tape tend to expand and unwind in the manner of a released clock spring. The various tapes presently employed inherently have some variation in boardiness and tack and the lay down pressure on the work piece is not variable to adjust for these variations in the tape.

One of the most serious problems encountered in the use of the conventional presently available tape heads resides in the failure of the head to properly sever the tape at a desired location, and at a pre-selected angle with respect to the work piece.

It is, therefore, the primary object of the present invention to provide an integrally complete composite-tape placement head for direct attachment to other actuating equipment.

It is another object of the present invention to provide a tape placement head of the type stated which can be actuated both in cooperation with and independently of the host actuating equipment.

It is a further object of the present invention to provide a tape placement head of the type stated which is highly reliable in its operation and which can be used with a wide variety of reinforced plastic composite tapes.

It is another object of the present invention to provide a tape placement head of the type stated which includes all of the tape forwarding, tape-placement, backing-film retrieval, and tape-cut-off mechanical and drive functions.

It is yet another salient object of the present invention to provide a tape placement head of the type stated which is constructed with a high degree of precision and thereby provides an extremely close dimensional accuracy with minimal tolerances.

With the above and other objects in view, our invention resides in the novel features in form, construction, and arrangement of parts presently described and pointed out in the claims.

In the accompanying drawings (6 sheets):

FIG. 1 is a perspective view of a host gantry machine having a tape placement head of the present invention operatively mounted thereon and schematically illustrating the application of tape strands to a work piece;

FIG. 2 is a perspective view of a tape placement head constructed in accordance with and embodying the present invention;

FIG. 3 is a perspective view of the tape placement head of FIG. 2, showing the opposite side of the placement head;

FIG. 4 is a side elevational view of the tape placement head, partially broken away and in section;

FIG. 5 is a horizontal sectional view taken along line 5—5 of FIG. 2 and showing a portion of the cut-off assembly forming part of the tape placement head;

FIG. 6 is a horizontal sectional view taken along line 6—6 of FIG. 2 and showing a portion of the edge sensing-alignment assembly forming part of the tape placement head of FIG. 2;

FIG. 7 is a fragmentary vertical sectional view taken along line 7—7 of FIG. 4;

FIG. 8 is a horizontal sectional view taken along line 8—8 of FIG. 2 and showing a portion of the heater assembly forming part of the tape placement head;

FIG. 9 is a fragmentary sectional view taken along line 9—9 of FIG. 8;

FIG. 10 is a schematic view illustrating the method of compensating for tape length when applying at varying angles with respect to the work piece; and

FIG. 11 is a schematic view illustrating the relationship in terms of length between a deceleration photocell, cutting mechanism and applicator roller forming part of the tape placement head of the present invention.

GENERAL DESCRIPTION

Generally speaking, the present invention relates to a filament tape applicator (often referred to as a "tape head" or "tape placement head") which is used on a selected type of host actuating equipment, such as a gantry machine. The tape placement head is normally shifted through X and Y coordinate axes through the action of the gantry machine. In addition, the tape placement head is constructed so that it can shift along additional axes with respect to the gantry machine.

The tape placement head of the present invention generally includes a relatively large major support bracket for removable securement to the host actuating equipment. A motor is suitably mounted on the supporting frame and is connected to a drive mechanism for rotating the tape placement head about a depending flange formed on the host actuating equipment. The drive mechanism is designed to rotate the entire tape placement head in a full 180° arc in either direction. Thus, if tape was being placed upon a work piece during the movement of the tape placement head in the X axis, the host actuating equipment would be programmed to automatically stop at the end of the tape application cycle. At this point in time, th motor is actuated to rotate the tape placement head 180°. The host actuating equipment would shift the head laterally in the Y coordinate axis so that a next strand of tape

can be placed adjacent to the previously deposited strand of tape.

Also mounted on the supporting frame is a shaft for removably receiving a roll of filament type tape such as boron tape. The tape is secured to a backing film, generally formed of paper, and is preferably pre-impregnated with a suitable resin curable matrix. Furthermore, the supply spool is maintained under a proper degree of tension as the tape strand is paid out from the spool.

A separating mechanism is provided to peel away the backing from the pre-impregnated tape and the backing is retrieved onto a driven wind-up storage spool. The relative position of all of the spindles in the tape placement head have been arranged to provide an alternate path for the tape-backing, if desired. After the backing web has been separated from the composite tape, the tape passes through a cutting mechanism to be hereafter described. The tape is again brought into contact with the backing web prior to engagement by a laydown roller. The backing web which is operatively interposed between the lay-down roller and the tape prevents the tacky resin matrix from being accumulated on the lay-down roller and subsequent soiling thereof. Thus, the lay-down roller is shielded by reutilization of the backing web. In some reinforced composite tapes, it is not necessary to separate the backing web from the tape prior to cutting and the backing web would then be separated from the tape at the lay-down roller.

As indicated previously, the supply spool is driven. The unspooling of a three inch wide tape, for example, can only be practically accomplished through physical containment and restraint due to the modulous induced rigidity. Otherwise, the convolute windings would tend to expand and unwind in the manner of released clock spring. The tape which is brought into contact with the backing web and the lay-down roller is then push-fed against a curving chute which terminates at the point of tangency with a substrate work surface.

A cut-off assembly or so-called "shear mechanism" or "shear assembly" is also mounted on the frame and is pneumatically operated by paired cylinders. The shear assembly is capable of cutting a 3 inch wide filament tape through an arc of $\pm 45°$ normal to the tape center line. The shear assembly is driven by a stepping motor which is controlled by a complex edge-sensing mechanism to be hereinafter described. The shear assembly comprises a combination of a shearing type blade and teflon anvil. The blade is attached to a fixed shear frame member and the teflon anvil is attached to a moving platen.

Also mounted on the frame is an edge-alignment sensory assembly which consists of a pair of photocells mounted on a linkage mechanism that swings the cells through an arc $\pm 45°$ from the tape center-line. The sensing mechansim is driven by and with the shear mechanism so that the relationship between these two members is kept constant. As one of the photocells of the edge-alignment sensory assembly picks up the reflection of its integral light source from the retro-reflective tape, a signal to the shear drive motor causes the drive motor to shift the cutting mechanism in the direction corresponding to the cells' position. When the second cell is activated, the shear drive mechanism is stopped and a solenoid valve controlling the shear's cylinders is energized thereby causing the tape to be severed.

A deceleration photocell is aimed approximately two inches ahead of the edge-sensing photocells. When this latter cell is activated by its light beam being reflected from the retro-reflective tape, it signals the machine to slow to a creep speed. This slow-down insures that the edge-alignment sensory assembly will have sufficient time to accurately rotate into position.

Also mounted on a frame is an infrared type of electrical heating device utilizing a quartz lamp as the heat source and an elliptical reflector to concentrate the heat in a small band at the focal point of the reflector, this band being transverse to the direction of movement of the tape. The quantity of heat is controlled by a transformer or a rheostat. The heating device is also designed to rotate away from the tape whenever the tape drive is stopped, in order to prevent localized heating of the tape, thereby providing any premature cure of the tape.

DETAILED DESCRIPTION

Referring now in more detail and by reference characters to the drawings which illustrate a preferred embodiment to the present invention, T designates a tape placement head which is secured to a somewhat conventional gantry-type machine in the manner as illustrated in FIG. **1.** In order to more fully understand the operation of the tape head, a brief description of the gantry-type machine is provided.

By reference to FIG. **1,** it can be seen that the tape head T is mounted on a gantry machine G having a gantry **1** shiftable along a longitudinal axis X. Furthermore, the tape head is mounted on a support plate or carriage **2** which shifts transversely with respect to a work platform **3** forming part of the gantry machine G. Thus, the support plate **2** shifts in a transverse or Y axis. The support plate **2** is also shiftable vertically in a Z coordinate axis. Thus, the tape head T can be shifted longitudinally with respect to a work piece W in order to apply longitudinal strands of tape to the work piece W. In like manner, the support plate **2** is shiftable transversely so that the tape head T can be shifted in order to apply a next adjacent strand of tape material. Finally, the support plate **2** is shiftable vertically in order to locate the tape head T at a proper distance with respect to the work piece W.

By further reference to FIG. **1,** it can be seen that the tape placement head T is also rotatable in an axis C in order to apply tape strands to the work piece in an axis which is angularly displaced with respect to the X or Y axes. Furthermore, the tape head is shiftable accurately with respect to the Y axis in order to provide an axis A_2. Finally, while the work piece W is illustrated as being located on a flat work surface, it should be recognized that the work piece W may be rotatable along its axis which is parallel to the X axis in a rotatable coordinate axis A_1.

By reference to FIGS. **2** and **4,** it can be seen that the tape placement head T integrally includes a bearing retaining ring **4** which forms part of a yoke **11.** A support ring **5** is mounted on the underside of the bearing retaining ring **4** in the manner as further illustrated in FIGS. **2** and **4** and a drive ring **10** is mounted in cooperative relationship to the support ring **5** and the retaining ring **4.** The drive ring **10** is provided with an exterior peripheral ring gear (not shown) and mating with

a pinion gear 13 driven by an electric motor 14, the latter being mounted on a bracket 12, in order to selectively rotate the entire yoke 11 in 180° arcs. Thus the entire tape placement head T can be rotated with respect to the work piece W and with respect to the gantry machine G. A pair of stops 15 are provided in order to hold the tape placement head T in position. Furthermore, the stops are provided with suitable magnetic or other type locking mechansims in order to maintain a rigid pattern for the tape placement head T, while the latter is shifting during the application of the tape.

The yoke 11 comprises a pair of oppositely disposed vertically depending legs 16 which are integrally formed with the support ring 10 in the manner as illustrated in FIG. 2 and the two legs 16 are connected by a plurality of transversely extending support bars 17 which are welded to or otherwise rigidly secured to the legs 16. At their lower end, the legs 16 are integrally merged into enlarged hubs 17' which retain suitable roller bearings 18 for journaling a transversely extending yoke shaft 19. Thus, it can be seen that the shaft 19 is pivotal with respect to the legs 16.

Pivoting on the shaft 19 and extending forwardly thereof, that is in the direction of movement of the tape head T are a pair of transversely spaced support arms 20 and 20', as illustrated in FIGS. 2 and 7. Secured to the support shaft 19 and extending forwardly therefrom is a cast metal side frame 21 which is more fully illustrated in FIG. 3. It can be seen that the side frame 21 has a forwardly extending horizontally located arm 22 and a somewhat triangularly shaped cast section 22'.

By reference to FIGS. 2 and 3, it can be seen that the major portions of the components on the tape head T are carried by the arms 20 and 20' and the slide frame 21 so that, in essence, substantially all of the components of the tape head T are pivotal with respect to the yoke 11 about the yoke shaft 19. A pair of micro-switches 23 are located on the arm 23 of the side frame 21 and indicate to a central control unit the relative vertical position of the tape placement head T. In essence, these micro-switches 23 indicate whether or not the tape head T has been pivoted upwardly to a shifting position or downwardly to a tape laying position.

Integrally formed with one of the lowermost transversely extending support bars 17 are a pair of rearwardly extending clevis forming brackets 24 for pivotally retaining a hydraulic cylinder 25, the latter being conventional in its construction and, therefore, not illustrated in any further detail herein. A piston 26 is operable by cylinder 25 and secured to the lower end of the piston 26 is a coupling 27 for pivotal securement to a bracket 28. It can thus be seen that the bracket 28 is formed with side frame 21 and is secured to the coupling 27 through a pivot pin 29. Thus, it can be seen that when the hydraulic cylinder 25 is actuated, the piston 26 will cause the link 27 to shift the cast side frame 21 and the forwardly extending arm 20 upwardly about the yoke shaft 19, thereby raising the assembly with respect to the main support yoke 11.

Integrally formed in the upper end of the side frame 21 in an enlarged hub 30 and journaled in the hub 30 is a transversely extending reel spindle 31 for supporting a pay-off reel 32. The reel 32 or so-called "spool" contains wound filament reinforced composite tape 33 suitably secured to a removable backing 34. As indicated previously, the tape is of the reinforced composite type and contains and may be pre-impregnated with a suitable resin curable matrix. The reel 32 is conveniently removable from the spindle 31 by means of a rotatable locking assembly 35. Furthermore, a magnetic brake 36 is secured to the outer end of the spindle 31 to provide a back tension on the spindle 31 and, hence, on the pay-off reel 32.

The backing paper may be conveniently formed of any suitable material which is inert with respect to the tape and any pre-impregnated matrix and which is conveniently removable from the tape by means of peeling. For example, the backing may be formed of paper or a thin flexible plastic material such as polyethylene, mylar or the like.

The composite tape is generally formed of a series of longitudinally extending substantially parallel strands of filamentary reinforced material such as fiberglass, lithium, boron, quartz or grown whisker crystals, etc. In addition, metal wire may be interspersed with the filaments in the event that it is desired to add some type of metallic body to the reinforced structure.

Any of a number of commercially available resin matrix materials can also be employed for pre-impregnating the tape. The matrix should be capable at some stage of the process of being liquidified and softened for a period of time and also should be sufficient to flow around the filaments forming the tape. In addition, the matrix should be capable of achieving a rigid stage of a complete polymerization to become a rigid solid and should also possess ability to adhere to the reinforced material. Some of the suitable matrix materials which can be employed for pre-impregnating the tape are many of the thermoplastic resins such as polypropylene, polycarbonates, etc. In addition, some thermosetting resins, such as the polyesters. Many of the phenolics and epoxies can be used as well.

The pay-off reel 32 is designed to carry either three inch or eight inch inside diameter cores and a wide number of tape widths. In order to account for tape reels of different widths, a side plate 37' having a teflon coated inner surface is disposed against the tape reel. A number of washers can also be disposed on the reel spindle 31 between the side plate 37 and the locking nut assembly 35.

The composite of the tape 33 and the backing 34 is then passed between a pair of tape guides 38 and trained through an idler pinch roller 39 and a drive roller 40 in the manner as illustrated in FIGS. 2 and 4. The combination of the drive roller 40 and the idler pinch roller 29 provides a means for feeding the tape through the system at a preselected rate. The pinch roller 39 is rotatably secured to a pivotally mounted arm 41 which is biased toward the drive roller 40, by means of a set screw mechanism 42 in order to maintain a proper pressure between the tape backing 34 and the drive roller 40. A suitable drive motor 43 is mounted on the side frame 21 for driving the drive roller 40. An overrunning clutch (not shown) may be fitted between the drive roller 40 and the motor 43 to allow the tape to be unspooled at a rate faster than the motor drive speed in such manner that the machine travel rate determines the tape speed during the actual tape laying operation.

The backing web 34 is separated from the tape 33 on the underside of the drive roller 40 in the manner as illustrated in FIGS. 2 and 4 and the backing web 34 is then trained around an idler roller 44, the latter being secured to a shaft 45 journaled on the side frame 21. As indicated previously, in many cases it is not neces-

sary to separate the tape from the backing web, in which case the idler roller **44** would not be employed.

The tape **33** which has been separated from the backing web **34** is then passed along a guide plate **46** and into tape cutting mechanism **47** and a heating mechanism **48** in the manner as illustrated in FIGS. **2** and **4.** The tape cutting mechanism **47** and the heating mechanism **48** will be hereinafter described in more detail.

Finally, the tape **33** is again brought into facewise engagement with the backing web **34** along the annular surface of a tape placement roller or so-called "applicator roller" **49,** the latter being journaled on a transversely extending roller shaft **50** and which is, in turn, secured to the extending arms **20, 20'.** The tape placement roller **49** is pneumatically inflated to provide an adjustable and variable pressure area. Secured to the side frame **21** and being connected to the extending arm **20** is an adjustable spring loading device **51** enabling an operator to adjust a roll-down pressure on the roller **49.** This mechanism provides for a type of spring suspension of the tape placement roller **49** to enable compliance with variations in a complex surface. The spring loading device **51** is more fully illustrated in FIG. **7** and is described in more detail hereinafter. It should be observed that the impregnated tape **33** does not contact any portion of the tape placement roller **49** since the backing web **34** is interposed between the tape **33** and the roller **49.** Furthermore, it can be observed that as the tape head T travels in the direction of movement of the arrow, reference being made to FIG. **4,** the tape will be applied to the work surface W.

The backing web **34** is trained around a take-up spool **52** which is mounted on a powered spool shaft **53,** the latter being journaled on the side frame **21.** The spool shaft **53** is driven by means of a high-slip motor **54** which provides a constant tension on the backing web **34** and with varying speed. It should be observed that the take-up spool **52** is retained on the shaft **53** by means of a locking nut **55** for convenient removal of the spool **52.**

By reference to FIGS. **2** and **4,** it can be seen that a guide shoe **56** clamps the tape **33** along with the backing web **34** to the tape placement roller **49** prior to retraction of the entire tape laying head T. With this mechanism, it is possible to maintain the tape position during the "turn around" phase of the tape placement operation. It can be seen that the guide shoe assembly **56** is provided with an accurately shaped shoe surface **57** conforming to the surface of the tape placement roller **49.** Furthermore, the guide shoe assembly **56** is pneumatically operable by means of a pneumatic cylinder **58.**

By reference to FIG. **1,** it can be seen that the tape laying head T travels with the carriage **2** along the axis X during the application of the tape **33** to the work piece W. As the tape is applied to the surface of the work piece W, it is severed in such manner that the terminal end of the severed section is coincident with the transverse margin of the work piece W. At this point, the gantry **1** is programmed to stop its shifting movement and the tape heat T will rotate for a 180° arc so that another strand of tape can be laid adjacent to the previously deposited strand of tape on the work piece W. Furthermore, the carriage **2** will be shifted transversely in order to properly locate the applicator roller **49** with respect to the work piece W.

The tape head T includes an edge-alignment sensory assembly **59** which, in part controls the movement of the tape head T. This edge-alignment sensory assembly is capable of detecting the terminal edge of the work piece W in advance of that edge during the movement of the entire tape head T. Thus, the tape head T will stop its advancing movement at a prescribed location, and is signaled to stop its advancing movement in advance of the prescribed location. In addition, the edge-alignment sensory assembly controls the cutting mechanism **47** so that the edge of the tape **33** is severed with an edge trim conforming to a peripheral edge of the work piece W.

The edge-alignment sensory assembly includes a deceleration photocell **60** which is secured to a pivotally mounted bracket **61** in the manner as illustrated in FIGS. **2** and **4.** In actual operation, a retro-reflective tape (not shown) is deposited on the edge of the work piece W, or preferably spaced from the edge of the work piece W, and is capable of being sensed by the photocell **60.** The retro-reflective tape will have a substantially different surface emissivity than the work piece W so that the photocell **60** will be capable of detecting a marked change in surface emissivity - as being the difference between the dark impregnated tape and a white strip of relfective tape. Thus, when the photocell **60** is actuated by its light beam reflected from the retro-reflective tape, it signals the tape head T and the controlling mechanism (not shown) for the gantry machine G to reduce the speed of movement of the carriage. This reduction in speed insures that the edge-alignment sensory assembly will have sufficient time to rotate into position accurately, in a manner to be more fully described in detail hereinafter.

The edge-alignment sensory assembly **59** also includes a pair of photocells **62, 62'** mounted on a linkage mechanism **63** which swings the photocells **62, 62'** through a $\pm 45°$ arc with respect to the centerline of the tape being deposited. The linkage mechanism **63** and the photocells **62, 62'** are more fully illustrated in FIG. **6.** The link mechanism is biased rearwardly, reference being made to FIG. **6,** by means of a compression spring **64** which bears against a flat plate **65.** The plate **65** is connected to the link mechanism **63** by means of a pair of spaced rods **66** which extend through axial bearings **67.** Furthermore, an adjustment screw **68** is provided for regulating the degree of bias rearwardly on the linkage mechanism **63.**

It can be seen that the photocells **62, 62'** are mounted on a flat cross bar **69** which is secured to a mounting plate **70,** the latter in turn being secured to a pair of shiftable links **71, 72.** Finally, the mounting plate **66** is shifted by means of a bar **73** connected to the rods **66.** By further reference to FIG. **6,** it can be seen that the links **71, 72** are secured to stepping links **74, 75,** respectively, which are in turn shifted through an anchor **76** on a vertical drive shaft **77.** The drive shaft **77** is in turn driven through a gear mechanism **78** by means of a stepping motor **79,** the latter being illustrated in FIGS. **2** and **5.** The link structure **63** with the attendant links **71, 72** and the drive link **73** all form a stirrup structure so that the photocells **62, 62'** essentially ride on an idle cross bar. In this manner, they are free to rotate $\pm 45°$ parallel to the work surface.

When either of the photocells **62, 62'** detects a marked change in surface emissivity — as being the difference between the dark pre-impregnated boron (or

graphite) tape and a white skirt or strip of reflective tape on the work piece W, the photocells will, in essence, hold to the colored change line. This allows the other of the photocells to swing forward. Thus, if the photocell **62'** first detected the colored change line, represented by the demarcation between tape and the work piece W, the other photocell **62** would swing forward through the action of the stepping motor **73.** Thus, as the tape head T continually moves forward, the photocell **62** will continually shift causing the link mechansim **63** to rotate the photocells **62, 62'** until both photocells are in complete alignment with the edge of the tape **33.**

By further reference to FIG. **4,** it can be seen that the photocell **60** is located so that it detects the position of a point during the movement of the tape head T toward that point and prior to the time that the tape head T reaches that particular point. Thus, in the case of the present invention, the photocell **60** will be the first of the photocells to detect the presence of the retro-reflective tape. In normal practice, it is desirable to place the tape approximately **2** inches from and in parallel relationship to the edge of the work surface. These relationships are more fully illustrated in FIGS. **10** and **11.** Thus, if the tape placement head were moving in a path such as that designated as Y_1 in FIG. **10,** the tape placement head T would be moving toward the work piece edge designated as Z_1. The photocell **60** would detect the retro-reflective tape Z_2 which is fixed approximately **2** inches from the edge of the work surface Z_1. As the photocell **60** detects the retro-reflective tape Z_2, a signal is generated to slow-down the movement of the tape head T. Furthermore, it can be seen that since the tape head T is moving in a direction completely perpendicular to the edge of the work surface Z_1 and the retro-reflective tape Z_2, that the photocells **60, 62'** will not change their relative position. Accordingly, when the two photocells **60, 62'** contact the retro-reflective tape Z_2, a signal will be generated to initiate the tape cutting mechanism **47.** At this point the tape **33** will be severed.

It is to be noted that these time-distance relationships are fixed, but yet are adjustable in the tape head T. For example, when the applicator roller **29** is located at the position illustrated in FIG. **11** and a cutting signal is generated, the tape **33** will be severed. The distance between the severed edge of the tape **33** and the point of contact of the applicator roller **49** (designated as S) is equal to the distance between the this point of contact S of the roller **49** and the work piece edge Z_1 (distance designated as X_1). Furthermore, it is to be noted that the cutting signal is generated when the photocells **62** and **62'** are aligned with work piece edge and both detect the line Z_2, as illustrated in FIGS. **10** and **11.**

It can be seen that if the tape placement head T was moving along the path Y_2 as illustrated in FIG. **10,** then a somewhat different time relationship is created. When the tape placement head T is moving in the path Y_2 the photocell **60** will detect the retro-reflective tape Z_2 generating a signal to slow-down the movement of the tape head. However, since the tape placement head T is moving in an angulated path the distance between Z_1 and Z_2 in the direction Y_2 is not equal to the distance between Z_1 and Z_2 in the direction Y_1. The tape placement head T of the present invention compensates for this change of distance. Thus, the two photocells **62** and **62'** will not contact the retro-reflective tape Z_2 at the same point in time. The first photocell **62'** will contact the retro-reflective tape Z_2. This will cause the other of the photocells **62** to shift around through the action of the link mechanism **63** as illustrated in FIG. **6.** However, it is to be noted that the link mechanism **63** actually extends forwardly in order to compensate for the additional distance between Z_1 and Z_2 as a result of the tape head moving in the path Y_2.

Accordingly, when the photocell **62'** detects the retro-reflective tape Z_2, the link **71** will remain stationary but photocell **62** will shift forwardly through the action of the link **72.** It is to be noted that the link **72** is movable through the stepping link **74** by the action of the anchor **76.** The actual point of rotation will occur about the point of connection between the link **71** and the mounting plate **70.** Furthermore, it can be observed that the entire linkage mechanism **63** shifts forward. The drive link **73** actually shifts forwardly through the action of the rod **66** moving through the axial bearings **67.** Furthermore, this forwardly moving action occurs against the action of the compression spring **64.** Thus, it can be seen that the photocells **62, 62'** not only compensate for the angle between the direction of movement of the tape head T and the edge of the work surface, but actually compensate for a variance in distance between the edge of the work surface Z_1 and the retro-reflective tape Z_2 caused by the angle of movement of the tape head T. It can also be observed at the end of the work cycle, that the two photocells **62, 62'** will be shifted back to their normal positions, as illustrated in FIG. **6,** and, furthermore, the entire assembly will be shifted to the right by the action of the compression spring **64.**

In addition, it can be seen that as a result of the tape head T movement in the path Y_2, an additional distance of X_3 is generated in FIG. **11.** Accordingly, when the two photocells **62, 62'** shift in order to match the edge of the work surface Z_1, they will be extended for a distance X_3.

The tape cutting mechanism **47** is more fully illustrated in FIG. **5** and generally comprises a frame **84** which is rotated through a $\pm$ 45° arc by means of the stepping motor **79.** It can be seen that the frame **84** is secured to a shaft **85** supported by roller bearings **86** and is driven through a pair of pulleys **87** and a drive belt **88.** Thus, it can be seen that when the stepping motor shifts the photocells **62, 62'** to become aligned with the retro-reflective tape, the stepping motor **79** will also shift the shear frame **84.** Rigidly secured to one end of the shear frame is a blade **89** and which is engagable with a similar blade **90,** the latter being secured to a slideable plate **91.** By further reference to FIG. **5,** it can be seen that the plate **91** is shiftable along a pair of guides **92** forming part of the frame **84** and is powered by means of a pair of pneumatic cylinders **93,** the latter being secured to the frame **84.** Thus, it can be seen that the cutting blades **89, 90** are pneumatically operated by the paired cylinders **93.** Furthermore, this mechanism is capable of cutting a three-inch wide tape through an arc of $\pm$ 45° with respect to the tape centerline. The blade **89** actually serves as a type of anvil and is preferably formed of teflon. The blade **90** which is shiftable with respect to blade **89** serves as a crushing type of blade.

Thus, the edge-alignment sensory assembly also drives the tape cutting mechanism **47.** As one of the photocells **62, 62'** pick up the reflections of its integral

light source from the retro-reflective tape, the motor **79** is actuated to operate in a direction corresponding to the cells' position. As the shear frame **84** rotates, it also drives the link structure **63** to the angle of the retro-reflective tape. When the second photocell is activated, the stepping motor **79** stops the rotation of the shear frame **84** and also thereafter energizes a solenoid valve (not shown) which controls the cylinders **93** to cause the tape to be severed.

By further reference to FIG. **7**, it can be seen that the spring loading device **51** is designed to provide an adjustable spring loading pressure on the applicator roller **49.** The spring loading device **51** essentially cooperates with the side frame **21** and the arm **20** in the manner as illustrated. The spring loading device **51** generally comprises a bracket **94** which is welded or otherwise secured to side frame **21** in the manner as illustrated. In addition, the bracket **94** has a flange **95** which extends through a slot **96** formed within the arm **201.** Furthermore, the bracket **94** has a lower flange **97** which also extends outwardly from the side frame **21** and the flanges **95, 97** carry adjusting screws **98, 99,** respectively. Both of the adjusting screws are capable of bearing against a spring bias **100** which is biased downwardly through the action of the spring **101.** Thus, it can be seen that the applicator roller **49** is carried by the arms **20, 20'** and partially held by the side frame **21.** However, the roller **49** is shiftable to a slight degree with respect to the side frame **21** so that it is capable of compensating for variance in the work surface W. The degree of bias tension maintained on the roller **49** is adjusted by the upper screw **98** with a possible degree of lowermost movement of the applicator roller **49** regulated by means of the screw **99.** The desired load pressure maintained on the applicator roller **49** is determined by the many factors which affect the tape laydown characteristics. For example, a soft, resin-rich tape would require less roller load for a good adherence than would be required for a dryer tape.

The heating mechanism **48** is more fully illustrated in FIG. **8** of the drawings and generally comprises a quartz lamp **104** which is located within a frame **105.** The frame **105** is rotatably mounted on a shaft **106** and operates a pair of microswitches **107, 108** by means of a cam **109** located on an extension of the shaft **106.** In like manner, the extension of the shaft **106** is secured through a coupling **110** to an electric motor **111.** The frame **105** is located so that the quartz lamp **104** provides an infrared type of heat source and the frame **105** concentrates the heat in a 0.06 to 0.09 inch wide band at the focal point of the reflector. The quantity of heat is controlled by a console mounted transformer or rheostat (not shown). At any point in time when the tape **33** stops moving in the tape head T, the electric motor **111** is energized to rotate through shaft **106** the frame **105** and, hence, the quartz lamp **104** away from the tape **33** to prevent localized heating of the tape and thereby avoiding a premature cure of the tape.

It should be understood that changes and modifications in the form, construction, arrangement and combination of parts presently described and pointed out may be made and substituted for those herein shown without departing from the nature and principle of our invention.

Having thus described our invention, what we desire to claim and secure by Letters Patent is:

1. A tape applicator for applying a tape formed of a plurality of longitudinally extending filament containing strands to a receiving surface, said applicator comprising support means, tape supply means operatively retained by said support means, tape placement means on said support means for applying said tape to said receiving surface during relative movement between said applicator and said receiving surface, means carried by said tape applicator for applying radiant energy directly to said receiving surface, means selectively locatable on said receiving surface to generate a differential reflected radiant energy response at a predetermined end position on said receiving surface, sensing means including a radiation active sensing element carried by said tape applicator and being located to scan the radiant energy reflected from said receiving surface, said sensing means being operable to generate an electrical signal responsive to receipt of the differential reflected radiant energy response upon sensing of said predetermined end position, and cutting means operable upon receipt of said electrical signal for automatically severing said tape in advance of said predetermined end position to form a terminal edge which will coincide with the predetermined end position, said cutting means also including means to form said terminal edge with a proper angle established by and conformable to said predetermined end position, to thereby form a final structural member comprised of the tape when the tape is removed from said receiving surface.

2. The tape applicator of claim **1** further characterized in that means are provided for rotating said support means so that said tape is applied to said receiving surface in a direction opposite the direction of relative movement during application of a previous tape to said receiving surface.

3. The tape applicator of claim **1** further characterized in that drive means are provided for causing relative movement between said tape applicator and said receiving surface, deceleration means operatively associated with said drive means for decreasing the speed of said relative movement upon detection of said predetermined position and in advance of said predetermined position.

4. The tape applicator of claim **1** further characterized in that said tape supply means comprises a supply spool of said tape, and means are operatively associated with said tape supply means for positively driving said tape supply means to dispense tape from said supply spool.

5. A tape applicator for applying a tape formed of a plurality of longitudinally extending filament containing strands to a work surface, and which strands are preimpregnated with a curable resin-type matrix, said tape dispensing applicator comprising support means, tape supply means operatively retained by said support means for dispensing said filament containing tape, application means located in proximity to said work surface for receiving said dispensed tape and applying same directly to said work surface, radiation type preheating means located intermediate said tape supply means and said application means for passing radiation into said pre-impregnated tape after dispensing of said tape from said supply means and during movement of said tape past said pre-heating means, and motive means for automatically shifting said pre-heating means to a position where substantial radiation is not directed toward said tape when said tape is not moving

with respect to said pre-heating means, to thereby form a final structural member comprised of the strands of tape when the pre-impregnated tape is cured and removed from the work surface.

6. The tape applicator of claim **5** further characterized in that the tape dispensable from the tape supply means is initially provided with and lies in contact with a removable backing member, means for removing said backing member from said tape prior to introduction into a location where it receives said radiation, and further means for reintroducing said tape into contact with said backing member after subjection to said radiation.

7. In an applicator for applying reinforcing strands comprised of a plurality of substantially parallel textile filaments to a work piece while relative movement exists between said applicator and work piece; means carried by said tape applicator for applying radiant energy directly to said work piece, means selectively locatable on said work piece to generate a differential reflected radiant energy response at a predetermined end position on said work piece, sensing means for detecting a predetermined end position on said work piece representing a desired terminal end location for the piece of strand being applied to said work piece, said sensing means including a radiation active element carried by said tape applicator and being located to scan the radiant energy reflected from said receiving surface, said sensing means being operable to generate an electrical signal responsive to receipt of the differential reflected radiant energy response upon sensing of said predetermined end position, means operatively associated with said sensing means for establishing a predetermined angle with respect to the predetermined end position on said work piece, and cutting means operatively connected to said sensing means for automatically cutting said strands to terminate at said desired predetermined end position and conformable to said predetermined angle, to thereby form a final structural member comprised of the strands when removed from said work piece.

8. In the applicator of claim **7,** said sensing means comprising a first radiation active sensing element initially detecting said predetermined end position, and a second radiation active sensing element capable of being shifted into a position where said first and second elements are aligned with said predetermined end position to thereby establish said predetermined angle.

9. In the applicator of claim **7,** further characterized in that said sensing means comprises a first radiation active sensing element initially detecting said predetermined end position, and a second radiation active sensing element capable of being shifted into a position where said first and second elements are aligned with said predetermined end position, and stepping motor means for intermittently shifting said second sensing element until said alignment is achieved to thereby establish said predetermined angle.

10. In the applicator of claim **8,** further characterized in that said sensing means comprises a third radiation active sensing element, and deceleration means operatively connected to said third sensing element for slowing down a relative movement between said work piece and applicator upon detecting of said predetermined end position on said work piece.

11. In the applicator of claim **8,** further characterized in that said sensing means comprises a first radiation active sensing element initially detecting said predetermined end position, a second radiation active sensing element capable of being shifted into a position where said first and second radiation active sensing elements are aligned with said predetermined end position, stepping motor means for intermittently shifting said second sensing element until said alignment is achieved to thereby establish said predetermined angle, and means operatively connected to said stepping motor means for shifting said cutting means to conform to said predetermined angle.

12. A tape applicator for applying a tape formed of longitudinally extending filament containing reinforcing strands which are pre-impregnated with a curable resin-type matrix to a work piece while relative movement exists between said work piece and applicator; said applicator comprising support means, tape supply means carried by said support means to dispense said tape, cutting means operatively carried by said support means for cutting said strands in advance of a preselected location on said work piece to create terminal ends of said tape coextensive with said preselected location, means for separating said backing member from said tape prior to cutting said strands, means for applying said tape to said work piece, and means for reintroducing the severed portion of the tape into contact with the backing member at least prior to the application of the severed strands to the work piece, to thereby form a final structural member comprised of the strands of tape when the pre-impregnated tape is cured and removed from the work piece.

13. The tape application of claim **12,** further characterized in that said applicator comprises photoelectric sensing means including a radiation active sensory element for detecting said pre-selected location, and deceleration means operatively connected to said sensory element and being operable to slowdown the speed of said relative movement prior to said preselected location.

14. The tape applicator of claim **12,** further characterized in that said photoelectric sensing means includes a radiation active sensory mechanism for detecting a preselected angle on said work piece at said preselected location, and means operatively connecting said sensory element and said cutting means to enable said strands to be cut at said preselected angle.

15. The tape applicator of claim **14,** further characterized in that said sensory mechanism includes a first radiation active sensing element initially detecting said preselected angle, and a second radiation active sensing element capable of being shifted into a position where said first and second radiation active sensing elements are aligned with said preselected angle.

16. The tape applicator of claim **14,** further characterized in that said photoelectric sensing means includes a first radiation active sensing element initially detecting said preselected angle, and a second radiation active sensing element capable of being shifted into a position where said first and second radiation active sensing elements are aligned with said preselected angle, and stepping motor means for intermittently shifting said second sensing element until said alignment is achieved.

17. A reinforced composite tape applicator for applying a tape formed of a plurality of longitudinally extending filament containing strands on a removable backing member to a work piece, and which strands are

pre-impregnated with a curable resin-type matrix, said applicator comprising support means, tape supply means operatively retained by said support means for dispensing said filament containing tape which has been pre-impregnated with said curable matrix, pre-heating means for passing radiation into said pre-impregnated tape during movement of tape past said pre-heating means to initiate a heating of the resin-type matrix impregnated in said strands, means for separating said backing member from said tape prior to passing radiation thereinto, means for applying said tape to a work piece, and means for momentarily causing contact between said tape and backing member just prior to placing said tape on said work piece, to thereby form a final structural member comprised of the strands of tape when the pre-impregnated tape is cured and removed from the work piece.

18. The reinforced composite tape applicator of claim **17,** further characterized in that means is provided for shifting said pre-heating means to a position where substantial radiation is not directed toward said tape when said tape is not moving with respect to and past said pre-heating means.

19. A tape applicator for applying a tape formed of a plurality of longitudinally extending filament containing strands to a receiving surface during relative movement between said receiving surface and said applicator, and which strands are pre-impregnated with a resin-type matrix curable material and located on a removable backing member; said applicator comprising:

a. support means,

b. tape supply means operatively retained by said support means for dispensing said filament containing tape therefrom,

c. radiation type pre-heating means located to receive the tape dispensed from said tape supply means and passing radiation into said pre-impregnated tape for initiating a heating of the matrix curable material,

d. motive means for automatically shifting said pre-heating means to a position where substantial radiation is not directed toward said tape when the tape is not moving with respect to said pre-heating means,

e. application means carried by said support means for receiving said tape and applying same directly to said receiving surface during relative movement between said tape applicator and said receiving surface,

f. means carried by said tape applicator for applying radiant energy directly to said receiving surface,

g. means selectively locatable on said receiving surface to generate a differential radiant energy response at a predetermined end position on said receiving surface,

h. sensing means for sensing said predetermined end position with respect to the application of the tape to the receiving surface,

i. said sensing means including a radiation active element located to scan the radiant energy reflected from said receiving surface and being capable of generating an electrical signal responsive to receipt of the differential reflected radiant energy response upon sensing of said predetermined end position,

j. cutting means operable upon receipt of said electrical signal for automatically severing said tape in advance of said predetermined position to form a terminal edge which will coincide with the predetermined end position,

k. said cutting means also including means to form said terminal edge with a proper angle established by and conformable to said predetermined end position,

l. means for temporarily separating said tape from said backing member while said tape is being severed by said cutting means so that said backing member is not severed therewith,

m. and means for bringing said backing member into contact with said tape momentarily at said application means and separating same therefrom after said tape has been applied to said receiving surface, to thereby form a final structural member comprised of the strands of tape when the pre-impregnated tape is cured and removed from the receiving surface.

20. A tape applicator for applying a tape formed of a plurality of longitudinally extending filament containing strands to a receiving surface during relative movement between said receiving surface and said applicator, and which strands are preimpregnated with a resin-type matrix curable material and located on a removable backing member; said applicator comprising:

a. support means,

b. drive means for causing relative movement between said receiving surface and said tape applicator,

c. tape supply means including a supply spool containing said tape operatively retained by said support means for dispensing said filament containing tape therefrom,

d. means for positively driving said tape supply means to dispense tape from said supply spool,

e. radiation type pre-heating means located to receive the tape dispensed from said tape supply means and passing radiation into said pre-impregnated tape for initiating a heating of the matrix curable material during movement of said tape past said pre-heating means,

f. separation means for removing said backing member from said tape prior to introduction into a location where said tape receives the radiation,

g. motive means for automatically shifting said pre-heating means to a position where substantial radiation is not directed toward said tape when the tape is not moving with respect to said pre-heating means,

h. application means carried by said support means for receiving said tape and applying same directly to said receiving surface during relative movement between said tape applicator and said receiving surface,

i. sensing means for sensing a predetermined end position and a predetermined angle with respect to the application of the tape to the receiving surface,

j. said sensing means including a first radiation active element capable of generating an electrical signal responsive to receipt of radiation, and initially detecting said predetermined angle,

k. second radiation active sensing means also capable of generating an electrical signal upon receipt of radiation and being shifted into a position where said first and second radiation active sensing elements are aligned with said predetermined angle,

l. stepping motor means for intermittently shifting said second sensing element until said alignment is achieved,

m. third radiation active sensing means capable of generating an electrical signal upon receipt of radiation,

n. deceleration means operatively associated with said third sensing element and with said drive means for decreasing the speed of relative movement upon detection of said predetermined end position and in advance of said predetermined end position,

o. cutting means operable upon receipt of said electrical signals from said first and second radiation active elements for automatically severing said tape in advance of said predetermined position to form a terminal edge which will coincide with the predetermined end position,

p. said cutting means also including means to form said terminal edge with a proper angle established by and conformable to said predetermined end position,

q. said separation means also being located to temporarily separate said tape from said backing member while said tape is being severed by said cutting means so that said backing member is not severed therewith,

r. means for bringing said backing member into contact with said tape momentarily at said application means and separating same therefrom after said tape has been applied to said receiving surface, and

s. means for rotating said support means so that said tape is applied to said receiving surface in a direction opposite to the direction of relative movement during application of a previous tape to said receiving surface, to thereby form a final structural member comprised of the strands of tape when the pre-impregnated tape is cured and removed from the receiving surface.

21. Apparatus for applying a tape formed of a plurality of longitudinally extending filament containing strands to a work receiving surface forming part of a work element, said apparatus comprising:

a. base means, means for retaining said work element on said base means,

b. a gantry member movable on said base means,

c. a tape applicator carried by said gantry member and movable therewith over and past said work element,

d. said tape applicator including support means,

e. tape supply means operatively retained by said support means for dispensing said filament containing tape therefrom,

f. radiation type pre-heating means located to receive the tape dispensed from said tape supply means and passing radiation into said pre-impregnated tape for initiating a heating of the matrix curable material,

g. application means carried by said support means for receiving said tape and applying same directly to said receiving surface during relative movement between said tape applicator and said receiving surface,

h. means carried by said support means for applying radiant energy directly to said work receiving surface,

i. means selectively locatable on said receiving surface to generate a differential reflected radiant energy response at a predetermined end position on said receiving surface,

j. a radiation active sensing element operatively carried by said support means for scanning the radiant energy reflected from said receiving surface and generating an electrical signal responsive to determination of said differential reflected radiant energy response at said predetermined end position,

k. cutting means operable upon receipt of said electrical signal for automatically severing said tape in advance of said predetermined end position to form a terminal edge which will coincide with the predetermined end position,

l. and means operatively associated with said cutting means to form said terminal edge with a proper angle established by and conformable to said predetermined end position, to thereby form a final structural member comprised of the strands of tape when the pre-impregnated tape is cured and removed from the receiving surface.

22. A tape applicator for applying a tape formed of a plurality of longitudinally extending filament containing strands to a receiving surface, said applicator comprising support means, drive means operatively associated with said support means for causing relative movement between said tape applicator and said receiving surface, tape supply means operatively retained by said support means, tape placement means on said support means for applying said tape to said receiving surface during relative movement between said applicator and said receiving surface, sensing means for sensing a predetermined end position with respect to the application of tape to said receiving surface, said sensing means including a first radiation active element capable of generating a first electrical signal responsive to receipt of radiation upon sensing of said predetermined end position, deceleration means operatively associated with said drive means and said first radiation active element and being operable on receipt of said first electrical signal for decreasing the speed of relative movement in advance of said predetermined end position, said sensing means including a second radiation active element capable of generating a second electrical response to receipt of radiation upon sensing of said predetermined end position, and cutting means operable upon receipt of said second electrical signal for automatically severing said tape in advance of said predetermined end position to form a terminal edge which will coincide with the predetermined end position, said cutting means also including means to form said terminal edge with a proper angle established by and conformable to said predetermined end position, to thereby form a final structural member comprised of the tape when the tape is removed from said receiving surface.

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