



Access/ATLAS II, Two-Stage Tape Placement System

abstract

The two-stage tape placement system isolates the functions of tape-angle and course-length shearing into one machine, the tape preparation machine, by cutting all the tape courses for a complete part and storing those prepared courses in a tape reel cassette. The second stage of the system, the tape placement machine, accepts this tape-filled cassette and performs the one remaining function by laying the prepared courses in their prescribed position. Separating these functions into two individual machines has solved the difficult tasks of dependable tape shearing and the accurate placement of long angle tape cuts.

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INTRODUCTION

The development of advanced composite continuous fibers, particularly graphite or carbon fibers, and the earlier development of thermoset resin pre-impregnation methods made these materials available for structural uses in the form of tow, and for use in fabrication techniques such as pultrusion and filament winding. For structural requirements not necessarily profiles nor surfaces of revolution therefore not producible by pultrusion or filament winding, and requiring relatively thin off-axis laminate composition, a demand arose for unidirectional preimpregnated material with individual fibers, or single tows, carefully columnated side-by-side on a paper backing creating a thin tape with the paper backing acting as a carrier for ease of handling.

This new material form, a unidirectional tape, made possible the construction of precisely oriented laminates by simply "laying up" using hand methods a series of plies each oriented in the precise direction according to the product design requirements. No longer was it necessary to use woven cloth, a mechanically less-efficient use of fibers, to achieve directional fiber orientation in a composite structure.

It soon became apparent that if this new material form, unidirectional pre-impregnated fibers, could be used in "hand layups," since it was made in continuous, relatively unlimited lengths and rolled up into spools for convenience in handling, it could then by design be made into spools of tape, say three inches wide, for dispensing and laying onto a flat surface by a machine specifically designed for that purpose. The first tape placement machines thus were designed in response to the need for an alternative to hand layup.

FIRST TAPE PLACEMENT MACHINES

The first tape placement machines were without exception all single stage machines, that is, all of the functions involved in tape laying were performed in one machine.

Because the materials were supplied from the pre-pregger in spool form, it seemed logical that the spool should be placed in a machine that would dispense a programmed length of tape while placing it on a flat surface in a straight path, cut the ending angle, lift and rotate, index one tape width, then repeat the process in the reverse direction. Indeed,

all machines were designed along these functional principles. The variations occurred only in degrees of automation. For example, a simple machine might use a limit switch or optical target placed directly on the table surface for determining tape course length, while the more sophisticated machine might employ computer controls which programmed course lengths. Lift and rotate could be done manually or with typical CNC control systems as could indexing for laydown position or direction.

The remaining function, tape shearing, virtually without exception in any machine was performed by a "guillotine-type" shear designed to cut through the composite tape, but not through the tape backing paper. Retaining the integrity of the backing paper was necessary because as the carrier for the composite tape it was used also to guide the tape to the laydown point, and to provide the means to dispense the tape from the supply spool. Typically, the backing paper remained intact from the original supply spool, through the entire tape head, to the backing paper takeup spool. Without this backing paper continuity the process could not be automatic, but would require a re-start for each tape course.

From the early 1970's when tape placement machines began to be used in the composites industry, to the current time, one of the most difficult problems to solve in the design of a tape placement machine is tape shearing, especially in wide width tapes cut at long sloping angles.

PROBLEMS IN TAPE SHEARING

Because of the need to precisely control the composite tape, keeping it on its backing paper until the last possible moment, that is, the moment it touches the tool or table surface under the laydown foot was virtually the only method available to the machine designer. Lifting the composite material from the backing paper to permit true shearing is quite difficult because of severe space constraints in the laydown foot area, and re-positioning the tape back onto the backing paper even though this might be done accurately does not solve the problem in long angle cuts of trying to lay the long tape "tail" of one course without at the same time trapping the beginning angular starting end of the next course.

To maintain tape position control, for lack of any better system, the machine designer was obliged not to cut the backing paper. The prevalent tape shear designs cut the material by pressing a sharpened blade (hence the name

"guillotine" but otherwise mis-named) vertically against the filamental material side of the tape while at the same time supporting the backing paper side of the tape with a semi-hard but resilient anvil. In principle and theory, the composite filaments, especially graphite, being stiffer and less resilient than the backing paper, are cut by the sharp blade. The backing paper, however, avoids being cut by in effect "recedeing" into the resilient anvil. The blade is stopped short of cutting through the paper; no real shearing action occurs.

This somewhat oversimplified explanation grossly understates the difficulty in executing most guillotine designs. Careful attention must be paid to precise alignment of the blade, selection of anvil material, as well as speed and pressure of the blade stroke, lest the backing paper is cut, or some filaments not cut, both events being highly undesirable.

The second most difficult problem to solve in tape placement machine design is also in the tape shear area, but has to do more with laying the material immediately after the cut, or the end of any course, commonly called the tape "tail." Except for 90 degree cuts which have no "tails," any other cut angle by geometric definition creates a right triangular-shaped "tail," the hypotenuse of which is equal to the width of the tape divided by the side of the cut angle.

For example, a 12 inch wide tape sheared at a 30 degree angle creates a tape tail 24 inches long at the end of its course. Obviously, this cut automatically creates the beginning of the next tape course, and in the case of this example it also is a right triangular shape having a 24 inch hypotenuse, but is a mirror image of the first since both are created by a single cut at 30 degrees across the 12 inch web.

Because these two triangular shapes, the end of one course and the start of the next, are both on the same backing paper, separated only by a thin knife cut, one cannot be placed by the laydown foot on the table surface without also placing the other, the leading end of the next course, on the table as well. Unfortunately, this leading end of the next course should not be in this position, but rather indexed over one tape width, and positioned in the reverse direction.

Attempts to solve this problem have resulted in very elaborate mechanisms: segmented laydown devices which progressively lift as the laydown point proceeds down the slope

of the angle, and vacuum pickup plates which retrieve the leading end tape tail as it is lifted free of the table when the tape head lifts, are two examples.

Whether or not these tape "tail" placement solutions function they all are complex, and in a single stage machine, must be placed in the immediate vicinity of laydown point where very little space is available. Lack of 100% dependability, as in the guillotine shear, is clearly a probability.

AN ALTERNATIVE SOLUTION

Any tape placement machine to be truly economic must be not only be accurate and fast, but also 100% dependable in all its functions. The two primary functions discussed above are especially important. For example, if even a single filament is not cut in a programmed shear, and the tape head lifts, the entire laminate might be lifted from the table resulting in a scrap part or at best a delay or re-work of the affected area. A similar result could be expected if a tape tail control device did not function causing a mis-placement or wrinkling of the laminate area.

Precisely because the solutions to tape shear and tape tail control dependability were extremely difficult if not impossible to execute, a new tape laying philosophy was defined.

Instead of stubbornly insisting on forcing all tape laying functions into a single machine, why not logically separate these functions into two machines: one to perform all the tape preparation tasks such as cutting angles and measuring course length; the other to perform only one function, that of laying the tape on the tool or table.

Using a variation of the well known principle of "division of labor," the tape preparation machine, not now needing to move over the surface of a table, could be highly specialized without constraints of weight or space. Similarly, the companion machine, the tape layer, having only one function to perform, could be streamlined and lay tape without pause for shearing and other non-productive operations.

Thus the philosophy of two-stage tape placement systems was originated.

STAGE I - TAPE PREPARATION MACHINE (Figure 1)

Dubbed "ACCESS," an acronym for "Advanced Composite Cassette Edit/Shear System," the tape preparation machine

processes pre-impregnated tape material from original supply spools by: continuously removing the tape from the original backing paper, cutting each tape course to length and angle, re-positioning the individual courses on a new backing paper, then re-winding the courses into a dispensing cassette for the Stage II, Tape Laying Machine.

Obviously, the tape preparation machine addresses the two primary considerations discussed earlier: tape shear dependability, and tape tail control. The shear used is not a guillotine, but is a proprietary device in the class of a vertical reciprocating knife. Because the tape can be lifted from the backing paper without space constraints, the reciprocating knife principle can be employed by passing the knife vertically through only the composite material leaving the backing paper intact.

Since all motions in this machine are under computer control, including the cutting device, it is quite easy to program the coordination of the tape through-put with the cross-feed of the cutting device, thus not only being able to cut virtually any angle, either positive or negative, but curves as well. Actually, two reciprocating knives function in concert in the design making possible compound angle cuts, e.g. "arrow-points" or "V's."

The all-important consideration of 100% cut dependability is rather simply achieved. The design inherently precludes a partial cut. Since the reciprocating cutter(s) pass from one side of the tape web to the other, any failure to do so is immediately apparent both to the computer and the operator. Because of the positive design, failure to cut can be caused only by a broken knife blade, a rare unlikely occurrence.

The tape tail control feature is also quite simply achieved by spacing the end of one course a sufficient distance from the start of the next course so that the laying of one does not trap the other. This is possible because the tape is lifted continuously from its original backing paper. The necessary "gap" between course ends is automatically programmed in by the computer control as the tape is re-placed on its new backing paper.

Typically, the entire laminate schedule for a part is programmed into the tape preparation machine, starting with the last course first and always working in reverse such that when the tape cassettes thus prepared are placed on the Stage II machine, the tape layer, the proper course sequence is achieved.

Without going through the entire sequence of operation, some unique features of the system should be mentioned.

Where the ending angle of one course is not complementary to the starting angle of the next course, the machine is programmed to re-cut the proper starting angle. The resulting very short piece of scrap is shunted into a scrap takeup spool, not into the part tape cassette. This obviates the need for the tape layer to perform the time consuming task of stopping to shear then moving off to the side of the part to deposit angle correction scrap.

Tape inspection devices are easily installed on the machine, and operator visual inspection is easy since all functions are at eye level and can be closely observed by the operator.

The shear device cuts all known reinforcements: graphite, boron, fiberglass, and aramid fibers. Materials with both backing paper and separator film can be processed in the machine.

To compensate for the accumulation of course length tolerances, the tape preparation machine "marks" the start and end of each course as it is prepared. The tape laying machine, Stage II, "reads" these marks thereby correcting for position at the start of every course.

STAGE II - TAPE PLACEMENT MACHINE (Figure 2)

The tape cassettes prepared on the Stage I machine, are loaded into the Stage II, Tape Placement Machine, called "ATLAS II," an acronym for "Advanced Tape Layup System (Second Generation). The prepared tapes are dispensed onto the surfaces of tools or a table exactly in the same manner as conventional single stage machines with the exception that the machine does not pause for shearing and performs no function other than actual tape laying.

The design objective of the Stage II machine is high speed tape laying achieved by eliminating non-productive functions, and by consequently decreasing the complexity and weight of all components to further improve speed by reducing inertia.

Unique features of the equipment now under construction include an all-composite gantry for light weight and high speed. Dual tape laying heads for product versatility, and six axes of computer controlled coordinated motion for growth potential and contour tape laying.

Since no new principles of tape laying are involved in the Stage II design, it is sufficient to list in Figure 3 the vital statistics of the machine to give the reader an idea of the machine size and capability.

SUMMARY OF ADVANTAGES

The two-stage tape placement system has a number of advantages over the conventional single stage machines. These specifically include:

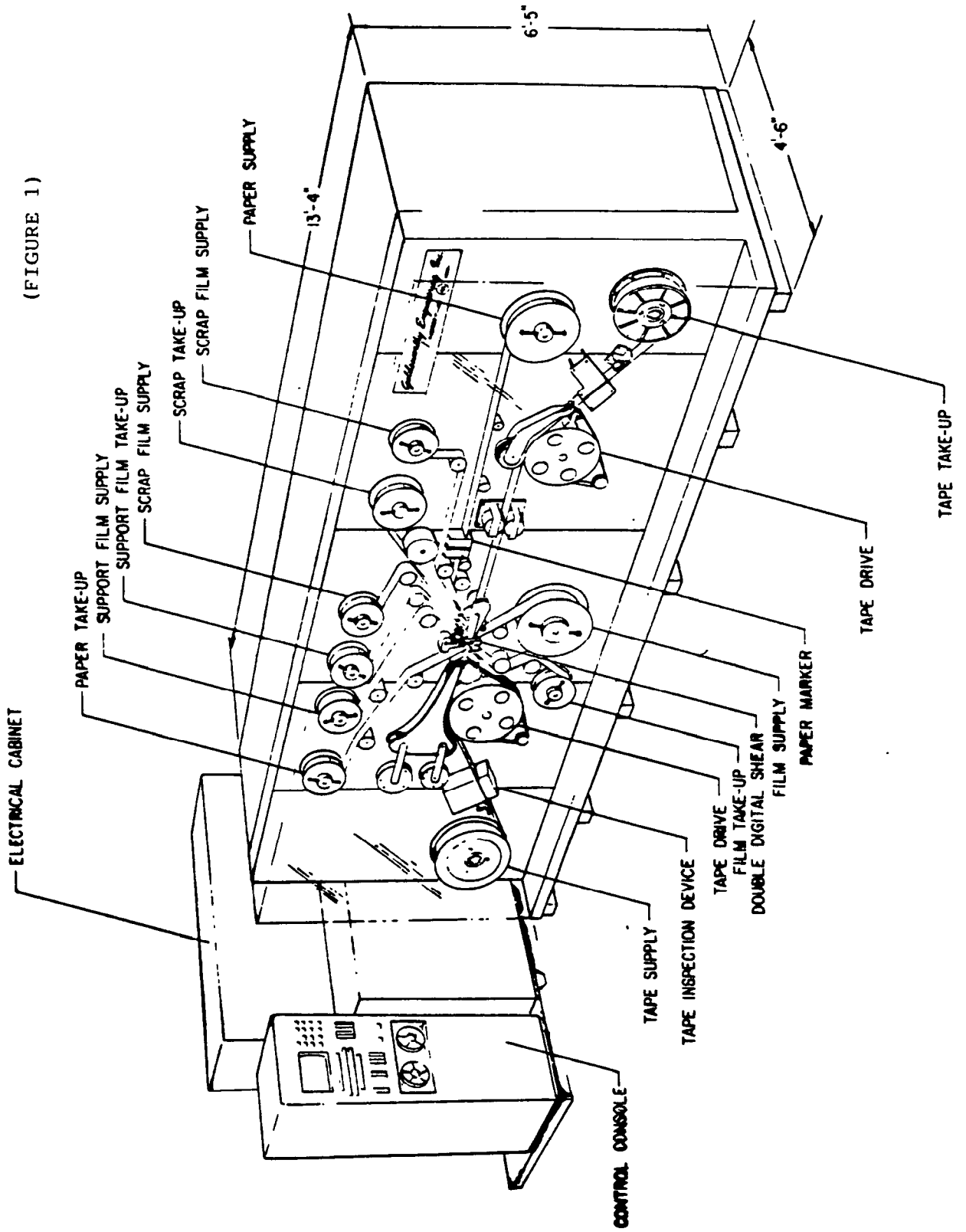
- * 100% shear dependability
- * Controls laydown of any-length tape "tail"
- * Inspects tape before laydown
- * Eliminates stop-to-shear laydown time loss
- * Decreases weight and complexity of laydown head to improve speed
- * All angle cutting scrap removed in tape preparation
- * Intermingling of different tape widths possible
- * Total versatility in shear angles (V-cuts, curves possible)
- * Any length however short or long can be programmed
- * Permits pre-stocking complete laminate "kits"
- * One ACCESS machine can service several ATLAS II machines
- * Materials can be intermingled (fiberglass, carbon, aramid)

CONCLUSION

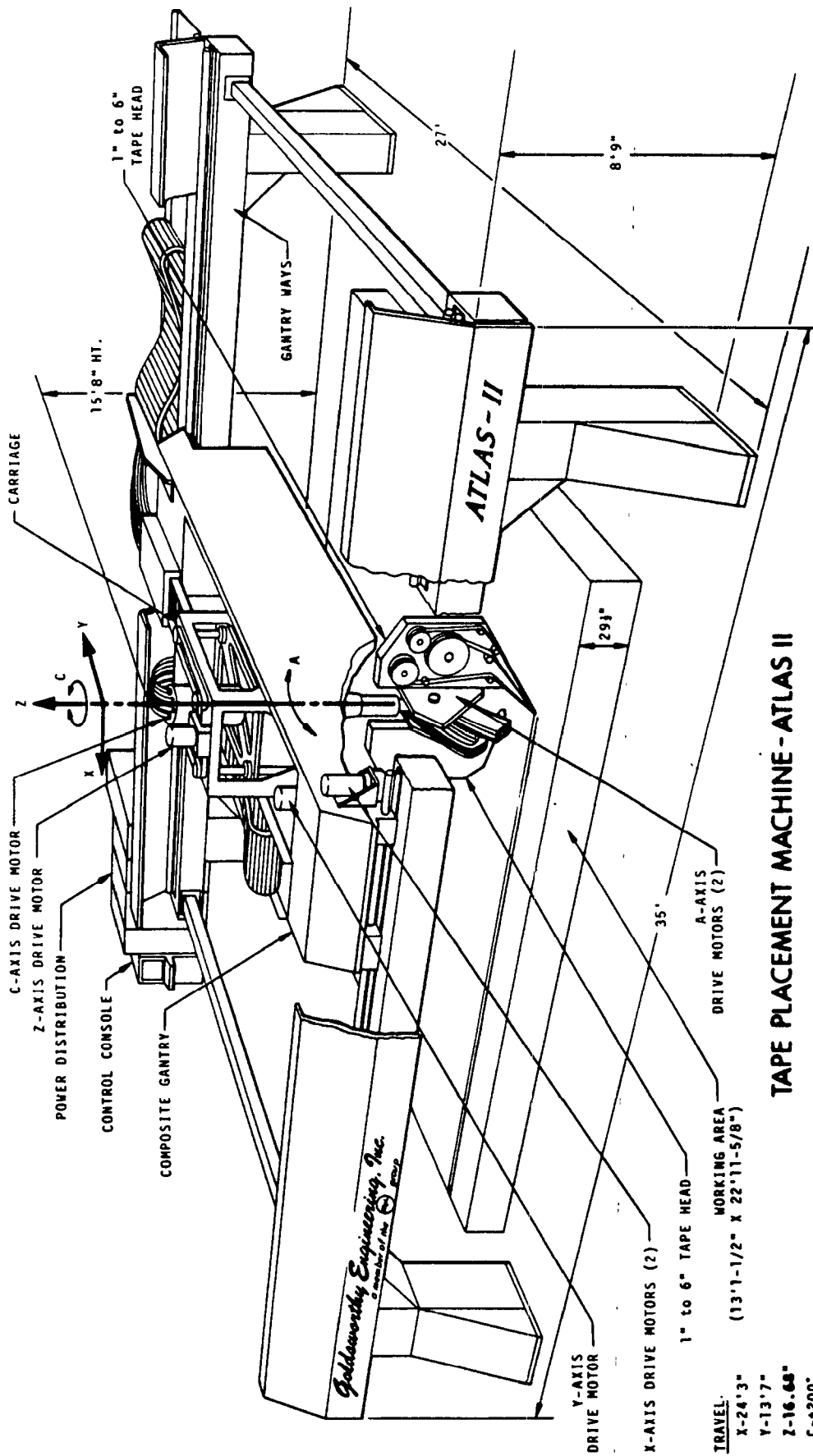
This entirely new approach to tape laying is not only innovative, but will substantially advance the economic and productive aspects of the composites fabrication industry by successfully solving some of the problems that have inhibited its growth. Perhaps for the first time a true, 100% dependable automated system can replace hand-fabrication methods.

TAPE PREPARATION MACHINE -- ACCESS

(FIGURE 1)



(FIGURE 2)



(Figure 3)

TYPICAL CAPABILITIES

| | | |
|---|-------------------------|---|
| ● | TAPE WIDTHS: | 1", 3" AND 6" |
| ● | TRAVEL: | X AXIS: 25 FEET Y AXIS: 15 FEET Z AXIS: 2 FEET C AXIS: 370 DEGREES ROTATION A AXIS: ±30 DEGREES |
| ● | FEED RATE: | X AXIS: 1200 IPM (INCHES PER MINUTE) Y AXIS: 1200 IPM X & Y AXIS: 1700 IPM Z AXIS: 360 IPM C AXIS: 7200 DEGREES/MINUTE A AXIS: 1800 DEGREES/MINUTE |
| ● | ACCELERATIONS: | X AXIS: 60 IN/SEC ² Y AXIS: 60 IN/SEC ² C AXIS: 340 DEGREES/SEC ² Z AXIS: 20 IN/SEC ² |
| | TAPE POSITION ACCURACY: | ± .005 IN. |
| | TAPE OVERLAP: | .000 IN. |
| | ALLOWABLE TAPE GAP: | .030 IN. |
| | RE-POSITION TIME: | 3 SEC. |
| | PLY STACK THICKNESS: | .005 TO 1.0 IN. |
| | SYSTEM REPEATABILITY: | ± .005 IN. |