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An Investigation into Computer Numerical Control to Computer Numerical Control Part Program Transfer

Paul Avis
University of Northern Iowa

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Abstract

The problem in this study was to identify and describe the serial communication parameters and hardware needed to provide computer numerical control(CNC) to CNC part program data transfer.

AN INVESTIGATION INTO COMPUTER NUMERICAL CONTROL TO COMPUTER NUMERICAL CONTROL PART PROGRAM TRANSFER

A Research Paper for Presentation
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In Partial Fulfillment of the
Requirements for the Non-Thesis
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by
Paul Avis

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Approved by:

Dr. R. Pershing
Advisor

Date: 8-4-93

Dr. J. Fecik
Graduate Faculty Member

Date: May 5, 1993

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Chapter 1

Introduction

In manufacturing industries the perpetual striving to maintain competitiveness has lead to concepts of World Class Production and World Class Maintenance. Along with these, manufacturing industries have incorporated technology as it has become available. This has lead to the introduction of Computer Numerical Controls(CNC) into the main stream manufacturing plant.

With Computer Numerical Controls, new methods of part programming have come to the forefront. Serial ports have replaced tapereaders and Direct or Distributed Numerical Control(DNC) systems have been used to load part programs. Since any system eventually will fault, a way of supplementing or backing up DNC has been recognized as needed. This paper has dealt with the concept of Computer Numerical Control to CNC part program transfer in like machines in cellular manufacturing.

Problem

The problem in this study was to identify and describe the serial communication parameters and hardware needed to provide computer numerical control(CNC) to CNC part program data transfer.

Purpose

The purpose of this research was to provide an alternative method of loading part programs into like computer numerical controlled machine tools. A secondary purpose was to provide a world class production and maintenance operation by providing more flexability to insure continuous production.

Need

The need for this study was based on manufacturing industries constant exploring of new and more reliable methods of manufacturing. In industry, the trend has been to shift all CNC part program down loading to direct or distributed numerical control(DNC) (Knight, 1990, p. 48). This has lead to a shift from machine tools with tape reader capabilities to machine tools that only have serial communication ports for part program loading. The industry standard has been RS-232 serial communications for direct or distributed numerical control part program loading.

Direct or distributed numerical control was considered to be the best method for CNC part program loading. Like all systems, failures occur and DNC has been no exception to the rule. An alternative method was needed, to substitute for DNC, at varying times.

Research Questions

The following research questions were explored in this study.

1. What hardware was required to effect computer numerical control to computer numerical control part program data transfer?
2. What physical hardware limitations exist for communications between CNC's?
3. What signals associated with handshaking and protocol were required for CNC to CNC part program transfer?
4. What CNC executive program parameters affect part program transfer between CNC's?

Assumptions

The following assumptions were used in this study.

1. The first assumption was that a need exists for CNC to CNC serial data transfer.
2. The second assumption was that serial data transfer could be accomplished.
3. The third assumption was that if failure of one CNC did occur that production could be transferred to another CNC.
4. The fourth assumption was that due to cellular manufacturing techniques, like machine tools would be in close proximity.

Assumptions cont.

5. The fifth assumption was that failure would occur at some point in the operation of the DNC network.

Limitations

The following limitations were adhered to in this study.

1. The study would only look at DynaPath Delta 10M and Delta 20M computer numerical controls.
2. The study would only address the RS-232C serial communication ports of these controls.
3. The study would be limited to a five machine production cell with four machining centers with DynaPath controls.

Terms

AMERICAN STANDARD CODE for INFORMATION INTERCHANGE (ASCII): A data transmission code which has been established as an American standard by the American Standards Association. A code where seven bits represent each character.(Luggen, 1988)

BAUD: A measurement of speed at which binary digits are transmitted. Bits per second.(Glasgal, 1990)

BINARY CODE: Based on binary numbers, which are expressed as either 1 or 0, true or false, on or off. Base-2 number system.(Luggen, 1988)

Terms cont.

BIT: Binary digit having only two possible states. (Gay, 1992)

BUFFER STORAGE: A place for storing information in a control system or computer for planned use. (Gay, 1992)

BYTE: A collection of binary digits(bits) used to represent letters, numbers, or symbols in a computer's memory.(Luggen, 1988)

CHARACTERS: A general term for all symbols, such as alphabetic letters, numbers, and punctuation marks. It is also the coded representation of such symbols.(Luggen, 1988)

CLOCK: A device in the computer that generates periodic signals that are used to synchronize a computer's operation.(Gay, 1992)

CNC: Computer Numerical Control(Luggen, 1988)

CODE: A system describing the formation of characters for representing information, in a language that can be understood and handled by the control system.(Noaker, 1992)

CONTROL CHARACTER: Normally non-printing ASCII code that controls the operation of hardware or that performs other functions.(Noaker, 1992)

DATA: A representation in the form of words, symbols, numbers, characters, digits, etc.(Noaker, 1992)

Terms cont.

DNC: Distributed Numerical Control; This study uses DNC to mean the use of a host computer to download part programs to CNC machine tools. DNC is not to be interpreted as one host computer running several machine tools in real time.(Noaker, 1992)

FULL DUPLEX: Simultaneous and independent transmission of data in two directions over one communications channel.(Glasgal, 1990)

HALF DUPLEX: Data transmission through a communication line in only one direction at a time. (similar to CB radio, push-to-talk, release-to-listen system) (Glasgal, 1990)

HANDSHAKING: An electrical signal used by a receiving device to stop transmission from the sending device until data already received can be processed. (Noaker, 1992)

MACHINING CENTER: Machine tools, usually numerically controlled, capable of automatically drilling, reaming, tapping, milling, and boring multiple faces of a part.(Luggen, 1988)

PARITY CHECK: A check that tests whether the number of ones (or zeros) in any array of binary digits is odd or even.(Luggen, 1988)

PROTOCOL: A formal set of rules governing the format and timing of messages exchanged between two

Terms cont.

communication devices.(Glasgal, 1990)

RS-232C: A widely used serial interface. (Glasgal, 1990)

SERIAL: Data sent one bit at a time. Serial communications devices permit sending one bit of data at a time.(Glasgal, 1990)

WORD: An ordered set of bits which is the normal unit in which information may be stored, transmitted, or operated upon.(Gay, 1992)

Chapter II

Computer Numerical Control

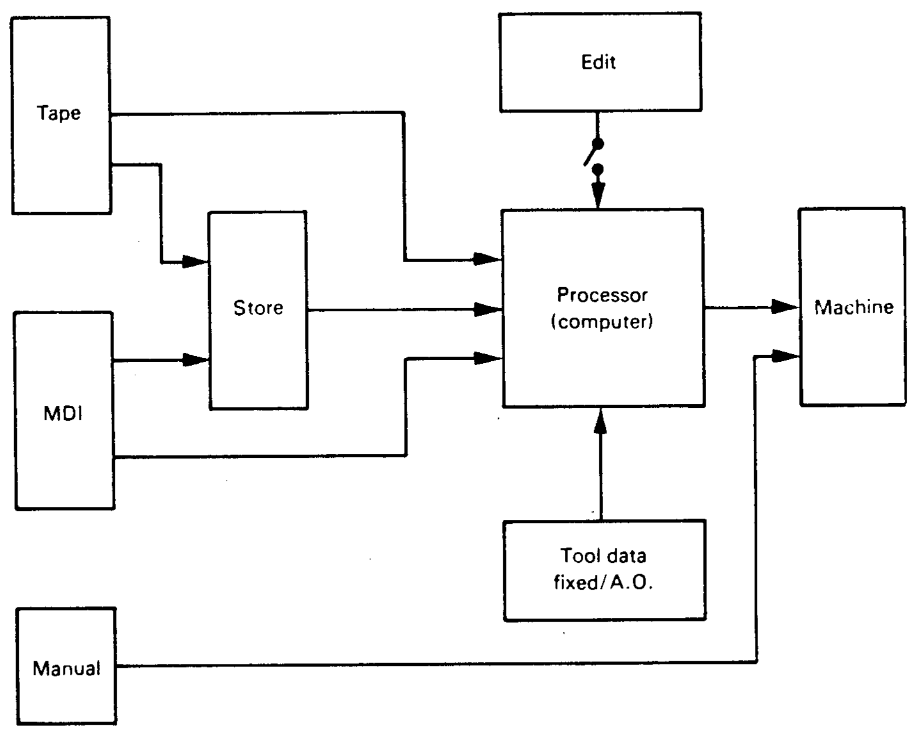
The concept of numerical control could not be appreciated without a brief review of its birth, growth, and makeup. John Wilkinson built a metal cutting machine in the eighteenth century, but it wasn't till the second world war that a great focus was put on numerical control manufacturing.

Prentence and Roberts (1978) stated, the Parsons Corporation, under contract to the united states air force, got the Massachusetts Institute of Technology(MIT) involved in 1951. M.I.T. demonstrated a milling machine run by a numerical control programed by a punched tape as the input media in 1952. (Vlahos, 1968)

Pusztai and Sava (1983) stated that the first generation numerical controlled machines used vacuum tubes and relays. These controls were large and very slow compared to controls of today. Second generation numerical controlled machines used miniature electronic tubes and sometime later solid-state circuits. With the advances in computer technology, numerical controlled machining started to rapidly change. By the time the third generation was introduced integrated circuits were in widespread use. This along with read only memory(ROM) used for exective program storage and random access memory(RAM) used for part program storage had set the stage for modern numerical control machining called computer numerical control(CNC).

The basic sections of the computer numerical control consists of the input section, the computing section, the memory section, the control section, and the output section. (Pusztai and Sava, 1983) The figure following shows a CNC data flow block diagram.

Figure 1. CNC Data Flow Block Diagram



Note. From Fundamentals of Numerical Control (p. 192) by W. Luggen, 1988, Albany; New York: Delmar Publishers Inc. Copyright 1988 by Delmar Publishers Inc. Adapted by permission.

The function of the input section was to provide data to the CNC in the form of coded instructions. Examples of units used as input devices are punched tape, magnetic tape, keyboard, laptop computer, direct numerical control, and distributed numerical control. (Prentice and Roberts, 1978)

The part program, once inputed into the CNC, became the set of instructions to perform calculations. (Vlahos, 1968) The control section of the CNC controlled how those operations were performed. It translated the part program and specified the sequence of events. The computing section performed simple addition, subtraction, multiplication and division. The resulting data was fed back to the memory for storage or outputed to the various output sections of the CNC. Output devices are servodrives, readouts, cathode ray tubes(CRT's) or tape punch units.

Serial RS-232C Communication

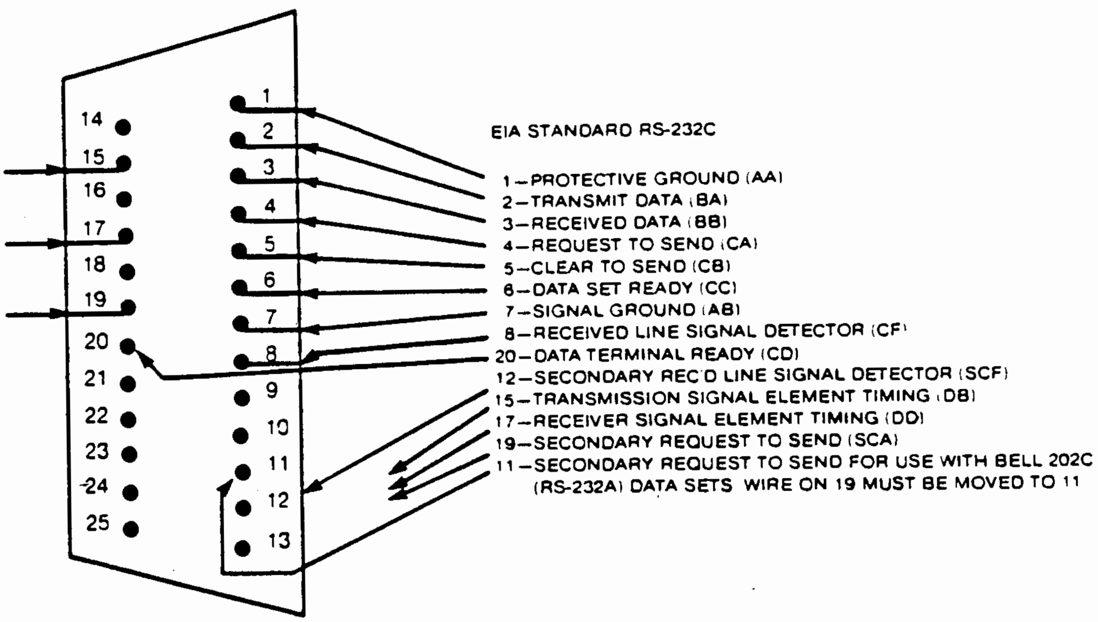
From the early numerical control machines which were part programed by punched cards or punched tapes to the modern CNC machines which have shifted to serial communication for part programming has led to an industry standard of RS-232 serial data transfer. Serial RS-232 communication has been around since the 1960's. In the 60's the maximum speed limit of 20,000 bits per second(bps) was considered to be the standard. Today, speeds in the tens of thousands and even millions bps are routine and require an interface that can operate in those ranges. It is testimony to the success of the RS-232 interface that the acceptance of newer, higher speed, and enhanced interfaces has been slowed by the widespread use of RS-232.

Helmers (1989) states the formal name of RS-232 serial communication is "Interface between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Exchange" (page 12). RS-232 uses the terms data terminal equipment(DTE) and data circuit-terminating equipment(DCE) to describe the computer and the signal-conversion devices, respectively. RS-232 applies only to the DTE and DCE interface and has nothing to do with the operation of the communication line (example: a phone line) between the DCE's. The RS-232 DCE interfaces, at each end of the communication line, are completely independent of each other.

The RS-232 standards were drafted by the Electronic Industries Association (EIA) to provide a common interface standard. (Karp, 1976) The "RS" in the title stands for "recommended standard" and the single letter often used following RS-232 indicates the revision level of the standard. (example: RS-232C or RS-232D) The standard specifies requirements for the mechanical, electrical, and operational aspects of the DTE-DCE interface.

Mechanically the RS-232 connector contains 25 pins arranged in the layout shown in the figure below.

Figure 2. RS-232 Pin Layout



Note. From Basic Data Communications (p. 29) by Tektronix Corporation, 1978, Beaverton; Oregon: Tektronic Corporation. Copyright 1978 by Tektronic Inc. Reprinted by permission.

The 25 pin connector implies that there are 25 wires in every RS-232 cable. Not all of these 25 wires,have functions assigned to them, and even the wires that do have assigned functions are not used in all the applications. Therefore, many RS-232 cables have fewer than 25 wires. Connecting two devices with an RS-232 cable requires caution to ensure that the cable has the correct wires for the application you wish to use it for. (ICOM, 1989)

Electrically, the characteristics of RS-232 serial communication deals with the voltage and the rate at which data is transmitted. RS-232 is a digital interface in which a positive voltage in the range of +3 to +25 volts represents a "0" or on condition. A negative voltage in the range of -3 to -25 volts represents a "1" or off condition. The range between -3 and +3 volts is the area of transition and does not represent a valid signal. The maximum speed of data exchange recommended for RS-232 is 20,000 bps over a cable of 15 meters. What happens in reality is a longer cable is often used when the transmission speed is less than the maximum recommended speed. Cable length can also exceed 15 meters when shielding is used to reduce noise and interference. The recommended speed limits and distance limits of the RS-232 standard result from the cable physical characteristics and specifications. Glasgal (1978) mentions these limits result from RS-232 using an unbalanced electrical interface, using a common ground wire for all signals(pin 7). An example of this technique is the wiring in automobiles. RS-232 electrical characteristics are somewhat flexible depending on the quality of transmissiom line and environment in which it is applied.

RS-232 functional signals in the table following are the most frequently used wires and pins.

Table 1

RS-232 Signal Designations

Function	Pin	Common Name	Abbreviated	Direction
				DTE DCE
Ground	7	Signal Ground	SG	
Data	2	Transmitted Data	TD	>>>>>
	3	Received Data	RD	<<<<<
Control	4	Request to Send	RTS	>>>>>
	5	Clear to Send	CTS	<<<<<
	6	Data Set Ready	DSR	<<<<<
	8	Data Carrier Detect	DCD or CD	<<<<<
	20	Data Terminal Ready	DTR	>>>>>
	22	Ring Indicator	RI	<<<<<

Table 1 cont.

Timing	15	Transmit Clock	TC	<<<<<
	17	Receive Clock	RC	<<<<<
	24	External Xmit Clock	ETC	>>>>>

Source: Basics of Data Communications (p. 89) by H. R. Karp, 1976, New York: Mc-Graw Hill. Copyright 1976 by Mc-Graw Hill. Adapted by permission.

Each wire is assigned a function and is used in only one direction. The two signals that carry data are transmitted data(TD) and received data(RD). All other signals exist to allow "0" and "1" bits to travel across these wires. When looking at the table on the last page it is important to note that all signals are named from the point of view of the data terminating equipment(DTE).

RS-232 protocol is carried out by the control signals. The bare minimum of control signals necessary for simple data transfer operate in pairs. First, two of the signals used to indicate that your equipment is powered up and running are data terminal ready(DTR) and data set ready(DSR). These two signals must be on for data to move across a RS-232 interface.

Another pair of signals called request to send (RTS) and clear to send(CTS) are used to control the flow of data on transmitted data(TD) and received data(RD) wires. The RTS/CTS exchange between the DTE and DCE is like a dialog of "may I" and "you may". The DTE requests permission to transmit by applying the appropriate voltage to pin 4, this turns on RTS. When the DCE detects the presence of RTS, it performs several functions, including turning on the outgoing carrier signal and giving permission for the DTE to transmit by turning on the clear to send(CTS) signal. Now the DTE sends data bits on TD to the DCE. When the DTE no longer has data to send it turns off RTS and the DCE responds by turning off CTS.

RS-232 serial communication is a basic method of sending data in series. By the use of hardware, standards, control signals, and signal protocol we see that RS-232 communication has served as a viable system for sending serial data since the 60's.

Chapter III

Part Program Transfer

The following steps were required to transfer a part program from one Delta 10 computer numerical control to another Delta 10 control. Each control was configured to run a Machining System Inc. horizontal machining center. Both Delta 10 controls were located in a cellular manufacturing layout.

The initial step was to idle both Delta 10's so that nothing done associated with the part program transfer would affect any machine function. The machines were put into manual and then a cable was plugged into each controls serial RS-232C communications port. This was done by locating the serial RS-232C port on the side of each CNC's panel. These were what is called a "D" shell connector with twenty-five pins.

The send end of the cable was plugged into the Delta 10 control that was to provide the part program to be transmitted to the second control. The receive end was plugged into the Delta 10 control that was to be the destination of the part program.

The serial RS-232C cable was constructed using two sub-miniature receptacles manufactured by Westinghouse with the part number of D25RHTK and a Beldin cable with six twisted pair of wires. The connectors had self contained pins, self stripping, and were complete with shell contact metal plated plastic backshells. Each 25D shell receptacle was rated for 28-22 AWG wire. The cable was constructed to be thirty feet long with the pin designation shown in the table below.

Table 2

RS-232C Cable Pins for Delta 10 Controls

Sending End		Receiving End
pin 1	Cable Shield	pin 1
pin 2	Transmitted Data	pin 3
pin 3	Received Data	pin 2
pin 4	Request to Send	pin 4
pin 5	Clear to Send	pin 5
pin 6	Data Set Ready	pin 6
pin 7	Signal Ground	pin 7
pin 8	Carrier Detect	pin 8
pin 20	Data Terminal Ready	pin 20

Note. From Customer Informational Manual (section 13 p. 1) by DynaPath Corporation, 1989, Detroit: Author. Copyright 1989 by DynaPath Corporation. Reprinted by permission.

The pinout of the cable was set up to a standard RS-232C configuration. Pin 1 of the sending plug was connected to the cable shielding and was not terminated at the receiving plug. Pins 4, 5, 6, 7, 8, and 20 were connected to their corresponding pins at each end of the cable. Pins 2 and 3 were connected so that they crossed and were connected to pins 3 and 2 respectively at the receiving end of the RS-232C cable. This produced what is called a "null modem" cable. This was necessary due to the fact that the serial RS-232C port in the Delta 10 CNC was found to be a DCE device.

Next the task of setting up the two Delta 10 CNCs to communicate so that a part program could be transfered was done. The sending control was set up first. To do this, "Program" was selected from the catalog menu by keying "Mode Select" and then keying "C" to get the main menu. Next, the program name was keyed in "XXXXXXX" and followed by keying "enter". "Mode Select" was keyed in next to allow access to the record screen. To get to record screen "8" was keyed in at this time. Selection of or highlighting of R-X-RS232, xxxxxBD rate, P1-parity on, and X1-control character on was done from this screen. With this done the setting up of the sending CNC to transfer a part program had been accomplished.

The receiving Delta 10M CNC was set up next. From the catalog menu or main menu key in "Mode Select". This allowed selection of the load screen by keying in "9". Once there the following were highlighted. R5-RS232 was highlighted to match port selection in the sending Delta CNC. XXXXXBD was highlighted to match baud rate selected in the sending CNC for data transfer. Pl-parity on was set to allow the same parity of data between both CNC's. Xl-control character on and ED-echo off were highlighted also to provide proper protocol for the transfer of the part program between the two Delta 10 controls. Next, to initiate the receiving Delta 10 CNC to look for a

part program the key "Load Program" was hit. The word "Loading" was observed on the screen at this time.

To initiate the sending Delta 10 CNC to send the part program to the receiving Delta 10 CNC thru the serial RS232C port the key "Record Program" was hit. At this time the word "Busy" was displayed on the screen of the sending Delta 10 CNC until the part program had been transfered to the receiving CNC. Once the part program had been transfered the word "Done" was displayed on the CRT of the sending Delta 10 CNC.

Once this was observed at the sending Delta 10 CNC a check of the receiving CNC's screen revealed the word "Done". This signified a complete transfer of a part program between the two CNCs.

Next, testing the accuracy of the transfer was accomplished by keying "Mode Select" on the receiving CNC and then keying "C" for catalog menu. The actual part program was checked by keying "Mode Select" and then keying "4" for program display. The part program came up on the screen thus showing that it had been transferred.

The final step was to remove the RS-232 cable from both Delta 10 controls. This allowed each CNC to resume operations as individual machine tools.

Chapter IV

Findings

Based on the research questions and the limitations, it was found that hardware was required. It was also found that limits existed for that hardware. Handshaking and protocol signals were required. The CNC also had setup parameters for part program transfer.

Question 1. What hardware was required to effect computer numerical control to CNC part program transfer?

Answer: The hardware needed was two "D" shell connectors with 25 pins and a cable thirty feet long. The cost of the two connectors and the thirty foot cable was under twenty-five dollars. The overall cable and connectors had to meet EIA standards and follow RS-232C pin designations for wiring.

Question 2. What pysical hardware limitations exist for communications between CNC's?

Answer: The physical hardware limitations were met by the cable not being over fifty feet long. This was the CNC manufacturers serial port output transmission distance limit.

Question 3. What signals associated with handshaking and protocol were required for CNC to CNC part program transfer?

Answer: The signals associated with handshaking and protocol were cable shield, transmitted data, received data, request to send, clear to send, data set ready, signal ground, carrier detect, and data terminal ready. These were spelled out by the CNC manufacturer. The one exception was the need to cross pins for transmitted data and received data. This had to be done because the communication was from one data circuit-terminating equipment(DCE) to another DCE.

Question 4. What CNC executive program parameters affect part program transfer between CNC's?

Answer: The CNC executive program parameters that affected part program transfer were program name, select R-5-RS232, baudrate, parity on, and control character. With these set to match on each CNC the transfer of a part program was accomplished.

Chapter V

Conclusions and Recommendations

The findings in this study provide a bases from which improvements in cellular production can be attained. This will enhance operations and provide another avenue to reach the World Class operating level. The findings will help provide more uninterrupted production, even with equipment failure, thus allowing more efficient use of the cellular production concept.

The ability to transfer part programs between Delta 10M and Delta 20M computer numerical controls via their serial RS-232 ports opens the possibility to do the same for other CNCs. The following recommendations are made:

1. It is recommended that all part programs scheduled to be used in each week of production be downloaded into the Machining System Inc. machining cell.
2. It is recommended that, within each cell, all part programs be loaded into each CNC's memory.
3. It is recommended that a RS-232C cable be available at the Machining System Inc. cell for part program transfer in case of equipment breakdown.

4. It is recommended that further study be done to expand this new method of part program transfer to other machining cells with like CNCs.
5. It is further recommended that this study be expanded to include CNCs from different manufacturers, with serial RS-232 ports, used in cellular manufacturing.

If the above recommendations are implemented, a reduction in cellular machining downtime will occur. The first evidence of this will be that off shift production will increase. This is due to the fact backup personnel are only on day shift. It means that the off shifts will not have to wait till day shift for access to part programs if the DNC system fails.

Chapter VI

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