

DEERE & COMPANY

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DES MOINES ROBOTIC COTTON PICKER SPINDLE ASSEMBLY SYSTEM

Attached is a report summarizing the development work and the technology advancements associated with the automated cotton picker spindle assembly system. The system features three AdeptOne robots.

The project breaks new ground for the Company in the use of robots to perform assembly work. Manufacturing Technology is available to assist unit personnel identify and apply the technology to assembly operations.

A 10-minute videotape summary of the project is available at the Technical Center. For further information, please contact Ken Dechert (5-3791) or me.

Darrell Donis

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Attachment

DES MOINES ROBOTIC COTTON

PICKER SPINDLE

ASSEMBLY SYSTEM

Ken Dechert

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INTRODUCTION

This report summarizes the development work and the technology advancements associated with Des Moines' Robotic Cotton Picker Spindle Assembly System. The system was designed to assemble cotton picker spindles, insert the spindles into a picker bar, and torque the spindle nut into the picker bar. All the system development work and build were performed in-house by Des Moines personnel.

CONCLUSIONS

Des Moines successfully applied robotic assembly technology to the manufacture of cotton picker spindles. The system is well built, has high reliability, and is designed to be highly interactive with the operator. The automated assembly system features several unique technologies that maximize the entire process utilization. A significant reduction in direct labor expense has resulted. The project successfully breaks new ground for the Company in the use of robots to perform assembly work. It provides the opportunity to utilize and better understand the capabilities of this newly emerging technology.

RECOMMENDATIONS

The Company should continue to pursue robotic assembly technology where appropriate. Applications within Deere may be limited due to low production volumes, system integration costs, and lack of product design for automatic assembly. However, a great amount of knowledge has been gained from the Des Moines experience. This experience can be leveraged when developing new applications.

The Company should monitor robotic assembly technology. The technology is maturing rapidly. Machine sensors have become better integrated with the robot controller. Assembly robots with much greater payload capacity were featured at the 1988 Robot Trade Show. Furthermore, manufacturing philosophies such as Design for Assembly (DFA) will also increase the potential for this technology.

I. BACKGROUND

The Des Moines Works first explored the concept of robotic assembly in early 1986 using an existing Hitachi welding robot. A prototype gripper and mock tool stations were built. During the same period, the Manufacturing Technology Department at the Technical Center was responding to multi-unit interest in robotic assembly. Several potential robotic assembly projects were identified, including the one at Des Moines. In addition, the Department investigated several assembly robot vendors. In May 1986, the Technical Center purchased an AdeptOne robot with integrated vision (Exhibit 1). The system was purchased to perform lab evaluations of candidate applications and to gain experience in robotic assembly.

In June 1986, the Des Moines Works borrowed the Adept robot and prototyped a robotic assembly concept. The prototype system was designed and built by Ray Gold, Engineer at Des Moines, with assistance from Rick Jerz, Engineer at the Technical Center. The system included the necessary hydraulics, software, and hardware to assemble cotton spindles. The concept of robotically assembling the spindle nut was evaluated and successfully proven. The prototype work helped everyone better understand the robot's capabilities and limitations. It helped Des Moines develop a better estimate of system capacity and overall build costs. It also increased their confidence in the capabilities of the technology.

An AFE was submitted in October 1986 for \$363,000 to build and install the assembly system. The proposal was to design and build the complete system in-house. Outside project build quotes were evaluated but considered too expensive to justify acceptance. The project AFE received management approval in February 1987.

The finished system was designed by Ray Gold and built by factory toolmakers and machinists. Ray Gold and John Orvis programmed the robot and the Allen/Bradley PLC. The system was transferred to the factory floor in February 1988 and is presently running production parts.

II. DISCUSSION

A. Selection Criteria

Several other cost reduction alternatives were considered before selecting robotic assembly. Fixed (hard) automation was determined to be more expensive and less flexible than robotic assembly. Partial automation of the present manual assembly method was also considered. However, this alternative did not meet cost savings objectives. Outsourcing the process was also considered. Stringent quality requirements made this alternative less desirable.

Robotic assembly was selected because it best fit the selection criteria. The robotic automation equipment was deemed capable of positioning the prime parts within the necessary insertion tolerance of .004". The robots could perform the assembly work within the required cycle time. The present cycle time is 2 picker bars assembled every 4.4 minutes. The spindle assembly weight (.43 lb.) and size (4-3/4" x 1-1/4") were within the rated payload. Furthermore, the robots could be redeployed elsewhere if necessary.

The spindle assembly is a high volume part and particularly well-designed for automation. Projected production schedules for cotton picker spindles vary between 600,000 to 1,500,000 per year. There is a small variety of spindle assemblies eliminating the need for frequent changeovers. Furthermore, assembly is accomplished in a single access plane (Exhibit 2). Stacking parts (versus multi-access assembly) greatly simplifies the system engineering requirements.

B. System Description

The picker bar assembly is a complex arrangement of rotating bar and spindle assemblies (Exhibit 3). The design provides efficient picking capability recognized to be the best in the industry. Each picker bar assembly contains twenty (20) spindle assemblies. A central rotating shaft contains gears that mesh with the gears on each individual assembly. As the central shaft turns, so does each individual spindle. The cotton spindle assembly is made up of five parts. The assembly consists of a spindle nut, an upper and lower bushing, a machined spindle, and a dust collar.

The system is designed to be highly operator-interactive. A Cherry message center displays status messages. A flashing light indicates operator attention is required. An Allen Bradley video control panel allows the operator to manually control the process. The video panel replaces 150 push buttons and 40 indicator lights. A paragraphic system layout is also available to the operator. This illuminated system map pinpoints overall system status. The operator and maintenance employee will also make use of "expert systems." This computer-based technology prompts the user as it attempts to diagnose the system failure. "Procedure Consultant" software written by Texas Instruments is used.

Overall system control of safety light beams, sequential operation, and start-up and shutdown is resident in Allen-Bradley PLC 2/17. All robotic logic, crash avoidance, work balancing, and assembly work is handled by the robot controllers. The system is designed around a six-station rotating carousel (Exhibit 4). Listed below is a station-by-station description of the assembly process.

Station 1

Station 1 is a manual load and unload station. The operator removes two assembled picker bars from the carousel and places them on a rack. An unassembled bar is then placed into position on the carousel. The operator must also stock the various parts loading stations, perform preventive maintenance, and oversee the entire operation.

Station 2, 3, 4

Each station features an AdeptOne robot. It is the robot's task to assemble the cotton spindles and either place them in the picker bar or reject the defective spindles. The robots are programmed to run as a trio or in any pair.

A complex arrangement of nine bowlfeeders position the dust collar, upper and lower bushings, and spindle nut within each robot's work envelope. The feeders are manufactured by Syntron, a Division of FMC.

The robot first enters the spindle nut pickup station. A fiber optic sensor verifies positioning of the nut. The robot grasps the nut and places it in the bushing press. Upper and lower bushings are pressed into the spindle nut. The nut assembly is bur-nished to ensure alignment and sizing between bushings. The nut assembly is then greased.

The cotton spindle is purchased as a forging and is machined at Des Moines. The operator positions two 10 x 10 racks of spindles within reach of the robot arm. The robot controller identifies the coordinate position of the next available spindle and positions the nut assembly over the correct spindle. A fiber optic sensor ensures that the spindle was properly gripped.

Lastly, a dust collar is picked and pressed into place. The collar holds the entire assembly together. Before leaving the dust collar press station, an electric motor and transducer instrumentation rotate the spindle and inspect for excessive torque. Over-torqued spindle assemblies are rejected. The robot positions the completed spindle assembly in the picker bar.

Robots share dust collar press stations and nut feeders. Crash avoidance is achieved by establishing conditional priorities. Each robot, prior to entering a crash zone, queries the other robot's status register to determine if the zone is available for entry. Sharing robot work envelopes reduced system build expense and maintenance costs.

Software was developed to totally integrate the three robots. Work balancing between the three assembly stations is accomplished through full, real time commu-nication between robot controllers. Each time a completed spindle assembly is placed in a picker bar, the robot updates the other two robots' registers. Before any robot begins another spindle assembly, the system evaluates whether to begin the next assembly or wait for a new set of bars to index into position. If one robot lags behind, the process control will perform logic to command the others to adjust. This routine compensates for delay that may occur at one assembly station or any combi-nation, thus maximizing the entire process utilization. Adept Corporation indicated this was the first time that anyone had developed serial communication software between their robots where no robot acts as host.

Station 5

This station is designated for in-process quality control. The operator is responsible for performing a variety of inspections.

Station 6

This station automatically torques the picker nuts into the picker bar. First, a gear box mechanism mounted on a swing arm drops down and engages the central rotat-ing gear shaft within the picker bar. The central gear shaft is then rotated. This is necessary to properly mesh the spindle gear with the central gear shaft.

Nuts are torqued in multiples of four (4) by double-roller Nichols hydraulic motors mounted to a ballscrew and servo-driven carriage. A new technology was developed for automatic starting of the spindle nut into the bar. A spring-loaded pilot applies pressure to the tip of the spindle as the socket engages the nut. Upper and lower torque limits are maintained by hydraulic pressure transducers and pressure-reducing valves. The transducers emit a digital analog

output to the process control. Previously, torque could only be held within a range of 25 to 75 ft. lbs. This new torquing method is capable of holding a much tighter torque range of 45 to 55 ft. lbs. This increased torque control greatly improves the accuracy of the spindle nut spacing. Bars are then automatically run in and tested for overall drive torque. Appropriate error messages regarding nut torque and shaft torque are displayed to the operator.

C. Savings

Several categories of savings were identified. The single largest portion of savings result from a reduction in direct labor. At present production schedules, the manual method requires approximately ten (10) direct labor employees. The incentive standard for the manual assembly method was 16.5 standard hours per 100 bars. Automating the process has reduced the standard to 6 standard hours per 100 bars. This represents a reduction of greater than 60 percent.

Savings of over \$20,000 are expected through a one-time inventory disinvestment. Finished spindle nut assemblies no longer accumulate ahead of the bar assembly process. A reduction in field service claims, less spindle nut repair work, and a reduction in defective spindle replacements at the gaging operation are also anticipated.

III. SUMMARY

This project is an excellent example of a factory and a corporate department identifying a need and working together to produce a solution. The project successfully breaks new ground for the Company in the use of robots to perform assembly work. It provides the opportunity to utilize and better understand the capabilities of this newly emerging technology.

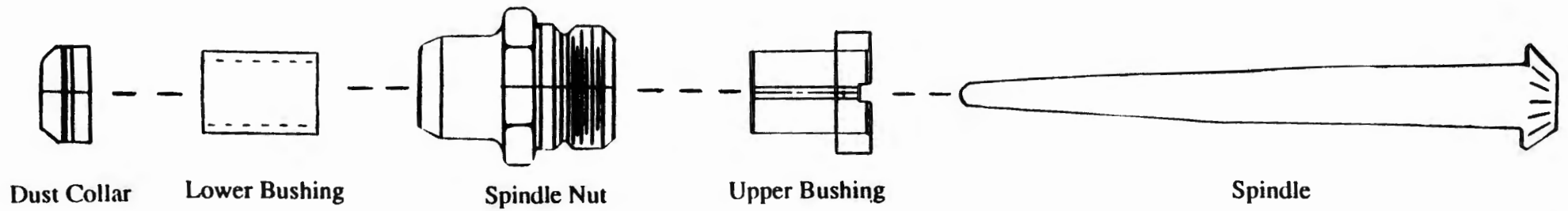
A ten-minute videotape summary of the project is available for loan from the Technical Center. For further information contact Ken Dechert at the Technical Center (5-3791) or Ray Gold at Des Moines (3300).

ADEPT ROBOT

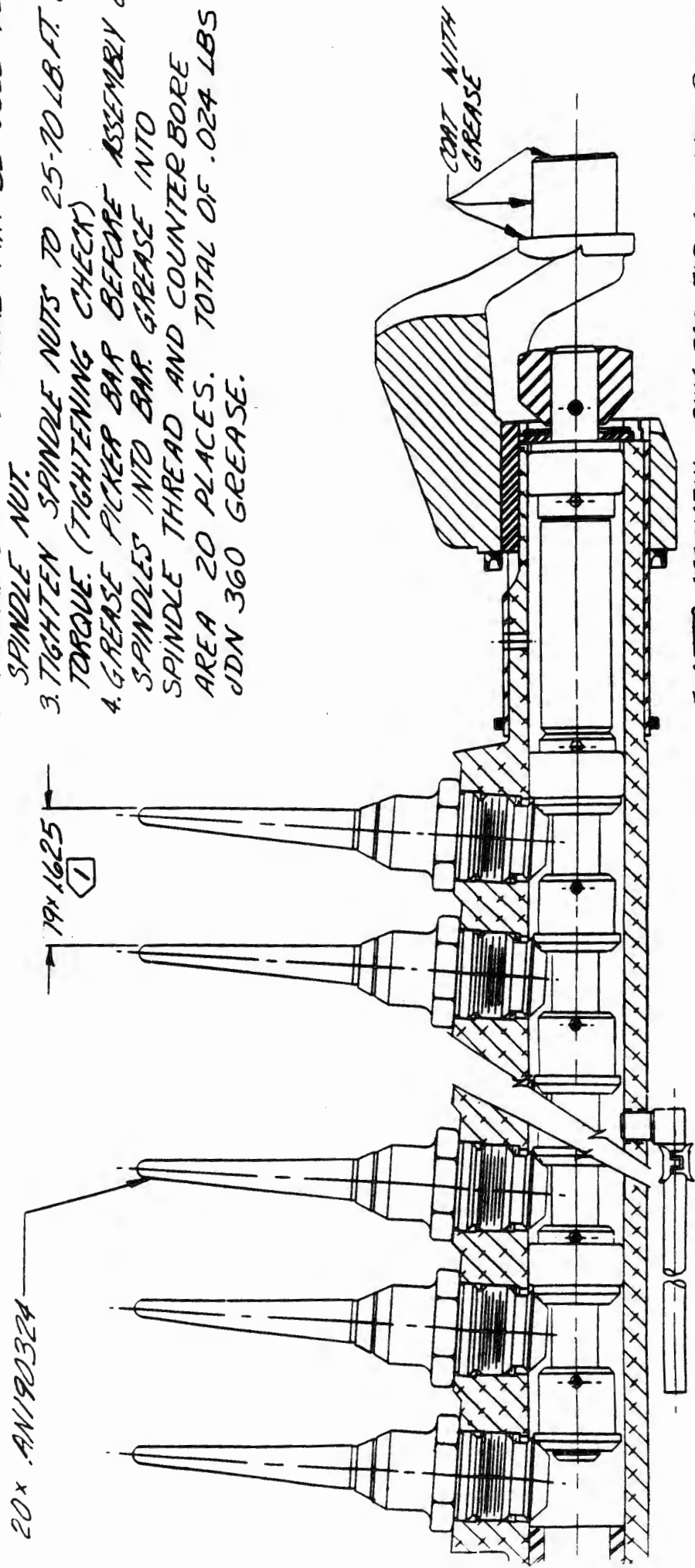


Maximum Reach: 31.5 inches
Maximum Vertical Stroke: 7.7 inches
Payload: 13 pounds
Maximum Velocity: 30 feet/second
Repeatability: +/- .001 inches
Programming Language: Val II

COTTON SPINDLE ASSEMBLY DIAGRAM

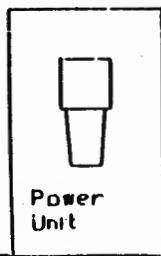
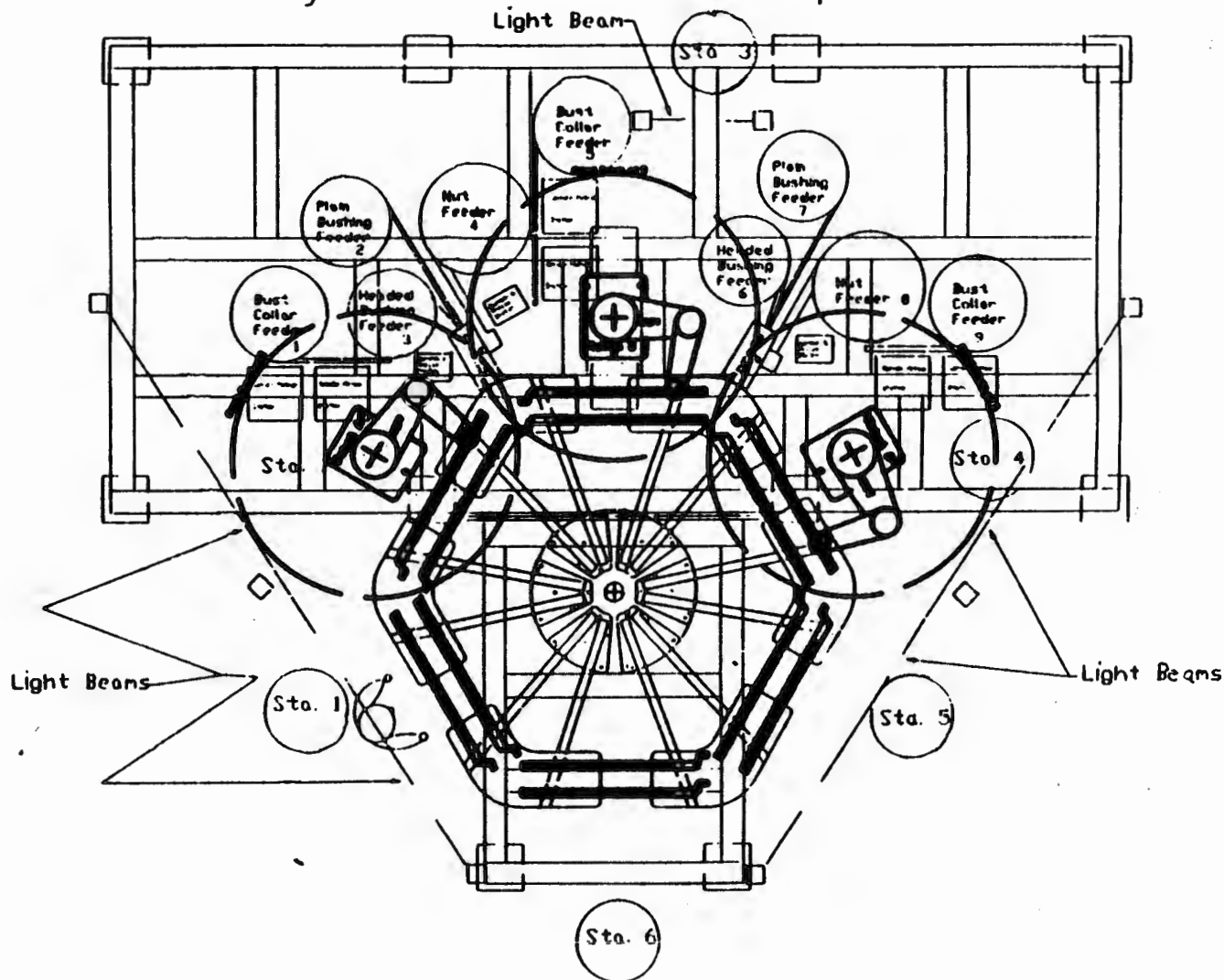


- 1. SPACING BETWEEN SPINDLES MUST BE WITHIN A TOLERANCE OF .000 TO +.010 MEASURED FROM THE HIGHEST SPINDLE "HIGHEST" SPINDLE IS DETERMINED BY A GAGE. CHECK ON CIRCULAR AREA OF TAPER WITHIN 1.25 INCH ZONE BEGINNING AT START OF TAPER.
- 2. A MAXIMUM OF 2 SHIMS MAY BE USED PER SPINDLE NUT.
- 3. TIGHTEN SPINDLE NUTS TO 25-70 LB.FT. OF TORQUE. (TIGHTENING CHECK)
- 4. GREASE PICKER BAR BEFORE ASSEMBLY OF SPINDLES INTO BAR. GREASE INTO SPINDLE THREAD AND COUNTER BORE AREA 20 PLACES. TOTAL OF .024 LBS JDN 360 GREASE.

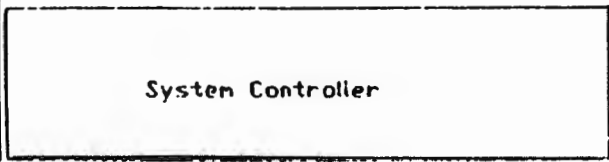


- 5. AFTER ASSEMBLY; RUN BAR FOR 1 MINUTE @ 2500-3100 RPM; DRIVE SHAFT ROLLING TORQUE ON THREE TURNS OF SHAFT SHALL BE 9 IN LBS MAX. AVERAGE WITH A PEAK OF NO MORE THAN 500 LB. SHIM SPINDLES WITH LOBBIN SHIMS AS NEEDED TO OBTAIN SPECIFIED TORQUE RANGE.

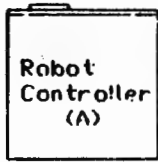
Plan View of Robotic Assembly System (Picker Spindles/Bars)



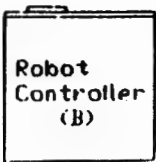
Power Unit



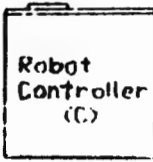
System Controller



Robot Controller (A)



Robot Controller (B)



Robot Controller (C)

EXHIBIT 4

20 in

Mach. # 6382
System DWG.

Drawing File Ray/Royl

John Deere
Des Moines

Spindle Assy System
Ray Gold
Jan 1987