BANDOLEER FEEDING MECHANISM FOR AN AUTOMATED ONION TRANSPLANTER

by

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ABSTRACT

A mechanism has been designed to separate individual onion transplant cells from a continous polyethylene bandoleer belt using a series of 19 gauge, nichrome resistance wires mounted on an eight inch aluminum disc. The mechanism is capable of processing 800 plants per minute at a ground speed of three miles per hour.

ACKNOWLEDGEMENTS

I would like to thank Dr. Steve Searcy who helped me define my project and served as my Undergraduate Fellows program advisor. I would also like to acknowledge John Ried, Terry Conn, and Susan Bryan for their work on the other components of the transplanter. I would especially like to recognize Dr. Wayne LePori who gave me support and motivation when it was needed most.

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Chapter I

INTRODUCTION

1.1 BACKGROUND

The bulb onion is an important vegetable crop in Texas, usually ranking first in value or second to that of carrots. Since 1979, an average of 26,400 acres of onions valued at $66,333,000 have been harvested annually. (Texas Vegetable Statistics, 1981). A significant amount of this acreage including the Laredo and Winter Garden areas, active during November and January; and the Trans-Pecos and High Plains regions, beginning in March, is transplanted. On the High Plains, the short-day, mild onions are grown exclusively from transplants because weather conditions -- frost, wind, and excessive rain -- make it impracticle to plant before early March. Brewer (1978) listed other advantages of transplanting over seeding:

1. Transplants start growing in the field much faster than seeded plants.
2. Seedlings compete better with weeds that must start from seed.
3. Seedlings utilize moisture better because their roots are placed deeper below the soil surface than seed and fast growth keeps the roots in moist soil.
4. Soil crusting is not a problem because plant tops are already out of the ground.
5. Healthy plants are placed at optimum spacings in the field forming strong, uniform stands.

Onions are presently transplanted by hand: a method that is costly, time consuming, labor intensive, and often inaccurate due to human error and poor plant placement. When planted by hand, the spacing in a large field tends to spread from the recommended distance, resulting in a thinner stand; and the plants are inserted into the ground with little concern about the root placement, resulting in "J-root".

Longbrake (1983) reported that 1983 labor costs for transplanting are ranging from $170 to $180 per acre for plants placed at a four inch row spacing. A fast worker can transplant about one acre per day by hand; however, the average is one half of an acre. Therefore, if a farmer wants to plant 100 acres in the critical two week planting period, he would have to have at least 15 reliable people in the field every day and would spend approximately $1700 to $1800; whereas, a four-bed, automated transplanter traveling at a constant ground speed of 3 mph would be able to plant 100 acres in approximately 21 hours, requiring one employee to drive the machine.

An automated transplanting system is now being developed that will be capable of containing transplants in a continous belt to be handled by automated machinery, seperating the individual plant cells from the continous belt, or bandoleer, immediately before they are placed in the ground, and placing them in the ground.

1.2 PURPOSE

The purpose of this study is to develop a mechanism that separates individual plant cells from a continous belt and feeds them to foam-covered belts that deliver them to the opened soil trench. The mechanism should:

1. Require a limited amount of human labor.
2. Withstand common field conditions such as vibration and dust.
3. Be able to operate at a minimum ground speed of 3 mph (4.8 kph).
4. Maintain a continous operation.

1.3 SCOPE

This study includes a review of the literature, discussion of preliminary considerations, discussion of the final design, and recommendations.

Chapter II

LITERATURE REVIEW

A method of containing the seedlings in a bandoleer of plant cells for automatic and high speed handling was concieved by Brewer (1978) who devised a system to intermittently join two polyethylene strips by heat welding to form cells, making a continous bandoleer belt. Brewer reported that roots were minimally disturbed, tops were easily untangled, and uniform cell size was attained using that method.

Maw (1981) developed a similar method to connect bare-root tree transplants in a continous belt by holding the plant stems between two strips of tape.

To detect bad seedlings and sort them from good seedlings, Ardalan (1981) designed, tested, and evaluated two devices; one utilizing an optical circuit and the other based on linear displacement of a potentiometer, concluding that both were acceptable for use on an unmanned tree transplanting machine.

The advantage of transplants raised in a greenhouse over those from a conventional plantbed was demonstrated by Huang (1979).

The effect of the plastic bandoleer on grass plants was tested by Hauser (1982), concluding that there was no difference between the performance of transplants set in the ground with plastic encasing the root plug and those with a bare root plug. He also noted that the transplants produced significantly larger plants than those seeded conventionally.

An automated "blockmaker" that produced paper bandoleers at 10,000 plant cells per hour was built by Boa (1979). He used 60 gm/m/m paper coated on one side with polyethylene and on the other side with latex adhesive to contain the plant cells.

A method of rapidly delivering ball-rooted plants to an opened soil trench using two foam-covered belts driven parallel to each other at a lineal velocity of 700 feet per minute was developed by Stevenson (1981).

An automated transplanter has been developed using the bandoleer concept which automatically fed and transplanted grass seedlings (Moden and Hauser, 1980) at a maximum ground speed, limited by the rpm of an electric feed-drive motor, of .78 mph (1.25 kph).

Chapter III

DESIGN METHOD

3.1 PRELIMINARY SINGULATING CONCEPTS

Four methods of severing the polyethylene plastic between the plant cells in order to separate an individual plug from the bandoleer belt were evaluated.

3.1.1 Punching

The first three preliminary designs made use of a sharp edge to punch the plastic webbing. As seen in Figure 1, a sharp knife that remains perpendicular to the travel of the bandoleer and is mounted on the radius of two discs, rotating at equal speeds, extends and punches the plastic band between the plant cells; however, it is difficult to maintain a continous operation using this technique because the relative velocity of the tip of the blade and that of the bandoleer,if both are moving at constant speeds, are equal only at one point.

A method of punching the plastic webbing using two rotating sets of knives was evaluated as Figure 2 illustrates. The knives mesh together at the point of contact with the plastic, causing a scissor or shearing effect. Angling the edge of the cutting blade would reduce the force required to cut the plastic by initiating a cutting motion beginning at the bottom of the webbing and progressing toward the top. Graphic evaluation showed that there would be a tangential force induced on the

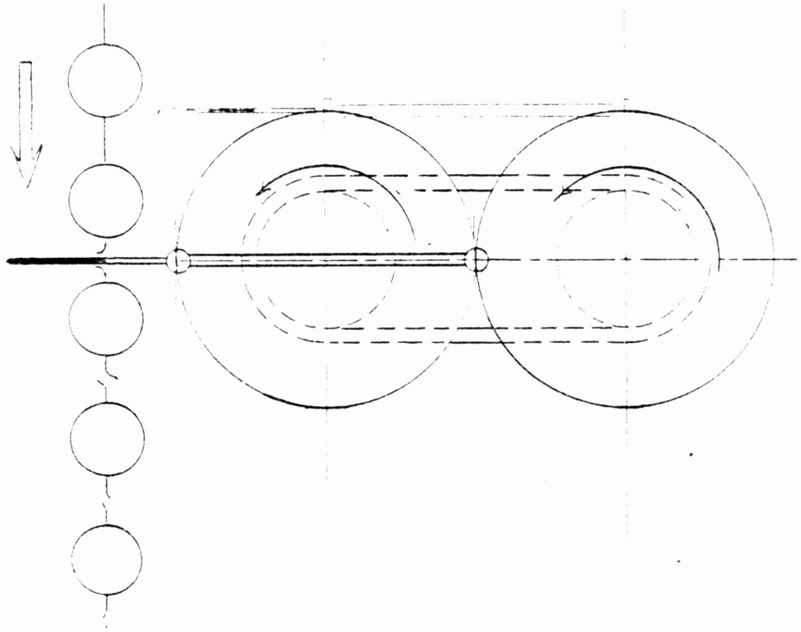

Figure 1: Punching Concept No.1

tips of the blades as they meshed together tending to break the brittle blades or, over a period of time, disturb the critical clearance between the blades.

The third concept dealing with punching the plastic contributed to the final design by introducing a sprocket arrangement. As seen in Figure 3 two sprockets used to drive the bandoleer belt, one containing small blades between each plant cell trough and the other having indentions for the blades to fit in, mesh together at a single point, separating a cell from the continous belt. A driven press wheel would be required to feed the bandoleer belt since the belt would be freed as soon as a plant cell was severed from it.

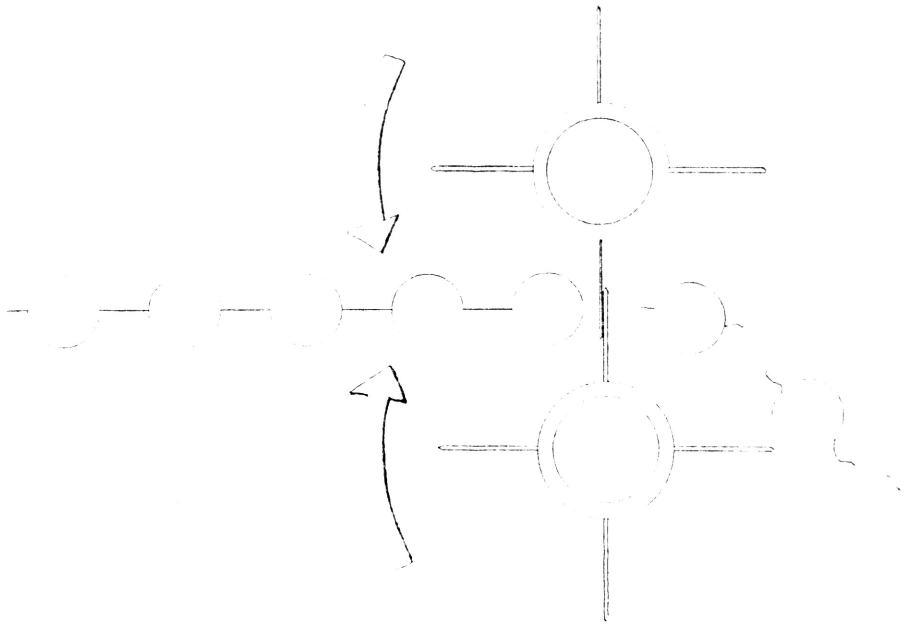

Figure 2: Punching Concept No.2

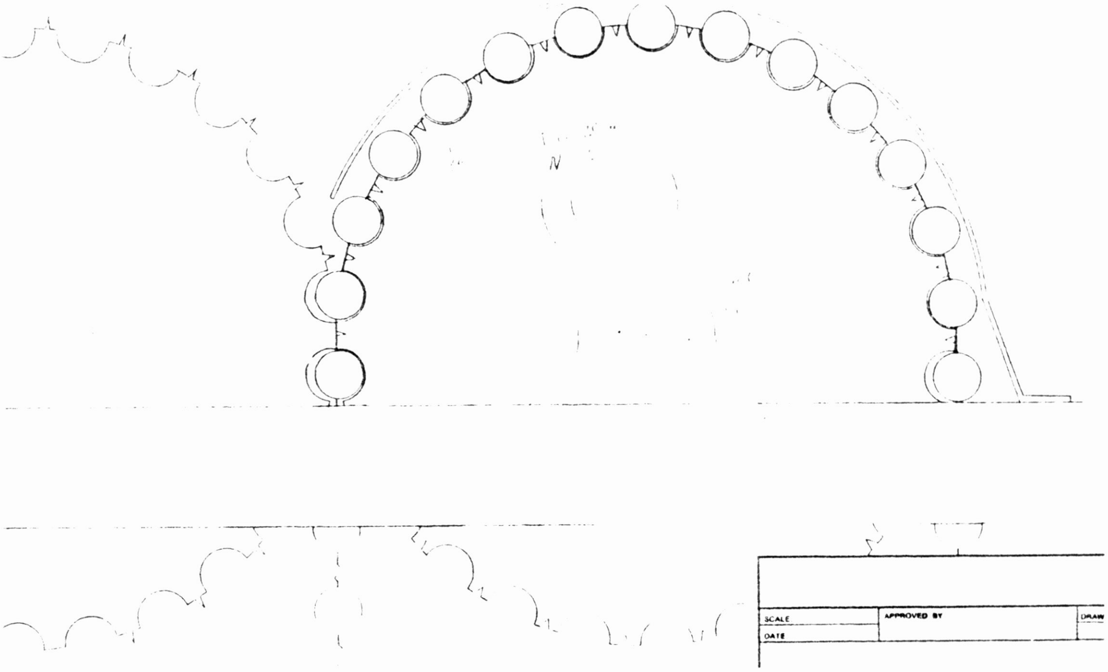

Figure 3: Punching Concept No.3

3.1.2 Slicing

Through some qualitative experimentation done with a razor blade and a bandoleer belt, I observed that slicing the plastic requires considerably less force than punching it; therefore, a design using that concept was developed. As illustrated by Figure 4, knives would be attached intermittantly to a driven chain mounted at an angle to the horizontal plane having a horizontal velocity equal to that of the bandoleer belt. The relative velocity of the blade to the bandoleer would only have a vertical component. holding the bandoleer and separated cells while exposing the plastic webbing to the blade presented problems.

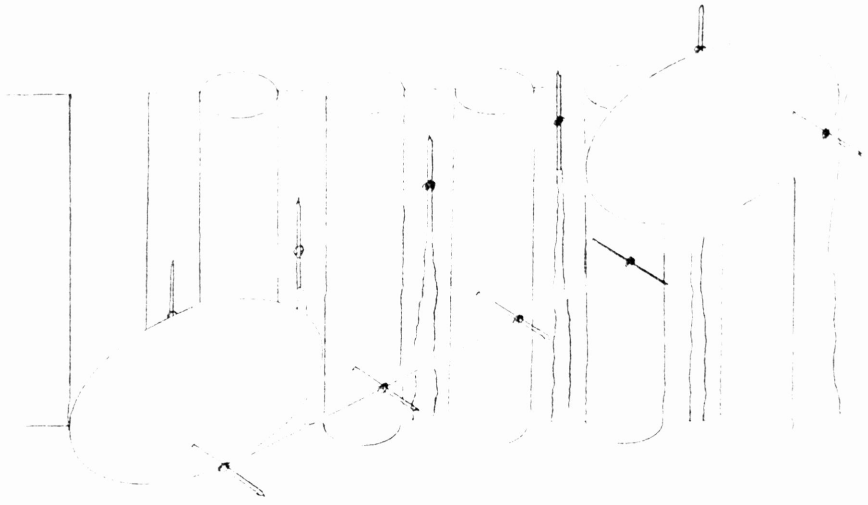

Figure 4: Slicing

3.1.3 Melting With a Laser

Lasers are used in industrial applications to cut a variety of materials, including plastics; so some basic calculations were performed to determine the feasibility of using one to cut a bandoleer. The energy required to bring a given volume of medium density, 8 mil polyethylene, the width of which was determined by a typical laser spot size of .05 inches, to its melting point in the time required, .023 seconds, was determined to be about 40 watts. A laser capable of generating 40 watts is not economically feasible for this project. It would also present a safety problem, being able to cut skin easily.

3.1.4 Melting With a Hot Wire

A method using a section of high resistance nichrome heating wire to melt webbing between individual plant cells was selected for incorporation into the final design. It was possible to develop a simple, efficient, and relatively low cost mechanism using this method; however, to determine the feasibility of its use, the current needed to maintain an adequate temperature level in the wire to cut the polyethylene had to be determined.

3.2 NICHROME WIRE CURRENT TEST

3.2.1 Apparatus

To determine the amount of current required, I set up an experimental wire test designed to simulate real conditions. The experimental set-up, as seen in Figure 5, consisted of the following components:

1. A 12.83 volt tractor battery.
2. A heavy-duty switch.
3. A 9.65 ohm variable resistor.
4. A six inch, .35 ohm, 19 ga. piece of Nichrome resistance wire mounted on a 1 cm wide strip of asbestos.
5. A 10.15 ohm resistor in series with a Fluke ammeter.

The 12.83 volt battery was connected in series with a switch using 4 ga. wire which was used throughout the system. The maximum current drawn from the battery was calculated to be 36.6 amperes when the variable resistor was set at a resistance of zero, so the use of 4 ga. wire was required. The switch was connected in series with a 9.65 ohm variable resistor.

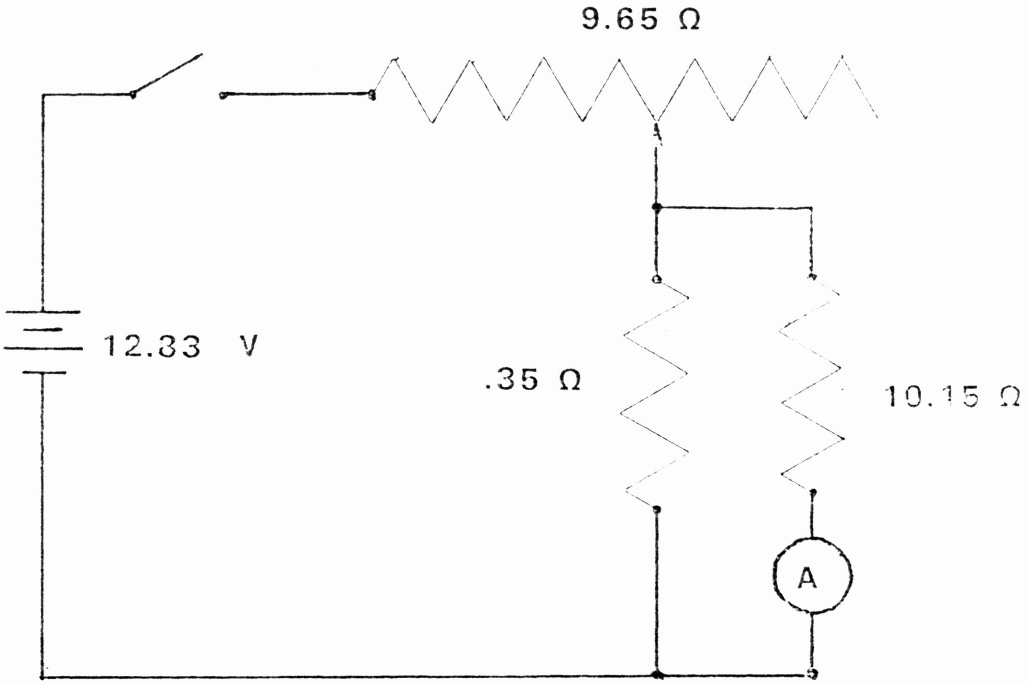

Figure 5: Nichrome Wire Test Circuit Diagram

A variable resistor that could handle up to 40 amperes and a high heat loss, signifying a high power loss, was not available within the department; therefore, I had to build one. The resistor was built using 20 feet of nichrome wire coiled through an asbestos plate. The resistance was varied by attaching the wire from the switch to one end of the coil rigidly, then allowing the wire leading to the test stand to be attached to any of the coils on the front side of the plate. A fan was directed on the coils to dissipate the heat generated. The variable resistor was then attached to the test wire.

The test stand consisted of a six inch piece of Nichrome wire attached to a five inch long, .25 inch wide piece of asbestos that had the sides shaved off at 45 degree angles, leaving approximately one-sixteenth of an inch flat surface area for the wire to rest on. The wire rested in a groove on this flat surface. A wire completed the circuit by returning to the battery.

The current drawn through the test wire was higher than any of the ammeters available could measure; therefore, I wired a 10.15 ohm resistor and ammeter in parallel with the test wire. The maximum current drawn through this line was less than 2 amperes which was accurately read using a Fluke ammeter.

3.2.2 Methodology

A number of tests were run using amperages ranging from 17.1 amperes to 3.1 amperes to determine the optimum current needed to melt the polyethylene webbing between the bandoleers. The response of different currents was evaluated by noting qualitative results such as the color of the wire, the ability of the wire to cut the plastic without tension, and the accumulation of plastic on the wire. Some of the most important data points are described below.

1. 17.1 amperes - The wire got very hot turning bright red and burning through the asbestos test stand. The plastic melted rapidly upon contact and left no residue or accumulation on the wire.
2. 9.5 amperes - The wire turned a dark red color and then grayer when a 3500 fpm wind was blown across it; as well as, when a long series of plant cells was fed to it quickly. The change in color signifies a decrease in temperature; however, in this case it did not inhibit the cutting in any detectable way.

3. 5.4 amperes - The plastic was cut as fast as I could feed the bandoleer belt to the test wire, even though it had no red color. The <u>first</u> <u>accumulation</u> of plastic on the wire occurred at this point.
4. 3.1 amperes - Tension had to be applied to the bandoleer to cut it. Accumulation of plastic on the wire was a problem.

From this data I determined that the optimum current needed to satisfactorily melt the polyethylene was approximately 10 amperes; information that was required to plan a circuit layout for the final design using the available voltage and current from a tractor battery.

Chapter IV

FINAL DESIGN

The final design used the resistance heating wire method to severe the plastic between the individual plant cells. Heating wires were mounted on a rotating sprocket that was ground driven. The system consists of five parts:

1. The electrical components.
2. The sprocket assembly.
3. The bandoleer feeding assembly.
4. The drive assembly.
5. The frame assembly.

4.1 ELECTRICAL COMPONENTS

Resistance are mounted across the width of a singulating sprocket at 25 places. The .21 ohm resistant heating wires were combined in series and parallel, using the desired current of approximately 10 amperes and the available voltage of 12 volts from the tractor's electrical system, as design parameters. As shown by Figure 6, three sets of six wires connected in series, drawing 10.3 amperes, and one set of seven resistance wires connected in series, drawing 8.3 amperes, were connected in parallel with the battery which supplied a total current of about 40 amperes. 8.3 amperes was acceptable since plastic accumulation was not observed on the wire until the current was reduced to 5.4 amperes and the polyethylene still cut satisfactorily. A John Deere 4440 tractor with a 72 ampere alternator generates a minimum current of 60 amperes. The air conditioner draws a maximum of 15 amperes; therefore, the existing electrical system will handle the singulating apparatus if there are a limited number of electrical devices operating on the tractor.

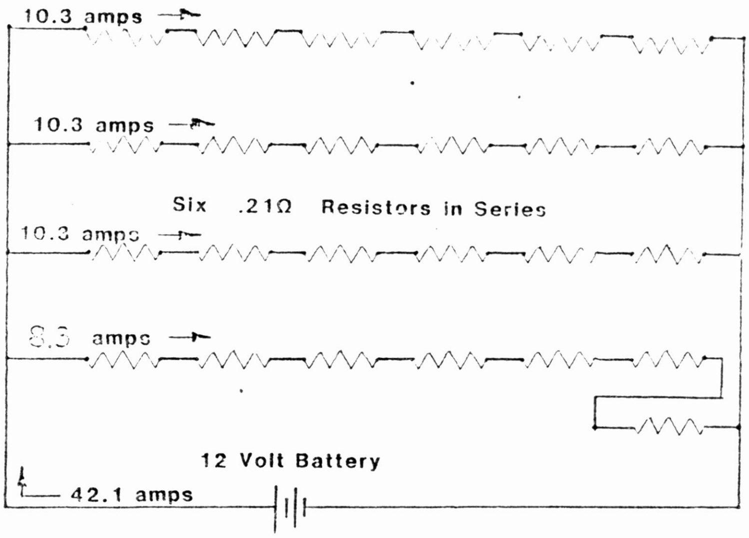

Figure 6: Circuit Diagram for Cutting Wires

The wires are connected to two-terminal, heat resistant blocks mounted on either side of the sprocket with the nichrome wire attached to one of the terminals and an insulated, low-resistance wire attached to the other, connecting it to the rest of the system. After some investigation, I discovered that many of the heat resistant plastic terminal blocks were resistant only up to an operating temperature of 380 degrees F; therefore, ceramic terminals should be used.

Transmitting the current to the rotating sprocket presented a problem. IEC Corporation; in Austin, Texas; gave me an estimate on a slip-ring, capable of transmitting 60 amperes at 12 volts, of $806. This is not economically feasible for this machine, so an alternate method of transmitting the current needs to be developed.

4.2 SPROCKET ASSEMBLY

Individual plant cells are separated from the bandoleer belt on the sprocket: an 8 inch diameter, 3 inch deep, aluminum disc constructed from an 8 inch outside diameter aluminum pipe with 1/2 inch thick, 6-1/4 inch diameter discs pressed and spot-welded into a 1/8 inch shoulder in the pipe. Semi-circular grooves, containing the plant cells, are machined at 25 equal spaces around the perimeter of the disc. The grooves are 29/64 inch deep and have a diameter of 21/32 inch as shown in Figure 7 Fluorosint 207, a heat resistant plastic made by the Polymer Corporation with an operating temperature of 500 degrees Farenheit, is mounted on the spaces between the grooves. Measuring 1/4 inch by 21/64 inch by 3 inches, the plastic wire support will have 45 degree angled sides to guide the plant cells into the grooves. A one inch shaft through the center of the sprocket recieves power from the ground drive system.

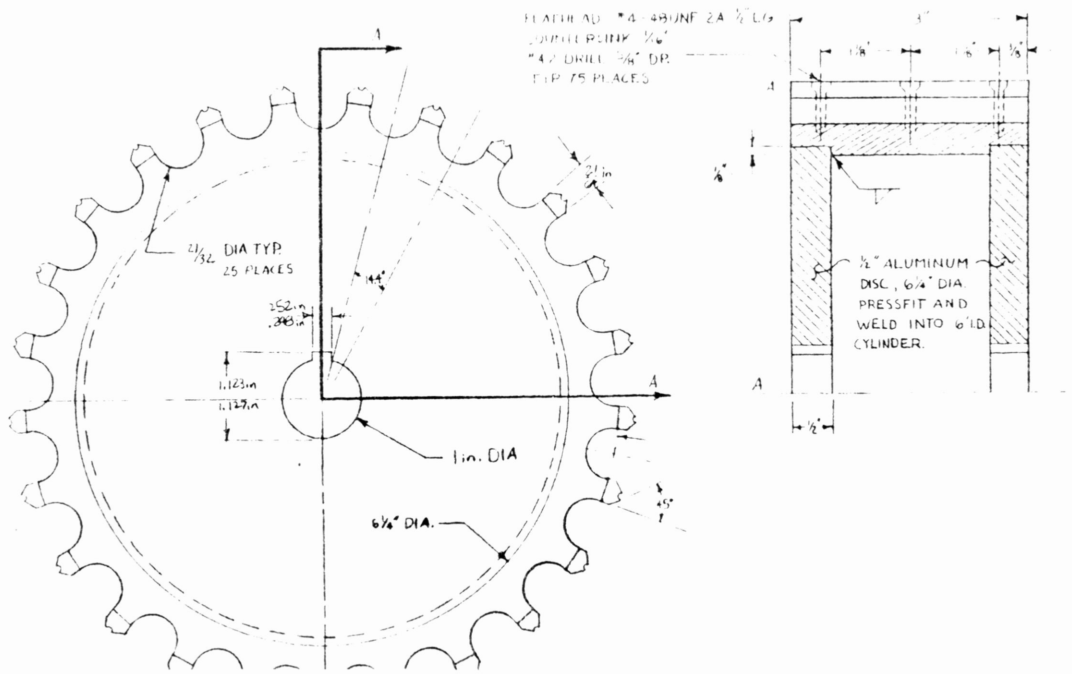

Figure 7: Singulating Sprocket Assembly

4.3 BANDOLEER FEEDING ASSEMBLY

The bandoleer must be positively fed to the sprocket since the sprocket will have no means of retaining the bandoleer after a plant cell has been cut off; therefore, the bandoleer belt will ride over a teflon coated, slide plate of light gauge metal driven by a 4 inch press wheel as seen in Figure 8 The press wheel is a 3 inch long, 2 inch diameter aluminum cylinder with one inch of foam epoxied to its surface. The foam serves to grip the bandoleer and drive it onto the singulating sprocket with minimal slip. A light gauge, teflon coated side pressure plate will gradually press the plants down onto the hot wire and eventually into the grooves.

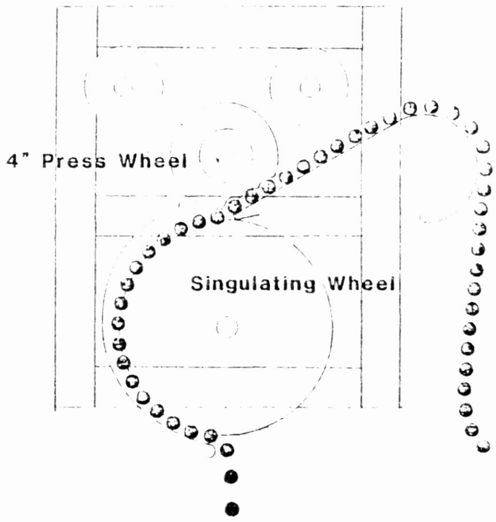

Figure 8: Bandoleer Feeding Assembly

4.4 DRIVE ASSEMBLY

A ground wheel drives the singulating mechanism, relating plant spacing and forward ground speed directly to the processing speed of the singulator. The shaft that the singulating sprocket is mounted on is driven by a chain connection to the ground wheel. From the singulating sprocket, the power is transmitted to the press wheel which turns twice as fast as the large sprocket. Two three inch roller-bearing idlers are used to keep tension on the chain and to reverse the directions of the press wheel and the singulating sprocket.

4.5 FRAME

The frame is made of 1-1/2 inch angle iron as seen in Figure 9

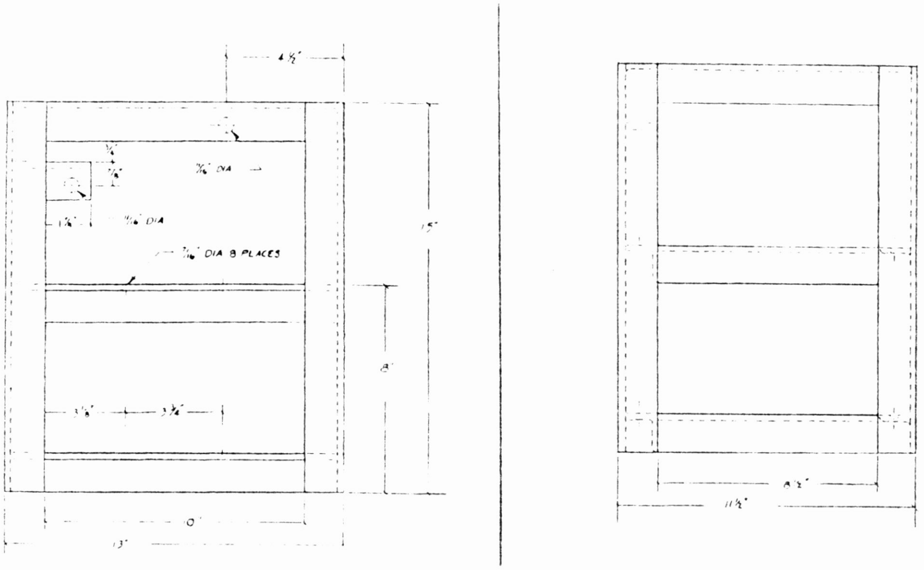

Figure 9: Frame Assembly

Chapter V

CONCLUSIONS

The wire test proved the hot wire method, used to cut webbing between the plant cells, is feasible. It was sucessfully incorporated into the design of a simple singulating mechanism capable of processing 800 plants per minute. I forsee some difficulties with this design -- listed below and followed by possible solutions -- that need to be addressed through further research.

1. A single row planter draws approximately 40 amperes from a tractor's electrical system. What could be used to generate enough power for an eight row transplanter, capable of transplanting 4 beds?

   A series of alternators mounted on the tractor and driven off of the V-belt drive that currently drives the alternator with a series of batteries added as a resivoir for the charge would supply the needed power; although, the alternators would tend to add a load to the driveshaft and use a given amount of horsepower.

2. The slip-ring assembly was estimated at $806 for each row unit: an unfeasible cost for this machine. How else could one transfer the power to the cutting wires on the rotating, singulating sprocket?

   One possibility is to use a less expensive slip-ring by increasing the voltage and reducing the current. This may be done in two ways:

a) Use a step-up transformer in front of the slip-ring, then mount a step-down transformer on the singulating sprocket.

b) Attach a commercially available generator to the power-take-off shaft of the tractor capable of generating up to 220 volts AC or DC.

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