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Military Standardization Handbook

ENGINEERING PRACTICES
PRODUCTIVITY ENHANCEMENT OF INDUSTRIAL PLANT EQUIPMENT AND PRODUCTION SUPPORT SYSTEMS

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Engineering Practices
Productivity Enhancement of Industrial Plant
Equipment and Production Support Systems

1. This standardization handbook was developed by the Department of Defense in accordance with established procedures.

2. This document was approved 1 August 1985, for printing and inclusion in the military standardization handbook series.

3. This document covers productivity enhancing industrial plant equipment and practices for developing creditable justification and analysis documents related to acquisition. It is not intended that this handbook be referenced in specifications for the procurement of industrial plant equipment except for information purposes, nor shall it supersede any specification requirement.

4. It is intended that this handbook will be reviewed periodically to insure its completeness and currency. Users of this document are encouraged to report any errors discovered and any recommendations for changes or additions to Commander, Defense Industrial Plant Equipment Center, ATTN: DIPEC-SSM, Memphis, Tennessee 38114-5297.

FOREWORD

Numerically controlled industrial plant equipment (IPE) and computer aided manufacturing systems properly selected and utilized will increase the productivity of defense plant operations. The large amount of capital investment required to purchase the NC IPE and supporting systems warrants a premium amount of effort to do a quality job in selection, justification, and post operation analysis.

This handbook provides guidelines to DoD operating officials on what constitutes a thorough set of documents related to selection, justification, and post operation analysis. It also provides DoD personnel basic information on the operating characteristics and technical features available on commercial items and systems.

This handbook should be used in conjunction with the references and guidance published by the Military Services covering subjects contained herein.

CONTENTS

CONTENTS - Continued.

CONTENTS - Continued

CONTENTS - Continued

CONTENTS - Continued.

CONTENTS - Continued.

CONTENTS - Continued.

CONTENTS - Continued.

CONTENTS - Continued.

CONTENTS - Continued.

CONTENTS - Continued.

FIGURES

CONTENTS - Continued.

CHAPTER 1

INTRODUCTION

1. ABSTRACT

This handbook provides engineering practice guidance for engineering personnel responsible for selection, justification, and post operation analysis of productivity enhancing industrial plant equipment (IPE) and related computer aided manufacturing support systems. Essential material on productivity enhancing IPE and computer aided manufacturing support systems is provided herein to familize engineers with the equipment and systems available for application to production in support of depot maintenance, research and development, prototype production and the development of manufacturing methods and technology for the production contract. Additional chapters of this handbook will be issued in the future covering subjects of interest to DoD components in the area of manufacturing methods and technology.

1.1 Objectives. The objectives of guidance contained in this handbook are:

a. Provide guidance for the engineering effort required to comply with existing DoD directives, instructions and other applicable regulations and manuals.

b. Assure that projects in support of the DoD Productivity Enhancing Capital Investment Program are supported with adequate documents.

Provide a disciplined method for determining production situations suited to utilization of numerically controlled IPE.

d. Provide guidance for searching out potential cost saving areas identified to numerically controlled machine production.

e. Provide instructions and examples for preparation of supporting documents.

1.2 Applicability. This handbook is applicable to DoD components supporting depot production maintenance and research and development missions by the in-house production of parts or those components planning to establish such capability. It is also applicable to DoD components responsible for furnishing IPE and related computer aided manufacturing support systems to defense contractors.

1.3 References. Current issues of the following instructions, directives, regulations and manuals provide detailed policy and procedural guidance on matters covered in this handbook.

1.3.1 Directives.

DoD

DoD Directive 4275.5 SUBJECT: Acquisition and Management of Industrial Resources

DoD Directive 5010.31 SUBJECT: DoD Productivity Program

1.3.2 Instructions.

DoD Instruction 5010.36 SUBJECT: Productivity Enhancing Capital Investment

DoD Instruction 5010.34 SUBJECT: Productivity Enhancement, Measurement and Evaluation Operating Guidelines and Reporting Instructions

1.3.3 Manuals.

JOINT DLAM 4215.1
AR 700-43 SUBJECT: Management of Defense Owned
NAVSUP PUB 5009 Industrial Plant Equipment (IPE)
AFM 78-9

1.3.4 Regulations.

FAR Part 52 Solicitation Provisions and Contract Clauses

1.4 Definitions.

Computer Aided Design (CAD). Process which uses a computer stored data base in the crestion or modification of a design.

Computer Aided Manufacturing (CAM). A system employing computer processing to manage and control the operations of a manufacturing facility.

Computer Numerical Control (CNC). Machine control units that are microprocessor, minicomputer or microcomputer based and perform substantial arithmetic and logic operations without intervention by a human operator during the run and supply the results of its performance to operate a machine. CNC provides the capability to store part program data in memory, link to a central computer, and operate with a softwired interface by virtue of the logic in the software (executive program). CNC's are capable of operation in the diagnostic modes and can diagnose control and interface component problems.

Digital Readout Systems (DRS). The term covering systems that detect, measure and display in readable form machine position in reference to the required or target position. These systems represent varying degrees of sophistication and can be purchased with memory sufficient to store part programs. Programming is accomplished by manual data input via the console keyboard. Manual positioning time on machines so equipped is reduced substantially by the elimination of mathematical computations, revolution counting and the problem of backlash.

Economic Analysis (EA). Economic Analysis is a systematic approach to the problem of choosing how to employ scarce resources and an investigation of the full implications of achieving a given objective in the most efficient and effective manner. An economic analysis is designed to systematically examine and relate costs, benefits and uncertainties of alternative ways for accomplishing an objective, mission, program or function.

Flexible Manufacturing System (FMS). A computer-controlled configuration of semi-independent work stations with an integrated material handling system designed to efficiently manufacture several parts at low or medium volumes."

Group Technology (GT). An approach to finding common solutions for the same or similar problems. It is a means for helping designers find solutions quickly, and helping manufacturing engineers solve industrial engineering problems optimally. It provides consistent solutions to current problems. based on experience. It does this in part through an identification method which classifies and codes design and manufacturing characteristics of parts and by then making design and manufacturing solutions based on these attributes available for future use.

Industrial Plant Equipment (IPE). Plant equipment with an acquisition cost of $3,000 or more; used for the purposes of cutting, abrading, grinding, shaping, forming, joining, testing, measuring, heating, treating or otherwise altering the physical, electrical or chemical properties of materials, components or end items entailed in manufacturing, maintenance, supply, processing, assembly, or research and development operations. IPE is identified by descriptive name in joint DoD Handbooks, DLAH 4215 Series.

Machine Control Unit (MCU). The bridge between the workpiece programmer and the machine tool. The machine control unit converts instructions contained in the NC workpiece program into a form that will operate the machine so as to produce the part.

Manual Data Input Numerical Control (MDI-NC). Manual Data Input Numerical Control units are microprocessor, minicomputer or microcomputer based numerical controls that are programmable in shop language by means of the keyboard. Manual data input controls normally provided with a means to record the program on magnetic tape cassettes to permit rapid loading of part program for the next production run. Macro programs featured on these to manually program rather complex parts without the expense of using computer prepared part programs or postprocessors.

Manufacturing System (MS). Materials, personnel, equipment, tooling and facilities (buildings) utilized in a manufacturing process.

Productivity Enhancing Capital Equipment (PECE). Equipment that improves the ratio of units of output to units of input of an organization or function.

Work-Mix Study (WMS). The systematic analysis of parts produced as to manufacturing parameters such as physical dimensions, type of machining operation, labor hours for NC and conventional production, lot size, and frequency of production.

1.5 General requirements.

1.5.1 Department of Defense Directive. Policies and procedures applicable to equipment covered in this manual are provided ‘by Department of Defense Directive 4275.5, Acquisition and Management of Industrial Resources, and the references cited therein. Paragraph A, 8, Encl. 1, DoD Directive 4275.5, assigns the responsibility for improving productivity of the industrial base to DoD components.

1.5.2 Department of Defense Instruction. Policies and procedures for DoD Productivity Enhancing Capital Investment. are provided in DoD Instruction 5010.36. This DoD Instruction authorizes the DoD Components to aggressively pursue the course of action required to improve productivity of their operations.

1.5.3 Operating guidelines and reporting instructions. Operating guidelines and reporting instructions related to productivity enhancing investments and actions are covered in DoD Instruction 5010.34, Productivity Enhancement, Measurement, and Evaluation - Operating Guidelines and Reporting Instructions. Monetary and personnel resource savings realized by the application of modern manufacturing technology to production operations are reportable in accordance with this DoD instruction.

1.6 Background.

1.6.1 Investment approaches.

1.6.1.1 Defensive approach. This approach defers management action or consideration of capital equipment until the point in time that a machine or system is no longer capable of functioning. Action taken in response to this situation is to replace the item with a like item which will perpetuate the same method of operation and productivity. Such action is not influenced by manufacturing or industrial engineering efforts to make basic changes in equipment utilized or method of operation. Replacement of deteriorated industrial plant equipment does restore capacity that has been lost to maintenance down time and the necessity to utilize lower than optimum feeds and speeds to produce parts of acceptable tolerance.

1.6.1.2 Cost-saving approach. The cost saving approach has the advantage of lending itself to easy calculation while offering a degree of overall progress. Using this basically conservative approach, equipment will be replaced with like kind based on some degree of improved performance. There is no engineering effort to examine the operation for improvement. It is not difficult to calculate the cost savings and payback term to support investments which are justifiable under the criteria established.

1.6.1.3 Aggressive approach. Utilization of the aggressive approach to capital equipment selection offers the greatest opportunity to make cost-saving and productivity improvements in the manufacturing process. The aggressive option analyzes industrial plant equipment and manufacturing support computers on the basis of the impact on personnel, personnel skills, methods and the manufacturing environment. Productivity enhancement projects representative of this option can vary from installation of digital readout systems on conventional machines to the application of completely integrated manufacturing systems.

1.6.2 Present productivity base.

1.6.2.1 Aged industrial plant equipment. The average age of industrial plant equipment supporting DoD components was 15 years in 1979. Although the average age of industrial plant equipment was 15 years, the metal-working equipment category, which accounts for over one-half of the equipment in inventory, was-over 21 years in age. The majority of old equipment in place is simply the result of the lack of available money for replacement or the mandatory trade offs to high priorities for funds.

1.6.2.2 Recognition of unfunded investment opportunities. The first significant and documented recognition of the DoD inability to finance productivity enhancing investments-came in 1972. At that time a joint study group composed of OMB, CSC (now the Office of Personnel Management) and GAO identified a backlog of over $200 million in unfinanced investment opportunities-- investments which would have returned costs through productivity improvements in three years. These were already documented opportunities and do not represent opportunities that can be identified by the aggressive approach to capital investment.

1.6.3 Emphasis on productivity improvement.

1.6.3.1 Productivity enhancing capital investment program. In 1975 the Secretary of Defense formally established the Department of Defense Productivity Program with DoD Directive 5010.31. An inherent part of this program is a sustained effort to identify and promptly finance opportunities where the DoD can reduce operating and support costs through judicious investments in modern labor and cost-saving equipment. On December 31, 1980, DoD published DoD Instruction 5010.36, Productivity Enhancing Capitol

Investment, which authorizes DoD components to aggressively pursue the course of action necessary to improve productivity of their operations thus supporting DoD Directive 5010.31 in the area of capital equipment investment.

1.6.3.2 General Accounting Office Studies. The General Accounting Office concluded, in three study reports (24 September 1974, 17 January 1975, and 26 June 1975), that: (1) the industrial base of the DoD could benefit from the application of NC to manufacturing operations; (2) numerically controlled IPE should be considered when a substantial quantity of IPE is required; and (3) numerically controlled IPE should be planned and considered as part of the total production system. Systems outside the manufacturing environment that make part programming, engineering design, process planning, and quality control less labor intensive are parts of the total production system that is supportive of and complimentary to numerically controlled operations.

1.7 The role of management.

1.7.1 Management support. Productivity improvement that is potentially available from modern equipment and manufacturing systems, developed to utilize this equipment, will not be realized unless the system is supported at all levels of management. People don't want to change and, for this reason, the intent of the system must be explained to all parties. The workers must be convinced that productivity improvement is good for them too, not just the DoD. Management must go through a process of learning how to manage changed personnel and organizations that are performing their work by methods that are uniquely different. In short, a bad system based on the cooperation of all will work well. A perfect system will ultimately fail if those operating it do not wish it to succeed.

1.7.2 Staff involvement. Industrial or manufacturing engineers and management analysts on the activity staff are required to perform the work involved in identifying opportunities, justification, and follow-up analysis of productivity enhancing equipment and systems. The staff has a significant contribution to make in determining, selecting and justifying the equipment and system most suited for supporting the long-range production requirements of the DoD component.

CHAPTER 2

PRODUCTIVITY ENHANCING INDUSTRIAL PLANT EQUIPMENT AND MANUFACTURING SUPPORT SYSTEMS

2. PRODUCTIVITY ENHANCING TECHNOLOGY

2.1 History.

2.1.1 The advent of numerical control. Through the efforts of Mr. John Parsons, the United States Air Force and the Massachusetts Institute of Technology, a numerically controlled, vertical spindle, Cincinnati Hydrotel was successfully operated to machine parts in 1952. The machine control utilized machine instructions in the form of straight binary coded tape and required the support of an off-line computer to generate the binary tape codes. Numerical control was announced to the public in 1954.

2.1.2 Advancement of manufacturing technology. Since numerical control was announced to the public in November 1954. manufacturers, manufacturing/ industrial engineers and system analysts have been intensively developing hardware, software and system configurations that integrate computers for design, manufacturing, inventory, and distribution into a computer system that provides management control over the manufacturing operation. Computers are capable of processing tremendous amounts of information, enabling a central computer to pass out information that controls manufacturing and its supporting functions and in turn receives information that can be acted upon by the computer to issue control commands. The technology available today is advanced to the point that the fully automated factory is attainable for those activities and companies having appropriate production requirements.

2.2 Automation.

2.2.1 Automation systems and processes. Automation is a term applicable to a broad gamut of mechanically, electrically and electronically controlled machines, material handling systems, mechanical manipulators (Robots) and processes that require a minimum of human labor and attention for continuing operation. Automated machines, systems and processes by virtue of the low labor requirement for their operation make it possible to use one operator to attend several machines or operate an entire process, thereby multiplying the productivity of applied labor. Automated equipment and machines may or may not be capable of providing feedback to a central control computer which is essential for integration into a computer aided manufacturing system or fully automated manufacturing system.

2.2.1.1 Automatic conventional/special purpose machines. Automatic conventional and special purpose machines have been around for many years in comparison to the span of time that numerically controlled machines have been available. Program control methods are used to automatically cycle these machines to produce a specific part. Automatic control of positioning, contouring, feed depth speeds and sequence (function or cycle) operate these machines as though they are being operated under numerical control. Industry has relied on automated conventional and special purpose production equipment to achieve the lowest possible unit cost per part. Automated production equipment serves the high volume producer well (over 500 units per part) as the lowest cost alternative for production. Automated machines will always be around to support the high volume producer. Only ten percent of manufacturing qualifies in the high volume category. Controls applicable to automatic machines are:

a. Cam type controls (mechanical or electrical) utilizing drums, adjustable cams, or solid cams to sequence and control machine movement and positioning. The electrical function drum utilizes electrical contacts as the means of sequencing and controlling movement of machine components.

b. Electro-Mechanical featuring adjustable trip dogs on the machine components that operate electrical switches controlling slide movement, spindle depth and machine function.

c. Tracer control - is comparable to contouring mode provided by numerical control. Mechanical contact of a stylus on master actuates machine components to move identical to movement of the stylus and thus guide the cutting tool so as to duplicate the master.

d. Electric or electronic - Electric control devices with plugs, dials or switches used to establish operating sequence, slide movements and machine functions. Electronic programmable industrial controllers operated by a program entered in memory to control movement, timing and functions of the machine.

2.2.2 Numerically controlled machines. Numerical control represents a complete departure from conventional machine tool operations. A machinist no longer has to study a drawing and direct the machining operations in sequence based on his knowledge of the machine and his interpretation of the drawing requirements. Conventional machine operations depend heavily upon the operator's knowledge and skill, and the inherent limitations of human dexterity skills, along with other subtle influences, such as alertness, fatigue, and even emotional well being. Human factors constantly vary, and the final output reflects these variables.

2.2.2.1 Numerically controlled machine tool consistency. Repeatability from part to part is one of the virtues of an NC machine tool. It will do precisely what it has been told to do within the limit of its capability, and will not vary from its programmed instructions. Programs can be repeated any number of times, and each part so produced is exactly like the preceding part, thus providing a degree of quality control and accuracy. Numerically controlled machine tools are not different in the sense that new machining concepts are involved. Drills drill as they always have, and the same milling cutters are generally found on both NC and conventional mills. The principal distinguishing feature about the machine tool is its usage. NC can deliver instructions so efficiently that the utilization rate will probably be much higher than a comparable manually operated machine. Appendix A describes NC machines.

2.3 Productivity enhancing technology for conventional machines. Although the Department of Defense has some numerically controlled machines, the overwhelming majority of DoD machines are conventional. This is likely to remain so for many years to come. Increasing the productivity of these conventional machines in the DoD industrial base provides an opportunity to: (1) reduce unit labor cost; (2) reduce jig, special fixture and template cost, (3) reduce the number of machines required to support mission workload; (4) lower the skill requirement for machine operation; and (5) prevent or delay the necessity for facility expansion (new buildings).

2.3.1 Productivity enhancing retrofit. Retrofit is a contraction of the words “retroactive” and "fit". It applies to the installation of systems or devices on machines that were not originally equipped with such devices. Retrofit is therefore the term that is appropriate for the installation of high technology systems and devices that enhance machine capability and increase machine productivity.

2.3.2 Numerical control retrofit to conventional machines. Retrofit of a numerical control system to a conventional machine has been considered by some to be a means of evolving from conventional machines to numerically controlled machines. The most invalid assumption being made in the decision process to retrofit existing conventional machines is that it can be beneficial for any machine, regardless of its current accuracy. The present accuracy of the conventional machine will not be improved by retrofit of a new numerical control system.

2.3.3 Candidates for numerical control retrofit. Long delivery time, high cost of capital, and knowledge that existing conventional machines can be converted to numerically controlled machines with enhanced capabilities lead users to consider retrofit as the viable alternative to procuring a new NC machine. Retrofit of existing conventional machines should be considered only in conjunction with rebuild of the machine to like-new condition, accuracy and capability. Conventional machines determined to be like-new can be retrofit with a numerical control system without being rebuilt. The economic feasibility of rebuilding and retrofitting a conventional machine must be evaluated during the decision process. Generally rebuild and retrofit of light machines costs 90 to 110% of new NC machine acquisition cost and do not qualify as candidates for NC conversion. Heavy machines that were originally built to perform accurate work can be rebuilt and retrofitted for 40 to 60% of new machine acquisition cost. Considerations for rebuilding and retrofitting a conventional machine are:

a. The machine is of a good design originally capable of accurate work under high torque and stress conditions.

b. The manufacturer supports the machine with spare parts.

c. Retrofit, rebuild and updating of the machine will provide a machine with state-of-the-art capabilities and features comparable to those available on a new NC machine of the same type.

2.3.4 Digital readout system. Thee digital readout system available today is based in electronic technology and consists of a scale; transducer resolver or encoder; an illuminated digital display and a keyboard for the entry of data. Resolution of digital readout systems is an option that can be chosen to be compatible with the accuracy of the machine to which it will be fitted. The digital display constantly displays the position of each axis of motion in relation to the target position. Digital readouts make it possible for the machine operator to position the machine to target more quickly and accurately and repeat the target position within the tolerance limit required for subsequent machining operations at the same location. Some digital readouts feature a multiple position memory that can store and display, upon command, all position data required to produce a complex part.

2.3.4.1 Advantages of digital readouts. Digital readouts make many of the advantages of numerical control available to the user of conventional machines. One-piece jobs or short production runs can be efficiently produced. The set-up time for production of parts is significantly reduced. An operator for a digital readout equipped machine can be trained in a few days. Skilled machinists are not required for production with digital readout equipped machines. The total cost of a digital readout system can be recovered by productivity improvement savings alone in six months or less.

2.3.4.2 Retrofit of digital readouts to conventional machines. A significant portion of the conventional machine tools in use today can be retrofitted with digital readout systems. The requirement for retrofit is that there be sufficient clearance between machine components to install a spar containing a linear scale and that the slides can operate without interference. Digital readout systems for retrofit are available from approximately fifty manufacturers who will furnish all components and install the system at the user’s facility. The cost of digital readout systems is nominal in relation to the benefits derived, and the total purchase price is within the amount authorized for local purchase. Digital readout systems are also applicable to mechanical or fixed-stroke hydraulic press brakes.

2.3.5 Manual data input (MDI) numerical controls. Manual data input numerical controls are offered by a significant number of control manufacturers. These controls are programmable in conversational or shop language by the operator at the control panel and they do not require computer support as required for computer numerical controls that are normally programmed with a higher program language. Part programs can be recorded for future use from the control memory by attaching a recorder appropriate for the part program media used by the control selected. Some of the controls in this category feature a cathode ray tube that displays a program prompting menu that takes the operator through each step of the programming process and thereby assures that all required information to machine the part is input. Ordinarily MDI controls are limited to the control of three axes of motion. Canned cycles are available as part of the software package available with these controls.

2.3.5.1 Manual data input (MDI) numerical control retrofit. Numerical control capability can be established in many plants by the retrofit of a MDI control to a conventional machine that is in good condition and presently produces the accuracy and repeatability desired. These controls can be retrofitted to the machine at the plant in a short period of time. These controls offer some of the features of computer numerical controls and provide the same productivity improvement benefits. The cost of retro-fitting a MDI control to a conventional machine can be amortized in a short period of time. Retrofit of a MDI control is quite appropriate for low volume production runs and single parts.

2.3.6 NC controlled axis drive system retrofit. Systems are available on the commercial market that provide all the components necessary to convert conventional lathes to state-of-the-art CNC lathes with full contouring, turning and threading capability. The axis drive system attaches to the bed of the conventional lathe and is interfaced to an MDI or CNC numerical control. The axis drive packaqe plus a computer numerical control costs approximately 20 percent of the cost of a new numerically controlled lathe having the same performance capabilities.

2.4 Computer applications to manufacturing.

2.4.1 Problems inherent with batch manufacturing. Low and medium volume production dominates the manufacturing performed by industrial facilities within the DoD. The DoD facilities must produce small quantities of as many as several hundred different parts. Automated production which pro-perly serves the needs of the high volume producer does not serve the needs of DoD industrial facilities. Problems inherent in low and medium produc-tion which await solution by application of new technology are:

a. Low utilization of capital investment. Loss of utilization due to one shift operation, vacations, holidays, down time, set-up time and idle time due to machine loading and unloading reduce the time that a machine is in the cut to only six percent of available time.

b. Complexity. Low and medium volume production is very labor intensive due to the necessity to coordinate the raw material, production print, fixtures and tooling for hundreds of different parts through the various machines involved and in the required sequence.

c. Predictability. It is not possible to predict that all essential materials, tools and preparations will be completed as planned. Delays or presence of the wrong print, tool or set-up disrupts the produc-tion schedule.

2.4.2 Computer aided manufacturing support systems. The DoD producer of parts in support of depot level maintenance is faced with the problems associated with low volume or batch mode production. Low volume and batch production by virtue of the complexity thereof makes product design, engineering, planning for manufacturing and manufacturing very labor intensive. Today's numerically controlled machines having a computer numerical control make it possible to produce low volume parts more efficiently than was possible with conventional machines. The concept of using a computer to process the details of part production and operate the machine to produce the part is an appropriate concept for application within activities faced with low volume production. DoD industrial facilities faced with the low volume production of as many as several hundred different parts present the situation that can benefit most from computer aided manufacturing support systems. The availability of small, low cost computers makes it feasible to consider utilization of dedicated computers for each manufacturing function. Computer aided manufacturing support enhances the productivity of labor applied to the manufacturing functions. Computers and software are available that make it possible to link the dedicated computers for manufacturing functions to a computer dedicated to overall control of the manufacturing and thereby provide a computer integrated or flexible manufacturing systems with control at the highest level within the organization. Computer applications to the individual manufacturing functions are discussed in the following paragraphs.

2.4.2.1 Computer aided design (CAD). The typical computer aided design (CAD) system consists of a control processor, memory for program and data storage covering part drawings, descriptions and engineering characteristics, a workstation consisting of a digitizer combined with a cathode ray tube or graphic tablet, function keyboard, typewriter keyboard and an output device for printing data or graphic material. The design engineer, sitting at the workstation interacts with the system to develop a product design in detail and monitor the results of his work by means of a video (graphic) display. By means of the digitizer and response to system prompts, the engineer can change and modify his design until it is acceptable. The engineer draws an outline of the part on the graphics display. Depth can be added automatically to produce a three dimensional part. The graphics system has the capability to display a three dimensional view of the part from any angle and also display top, bottom and side view of the part. When the design is completed the engineer can command the system to output a dimensioned and annotated drawing, engineering characteristics data and a tape or flexible disk for part production on a numerically controlled machine. Computer aided design systems are modular as to the hardware configuration and computer programs and the capability of the system is dependent on the selection of features made by the user. A two-way, computer-to-computer communication link can be added to the CAD computer for integration of the CAD system into the manufacturing system.

2.4.2.2 Group technology. Group technology (GT) is an approach to finding common solutions for the same or similar problems. It is a means of helping designers find the best possible design solutions quickly, and helping manufacturing engineers solve industrial engineering problems optimally. It provides consistent solutions to current problems, based on experience. It does this by classifying and coding design and manufacturing characteristics of parts which provide the basis for solving current design and manufacturing problems.

2.4.2.2.1 Data base. A file covering all designs based on data developed under the group technology concept should be entered in the CAD system memory. Although some of these parts are not required to support current requirements, the data available from the file can expedite the design of parts to meet current requirements. Parts similar to those currently required will be found in the file and the design task then becomes modification of a previous design. Group technology data on file in the CAD system can also serve the data requirement of the computer aided manufacturing support system. Further detail regarding group technology is provided in Appendix B.

2.4.2.2.2 Documentation. Non-graphic data from the CAD system can be provided in the form of hard copy documents to provide data for preparing bill of materials, generate models for engineering analysis, calculate areas, volumes, and weights and provide basic quality assurance data.

2.4.2.3 Distributed numerical control (DNC) system. Distributed numerical control is descriptive of a computer system that provides the capability to store and retrieve numerical control part programs and transmit these programs to the particular machine control unit requiring the program. Storage of numerical control programs in the memory of the computer dedicated to the direct numerical control function eliminates the necessity to prepare and store part program tapes and transport program tapes from storage to the machine control on the plant floor. Two-way communication must exist between the DNC computer and the individual machine computer numerical controls on the plant floor. Programs required by the machine are loaded into the part program memory in the control unit. Executive and diagnostic machine control data files are entered into the DNC computer for down loading to the machine control as required. A two-way, computer-to-computer communication link can be added to the DNC computer which makes it possible to integrate the DNC system into the manufacturing system.

2.4.2.4 Computer aided process planning (CAPP). Manual process planning is centered around a process planner who examines new parts and considers them in relation to previously produced parts. Retrieval of the plan for the previous part or recall from his background of experience enables the process planner to totally or partially plan production of the new part. The concept of computer aided process planning is to record experience gained from the previous production of parts in the memory of the CAPP system and update the file by interchange of data with the CAD system. In order that the system shall not automatically output the process plan, the system should provide aids at each step in the creation of a process plan. A typical CAPP system consists of the following aids:

a. Group technology retrieval: Previous part data is displayed to the process planner upon command.

b. General planning aid: Generalized graphic routines combined with the graphical output from the CAD system enables the planner to develop tooling layouts, setup, clearances and graphic work instructions.

c. Generative process planning: Utilizes group technology data to generate sequence of operations, tooling requirements, machine tool settings and machine and labor time standards.

d. Process optimization: Assigns machining operations to those machines that will produce the part at the minimum cost and maximum rate.

e. Process monitoring: The computer tracks Progress of the actual production against the production plan and communicates problems encountered to the production planner.

2.4.2.4.1 System output of CAPP. The CAPP system outputs a production schedule for each machine on the production floor that loads the machine to capacity, the tool requirements for each machine and the schedule for providing the tools, set up by machine and at appointed time, and a material delivery schedule. The system also outputs hard copy documents providing special instructions for the operator and a graphic configuration of the part.

2.4.2.4.2 Integration with other systems. A communication link with other computer aided manufacturing systems can be a feature of the CAPP system. Data placed in the memory of a system computer as the result of processing or file maintenance actions should be available to other systems requiring such information and thereby prevent the duplication of files within the organization. Manual machines can be integrated into the system by means of a terminal on the floor for the transmittal of production data to the computer on a real time basis.

2.4.2.5 Computer aided quality control (CAQC). The computer has been a valuable tool in the area of inspection and quality control. A computer interfaced to an automated coordinate measuring system will accumulate data concerning the production process and provide data on each part if desired. The computer can be instructed to measure each part and accumulate as long as the parts remain within a given range of value. When out of tolerance parts are detected, the system can inform the CAPP system and the Manufacturing Management System of the condition.

2.4.2.6 Computer aided material management system (CAMM). A computer system interfaced to other computers in the manufacturing complex which provides and receives data basic to computing material requirements by kind and quantity to support the production schedule, scheduling of material delivery to machine location, processing of appropriate data to maintain the current inventory of material and finished products, computation of material cost chargeable to production by part number, value of finished products and a record of the final disposition of products. Automatic output of purchase requests for material to replenish established inventory levels is a feature of this system. Complete cost accounting computations could be assigned to this system, although this is usually assigned to the Manufacturing Management System.

2.4.2.7 Manufacturing management system (MMS). A computer system that controls, directs, plans and monitors other computers in the manufacturing system to achieve an integrated computer aided manufacturing capability. Software of the system is designed to provide the top level of management information and reports concerning manufacturing and improve management effectiveness in planning resource utilization (personnel and machines, measuring performance, cost accounting, tracking orders, assignment of priorities for accomplishment of work and responding to operational problems and changes as they occur. These systems typically determine the master production plan and register attendance of personnel. Communication with other computers in the manufacturing system is provided by the communication links which form a closed loop system between the MMS computer and computers dedicated to functional level tasks.

CHAPTER 3

SELECTION OF NC MACHINE WORK

3. Identification of opportunities to apply productivity enhancing technology. Numerically controlled machines establish within the production facility an automated production capability in its most flexible form. Flexible manufacturing is the capability to convert from one part to another with a minimum of labor involvement in setup and tooling changes. As stated previously, manufacturing that involves low volume production of many different parts can benefit from the application of manufacturing technology to increase productivity and reduce costs. A Government study completed in January 1979 recommended that planning for NC machine purchases be improved by developing guidelines on planning for NC as a total production system. Although there is evidence that NC machines are more productive than conventional machines, it is essential that the work available at the activity be appropriate for NC production in order to be cost effective.

3.1 Considerations for NC machine production. An analysis of parts produced in the manufacturing plant is required to determine whether numerically controlled machines are suited to the manufacture of some or all of the parts. Experience has shown that numerically controlled machines will improve productivity of manufacturing when:

a. A setup is required to produce a low volume of parts. The volume of production may vary from 1 to 100 parts. Each setup is a fixed cost and is absorbed by the quantity of parts in the production run when produced on a conventional machine. Production on a numerically controlled machine incurs the cost of part program preparation and placement of the material in a universal holding fixture. The cost for all preparatory steps for NC machine production is less than these same steps for conventional machine production. The cost for setting up an automated machine is in most cases greater than either a conventional or numerically controlled machine and at some volume of production the unit cost will be less than production on NC or conventional machines.

b. Complex parts required. Numerically controlled machines are capable of multi-axis motion simultaneously. This capability makes it possible to quickly machine parts that are extremely difficult to machine or impossible to machine on a conventional machine.

c. Frequent engineering changes are necessary. Design changes made by engineers as the result of field experience or prototype testing impose tasks on the tooling, fixture and template personnel that incur costs and involve lead time. Production of the changed part can be initiated on numerically controlled equipment when the part program has been prepared. Numerically controlled equipment can accommodate engineering changes more quickly and economically than conventional machines.

d. Expeditious production of parts is required. Manufacturing performed in support of depot level maintenance is such that the time from part print to finished part is essential to completion of maintenance within the targeted date. As discussed in the fore going paragraph, the lead time for NC machine production is the minimum attainable.

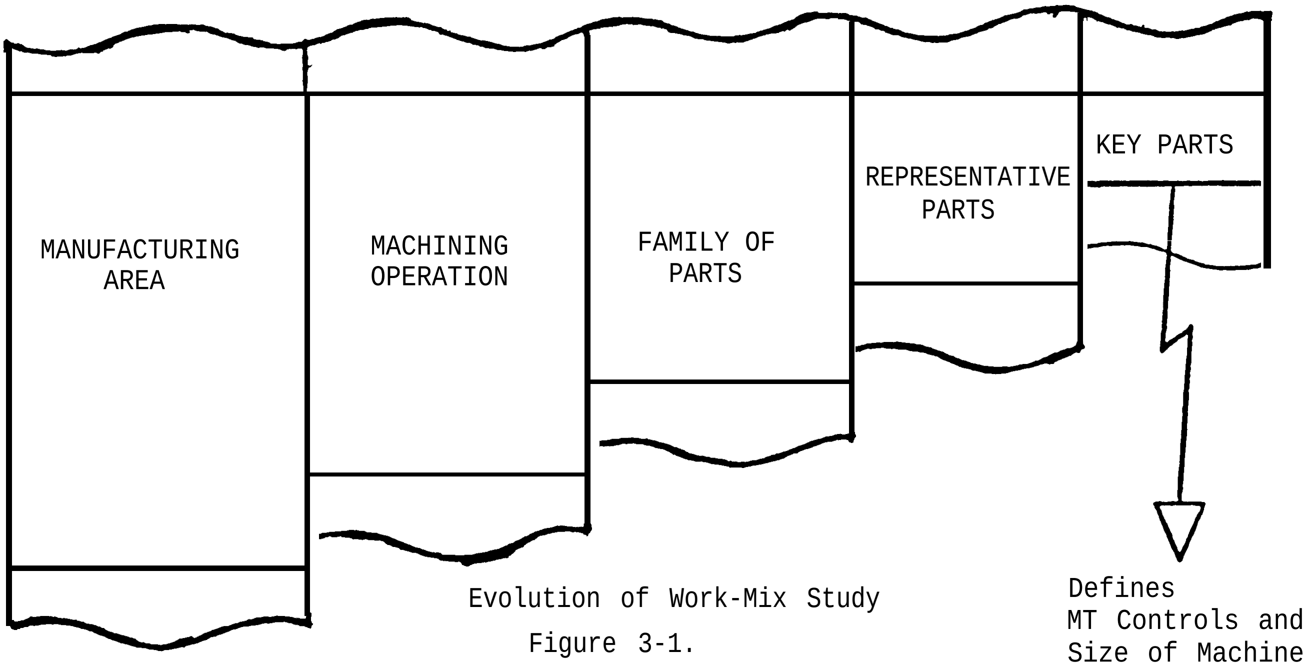
e. Tooling costs are a significant portion of manufacturing costs. Numerically controlled machines minimze the requirement for special tooling, fixtures, jigs and templates.

f. Inspection of each part is required. Parts that have critical tolerances at many locations on the part requiring the inspection of each part incur high costs. Numerically controlled machines produce to extremely close tolerance and repeat the same tolerance from part to part and make it possible to reduce inspection to the first part and sampling inspection of remaining production.

g. High value part material is scrapped. Manufacturing in support of mission work requires machining of a casting that is expensive due to the intricacy of its design or is made of an expensive metal or alloy. Scrapping of a part due to an operator error at the point in production where the investment in material and machine time is very valuable imposes a heavy financial loss on the activity and delays mission accomplishment.

h. Floor space within the facility is crowded. Numerically controlled machines are more productive than conventional machines and provide productivity ratios of two to six times that of conventional machines. The latest numerically controlled machines with electrical drives are compact in comparison to the earlier machines with hydraulic drives. Fewer NC machines are required to support production and less floor space is required which can be as much as 60 percent less.

3.2 Work-mix analysis. Work-mix analysis is concerned with the development and use of data that describe parts in terms of manufacturing parameters, such as physical dimensions of the material blank, type of machining operations, labor requirement for the present and proposed method of production, lot size, number of lots per year, part number and drawing number covering the part. It will be recognized that data required for the work-mix analysis is essentially the same as that available on process planning documents or other manufacturing records. An analysis of parts produced in the manufacturing plant is required to determine whether numerically controlled machines are suited to manufacture all or some of the parts required. An analysis of the work required of a manufacturing facility can be narrowed down-as illustrated in Figure 3-1.



Evolution of Work-Mix Study

Figure 3-1.

3.3. Work-mix analysis procedures.

3.3.1 Representative sample. Start by sampling parts representative of the typical part that is produced in the shop. Those parts that possess one or more of the characteristics in paragraph 3.1 shall constitute the population from which the sample is drawn.

3.3.2 Recording information. Record information for each part included in the sample on work-mix analysis sheets (see figures 3-2, 3-3, 3-4, and 3-5). Figures 3-6, 3-7, 3-8 and 3-9 are examples of completed analysis sheets that cover part production information for conventional and numerically controlled machines. Data sheets presented here are for the purpose of illustration only and are not prescribed. Activities performing a work-mix analysis are free to develop data sheets that are appropriate for operations in their plant.

3.3.3 Productivity improvement data. Information recorded on the analysis sheets for conventional and numerically controlled machine production provided a basis for computing the productivity improvement ratio (PIR) that applies to sample parts. Computation of the productivity improvement ratio for numerically controlled machine production is illustrated in the following:

a. Drilling, Boring, Tapping - Total Time Per Year

Part No.	Conventional	Numerically Controlled
VB-0670	474.00	108.60
HV-16198	244.20	79.50
PWP-O11OO	1836.00	324.00
GB-10221	1116.00	246.00
TOTAL	3670.20	758.10

b. Turning - Total Time Per Year

Part No.	Conventional	Numerically Controlled
SM-1320	124.88	82.47
P-18119	53.28	35.00
GS-4515	186.96	71.28
CS-1420	330.76	97.60
TOTAL	695.88	286.35

c. Productivity improvement ratio (PIR). This ratio expresses the productivity advantage of proposed equipment over that of existing equipment. Computation of the PIR for the work-mix analysis discussed in forgoing paragraphs is:

$$PIR = \frac{\text{HOURS FOR PRESENT EQUIP}}{\text{HOURS FOR PROPOSED EQUIP}}$$

$$PIR = \frac{3670.20}{758.10} = 4.84 \text{ For Drilling, Boring, Tapping}$$

$$PIR = \frac{698.88}{281.18} = 2.49 \text{ For Turning}$$

The PIR value for Drilling, Boring, Tapping means that a numerically controlled drilling, boring and tapping machine does the work of 4.84 conventional machines. The value for turning means that a numerically controlled lathe will do the work of 2.49 conventional lathes.

3.3.4 Break-even analysis. The PIR relates the productivity of alternative equipment choices capable of supporting production operations. The PIR for numerically controlled machines in relation to conventional machines is such that we might conclude that numerically controlled machines are more economical at all production quantities.

3.3.4.1 Computation procedures. Time related to part production on conventional and numerically controlled machines consists of two categories: fixed elements which occur each time the particular part is produced and the variable elements that cover the total cycle time per part. Data for Part No. HV-16198 in the work-mix analysis is used in the following example for computing the break-even quantity.

a. In this example the assumption is that the part is now being produce on a conventional machine and production on a numerically controlled machine requires a part program which is chargeable as one of the fixed time elements.

(1) Fixed Time (F)

	Time (hours) Conven	NC
Tools, jigs and fixtures	4.7	1.25
Part program conv. planning	27.0	48.00
Total Fixed Time	31.7	49.25

(2) Variable Time (V)

Machine cycle time per part	3.6000	1.2000

Part No Hv-16198 in the work-mix analysis

(3) Time Equations

$T = F + VQ$

Where T equals time in hours to produce Q parts.
F is fixed time in hours and Q is the quantity of parts.

$Tc = 31.7 + 3.6Q$

$Tn = 49.25 + 1.2Q$

(4) Solution:

Solve the time equations for conventional and numerically controlled machines to determine the break-even quantity.
Set Tc = Tn

$31.70 = 3.6Q = 49.25 + 1.2Q$

$-17.55 = -2.4Q$

$Q = 7.31$ pieces

Lot size is 10. The production of the first lot of 10 is above the break-even quantity of 7.31 pieces. Part program time is amortized at a production quantity of less than eight pieces.

b. In this example it is assumed that a part program is available and conventional planning has been completed and the discussion is to be based on the quantity required.

(1) Fixed Time (F)

	Time (hours) Conven	NC
Tools, jigs and fixtures	4.7000	1.25

(2) Variable Time (V)

Machine cycle time per part	3.6000	1.2000

(3) Solution

$Tc = 4.7 + 3.6Q$

$Tn = 1.25 + 1.2Q$

$4.7 + 3.6Q = 1.25 + 1.2Q$

$-3.45 = -2.4Q$

$Q = -1.438$ pieces

We can conclude that any quantity can be more economically produced on the selected numerically controlled machine.

3.4 Selection of the numerically controlled machine tool.

a. The work-mix analysis shows that the requirement is for a boring, drilling, tapping, and milling machine which replaces two conventional drilling and tapping machines and one milling machine. This requirement is satisfied by a machining center having a work envelope large enough to accommodate the largest part in the family of parts. The numerical control must be capable of controlling all of the functions which a machining center is capable of performing.

b. Military specifications in Federal Supply Group 34 cover conventional and numerically controlled machines included in the Federal Supply Classes within the Group. Specifications state the minimum requirements for machines acquired for use by the DoD, and for numerically controlled machines, a detailed set of specific requirements for the numerical control is stated. Detailed numerical control requirements are stated so as to offer the reguiring activity options which can be used to tailor control features to satisfy the users requirements.

The activity faced with the selection of a numerically controlled machine should refer to the DoD Index of Specifications and Standards (DoDISS) to determine the availability of a military specification covering the specific type of machine identified. The military specification or specifications identified in the DoDISS can be ordered from Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120. Numerically controlled machines are included in the following Federal Supply Classes:

FSC
3408 - Machining Centers
3410 - Electrical and Ultrasonic Erosion Machines
Includes Electrical Discharge Machine; Electrolytic Grinding Machines
3411 - Boring Machines
3415 - Grinding Machines
Excludes Electrolytic Grinding Machines
3416 - Lathes
Includes Screw Machines
Excludes Speed Lathes; Metal Spinning Lathes; Cartridge Case and Shell Lathes
3417 - Milling Machines
3431 - Arc Welding Machines
3433 - Gas Welding, Heat Cutting, and Metallizing Equipment
3441 - Bending and Forming Machines
3445 - Punching and Shearing Machines

d. The requiring activity should review military specification for satisfaction of their numerically controlled machine requirements. Optional requirements stated in the specification can be satisfied by responding to the procurement requirements in paragraph 6.2.1 of the specification. The military specification tailored in accordance with the procurement requirements should be used to procure the required numerically controlled machine.

3.5 Selection of parts for production on existing NC machines.

3.5.1 Application of work-mix study to new part production. When a numerically controlled machining capability exists in the facility, new parts introduced for production should be examined for production on conventional or numerically controlled machines in accordance with paragraphs 3.1.

3.5.2 Process planning. Process planning directed at specifying appropriate jobs for NC production will increase the utilization of NC machines and minimize the cost of production. An investment in numerically controlled machines requires that management accept the responsibility to load the numerically controlled machines to capacity and ultimately realize the cost savings computed to justify acquisition. Management effort in this area can make a difference between quick payback and a loss.

WORK-MIX ANALYSIS

PARTS ANALYSIS - DRILLING, BORING, TAPPING

FAMILY: Sheet of — Part No.				
Drawing				
Lot Size				
No. of Lots/Year				
Labor Hours/Part				
Total Setup Hours/Lot				
No. of Setups Reqd.				
Material Description				
Mat'l Blank (L-W-H)				
Dia. of Largest Hole				
Dia. Tolerance*				
Location — Toler.* / No.				
Total No. of Tools				
No. of Drilled Holes				
No. of Bored Holes				
No. of Reamed Holes				
No. of C' Bore Holes				
No. of C' Sink Holes				
No. of Tapped Holes				
No. of Surf. Milled				
Work Surf. not 90 deg. to other surf.				
No. of Milled Pockets & Slots				
* Tightest				

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GENERAL PURPOSE DATA SHEET (INTERNAL REQUIREMENT)

Figure 3-2

WORK-MIX ANALYSIS

PARTS ANALYSIS - MILLING

Family: / Sheet of / Part No.				
Drawing				
Lot Size				
No. of Lots/Year				
Labor Hours/Part				
Total Setup Hours/Lot				
No. of Setups Req'd				
Mat'l Description				
Mat'l Blank (L-W-H)				
Dia. of Largest Hole				
Dia. Tolerance*				
Location Toler* / No.				
Total No. of Tools				
No. of Drilled Holes				
No. of Bored Holes				
No. of Reamed Holes				
No. of C' Bore Holes				
No. of C' Sink Holes				
No. of Tapped Holes				
No. of Surf. Milled				
Work Surf. not 90 deg. to other surf.				
No. of Milled Pockets & Slots				
No. of Contoured Pockets & Slots				
No. of Contoured Surfaces				
No. of Part Faces Requiring Machining				
* Tightest				

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GENERAL PURPOSE DATA SHEET (INTERNAL REQUIREMENT)

Figure 3-3

WORK-MIX ANALYSIS

PARTS ANALYSIS - TURNING

Family: Sheet of / Part No.				
Drawing				
Lot Size				
No. of Lots/Year				
Labor Hours/Part				
Total Setup Time/Lot				
No. of Setups Req'd				
Material Description				
Stock Diameter				
Blank Length				
No. of Diameters				
Contours? / Ground Dia's?				
Total Number of Tools				
Turning Tolerance				
Grinding Tolerance				
Keyways				
No. of Milling Opn's Other than Keyways				
No. of Holes				
Other Opn's-Plate Heat Treat, Etc.				

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GENERAL PURPOSE DATA SHEET (INTERNAL REQUIREMENT)
Figure 3-4

WORK-MIX ANALYSIS PARTS ANALYSIS - SHEET METAL				
Family: Sheet of — Part No.				
Drawing				
Lot Size				
Labor Hours/Part				
Total Setup Hours/Lot				
No. of Setups Req'd				
Material Description				
Mat'l Blank (L-W-T)				
Largest Hole				
Total Number of Tools				
No. of Holes & Slots				
No. of Notches				
No. of Bends				
No. of Hits for Following Opn's				
Pierce				
Blank				
Bending Brake				
Draw Form				
Other Opn's Req'd Nibbling Rolling				

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GENERAL PURPOSE DATA SHEET (INTERNAL REQUIREMENT)

Figure 3-5

WORK-MIX ANALYSIS
PARTS ANALYSIS - DRILLING, BORING, TAPPING (Conventional)

FAMILY: Sheet of — Part No.	VB-6070	HV-16198	PWP-01100	GB-10221
Drawing/Noun	Valve Body	Valve Inlet	Pump Wobbler Part	Gear Case Base
Lot Size	25	10	10	5
No. of Lots/Year	12	6	12	12
Labor Hours/Part	1.8	3.6	14.5	17.5
Total Setup Hours/Lot	3.5	4.7	8.0	5.5
No. of Setups Reqd.	12	6	12	12
Material Description	Steel	Steel	A1S1 4140 Forging	Cast Iron
Matl. Blank (L-W-H)	18-9-3	12-9-9	4½ 1-3	24"-18"-3"
Dia. of Largest Hole	5/8"	3/8"	1"	1"
Dia. Tolerance*	0.001"	0.0005"	0.0005"	0.0005"
Location Tolerance*	0.001"	0.0005"	0.0005"	0.0005"
Location No.	15	12	2	96
Total No. of Tools	5	12	10	32
No. of Drilled Holes	10	12		96
No. of Bored Holes	5	4	4	32
No. of Reamed Holes		4		32
No. of C' Bore Holes		4		
No. of C' Sink Holes	14			36
No. Tapped Holes				20
No. of Surf. Milled	4	6 contoured	15 Flat 2 contoured	2
Work Surf. not 90 deg. to other surf.				
No. of Milled Pockets & Slots				2
Total Time Per Lot	39.50	40.70	153.00	93.00
Total Time Per Year	474.00	244.20	1836.00	1116.00
* Tightest				

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GENERAL PURPOSE DATA SHEET (INTERNAL REQUIREMENT)

Figure 3-6

WORK-MIX ANALYSIS (Numerically Controlled)
PARTS ANALYSIS - DRILLING, BORING, TAPPING

FAMILY: Sheet of — Part No.	VB-0670	HV-16198	PWP-01100	GB-10221
Drawing/Nound	Valve Body	Valve Inlet	Pump Wobbler Part	Gear Case Base
Lot Size	20	10	10	5
No. of Lots/Year	12	6	12	12
Labor Hours/Part	0.40	1.200	2.5	3.5
Total Setup Hours/Lot	1.05	1.25	2.0	3.0
No. of Setups Reqd.	12	6	12	4
Material Description	Steel	Steel	4140 Steel Forging	Cast Iron
Matl. Blank (L-W-H)	18"-9"-3"	12"-9"9"	4½d - 3"	24"-18"-3"
Dia. of Largest Hole	5/8"	3/8"	1"	1"
Dia. Tolerance*	0.001"	0.0005"	0.0005"	0.0005"
Location Tolerance*	0.001"	0.0005"	0.0005"	0.0005"
Location No.	15	12	2	96
Total No. of Tools	5	12	6	20
Do. of Drilled Holes	10	12		96
No. of Bored Holes	5	4	4	32
No. of Reamed Holes		4		32
No. of C' Bore Holes		4		
No. of C' Sink Holes	14			36
No. of Tapped Holes				20
No. of Surf. Milled	4	6 Contoured	15 Flat 2 Contoured	2
Work Surf. not 90 deg. to other surf.				
No. of Milled Pockets & Slots		12		6
Total Time Per Lot	9.05	13.25	27.00	20.5
Total Time Per Year	108.6	79.50	324.00	246.00
* Tightest				

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REV 2 JUL 70

GENERAL PURPOSE DATA SHEET (INTERNAL REQUIREMENT)
Figure 3-5

WORK-MIX ANALYSIS
PARTS ANALYSIS - TURNING (Conventional)

FAMILY: Sheet of / Part No.	SM-1320	P-18119	GS-4515	GS-1420
Drawing/Noun	Mainshaft	Piston	Gear Sleeve	Coil Support
Lot Size	100	64	10	50
No. of Lots/Year	4	4	12	4
Labor Hours/Part	0.31	0.20	1.48	1.64
Total Setup Time/Lot	0.22	0.52	0.78	0.69
No. of Setups Reqd.	4	4	12	4
Material Description	A1S1 8625	Pearlitic Mallable 229B	A1S1 4140 320B	60-40-10 Ductile Iron
Stock Diameter	3.477"	3.8"	9.875" Forging	9½" Casting
Blank Length	22.3/8"	5.45"	3.75"	
No. of Diameters	15	3	6	2 and Facing
Contours? / Ground Dia's?	/ 15			
Total Number of Tools	6	3	3	2
Turning Tolerance	± 0.001"	± 0.0005"	± 0.0005"	± 0.001"
Grinding Tolerance	±0.0005"			
Keyways				
No. of Milling Opn's Other than Keyways				
No of Holes		2	1	
Other Opn's Plate Heat Treat, Etc.				
Total Time Per Lot	31.22	13.32	15.58	82.69
Total Time Per Year	124.88	53.28	186.96	330.76

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REV 2 JUL 70

GENERAL PURPOSE DATA SHEET (INTERNAL REQUIREMENT)

Figure 3-7

WORK-MIX ANALYSIS
PARTS ANALYSIS - TURNING (Numerically Controlled)

FAMILY: Sheet of / Part No.	SM-1320	P-18119	GS-4515	CS-1420
Drawing/Noun	Mainshaft	Piston	Gear Sleeve	Coil Support
Lot Size	100	64	10	50
No. of Lots/Year	4	4	12	4
Labor Hours/Part	0.20	0.125	0.514	0.458
Total Setup Time/Lot	0.617	0.75	0.800	1.50
No. of Setups Reqd.	4	4	12	4
Material Description	A1S1 8625	Pearlitic Mallable 229B	A1S1 4140 320B	60-40-10 Ductile Iron
Stock Diameter	3.477"	3.8"	9.875" Forging	9½ Casting
Blank Length	22 3/8"	5.45"	6	2
No. of Diameters	15	3	6	2
Contours? / Ground Dia's?	15			
Total Number of Tools	6	3	3	2
Turning Tolerance	± 0.001"	± 0.0005"	± 0.0005"	± 0.001"
Grinding Tolerance	± 0.0005"			
Keyways				
No. of Milling Opn's Other than Keyways				
No. of Holes		2	1	
Other Opn's-Plate Heat Treat, Etc.				
Total Time Per Lot	20.617	8.750	5.940	24.40
Total Time Per Year	82.468	35.000	71.280	97.60

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GENERAL PURPOSE DATA SHEET (INTERNAL REQUIREMENT)

Figure 3-9

CHAPTER 4

JUSTIFICATION

4. Problems of justification. Once it is determined that the work-piece load is such that NC equipment is appropriate for part production, the next problem is to prepare justification documents that include the cost savings and new cost elements that are incurred with NC machines. The savings for numerically controlled machines is difficult to determine because many impacted functional costs are outside the manufacturing area. The DoD has recognized that many justification documents prepared in the past have omitted both costs and benefits related to NC equipment. This chapter is provided to inform DoD personnel of the various areas impacted by NC equipment so that justification documents can be completed without overlooking relevant details.

4.1 Data base. Data covering the cost involved with the direct manufacturing operations and the cost of those functions directly supporting manufacturing provides the basis for computing the savings that can be identified to proposals for investment in more productive equipment. The best source of such data is a detailed cost accounting system. Some cost accounting systems provide the detail required to assign expenses to a particular operation. Cost accounting data examined with additional data available from time studies, proposal estimates and process planning can provide a basis for making very accurate estimates of operation costs.

4.2 Estimating NC machine savings. The impact on manufacturing from conversion to numerically controlled machines reduces direct manufacturing costs and the costs in functions that support manufacturing. Total conversions to NC manufacturing equipment impact the following cost elements by approximate percentages stated and are provided to assist in seeking out savings opportunities and preparing reasonable estimates for justification documents. Partial conversions to NC operation would impact the cost elements in proportion to the fractional part of total production converted to NC. Methods and organizations in effect at individual activities can influence the impact, and individual activities are encouraged to develop impact percentages appropriate for existing conditions.

a. Machine labor savings.

(1) Improved accuracy available from the NC machine reduces direct labor cost by 5 percent.

(2) Tool offset values input to the numerical control can be adjusted when necessary by a keyboard entry reducing the time for tool adjustment to the extent that direct labor is reduced by 5 percent.

(3) Tools used on NC machines last longer than on conventional machines by being under program control so as to maintain optimum cutting conditions. The savings results from fewer tool changes and is approximately 20 percent of the tool allowance included on time standards.

(4) Improved machine utilization which is 80 to 85 percent on NC machines compared to 40 to 60 percent on conventional saves 10 percent of the overhead.

(5) Reduced set-up time enabled by combined operations on the NC machine can reduce set-up cost by 80 percent.

b. Tooling costs.

(1) The tool manipulation capability of an NC machine makes it possible for one tool to complete cuts that required two or more tools on a conventional machine. A smaller tool inventory is required which will reduce required toolroom space by 25 percent. Fewer and more simple tools are used which reduce the storage area of the tool crib by 50 percent.

(2) More standard tools featuring replaceable cutters are used with the NC machine reduce tooling cost by 25 percent.

(3) Program control of the tool in the cut at optimum cutting speed increases the life of tools. Longer tool life reduces overall tool cost by 30 percent. It also reduces the number of tool procurement savings 5 percent of tool cost. Longer tool life reduces the cutter grinding time by 20 percent.

c. Engineering costs.

(1) Fewer and simpler tools applicable to the operation of NC machines reduces tool engineering cost by 30 percent.

(2) More part production information included in the part program for an NC machine improves productivity of tool and process engineers by 15 percent.

(3) Production on NC machines require less paper documents to support production such as tool engineering records, part drawings and process sheets such that 40 percent less printing is required.

(4) Simple holding fixtures are required for most NC machine production which eliminate special fixture design and fabrication, saving 75 percent of durable fixture cost.

(5) Program control led machine cycles reduce the cost to establish and maintain time standards by 50 percent.

d. Maintenance costs.

(1) Simpler and improved designs featured on NC machines make these machines more durable and easier to repair with a savings of 25 percent on machine repair labor.

(2) Fewer machine repair parts required due to durability and simplicity will save 25 percent of machine repair material.

(3) Higher training cost for maintenance personnel.

e. Miscellaneous costs.

(1) Inspect ion performed by an NC inspection machine will reduce the cost of inspection by 80 percent.

(2) Manual inspection of NC parts is reduced by 30 percent due to part repeatability.

3. Scrap generated by set up is reduced by 30 percent and the segment of scrap caused by tool change or adjustment by 20 percent.

4. Power consumption of NC machines is 5 percent lower than that of conventional machines performing the same work. The numerical control applies power to motors only when motion is required.

5. Material handling costs are reduced by 5 percent or more due to elimination of secondary operations and combination of multiple machine operations on a single machine.

4.2.1 Direct and indirect savings. The basic data for computing direct savings was developed in the example covering preparation of a work-mix analysis for turning. Computation of the direct and indirect savings identified to the more productive machines is presented in Appendix C. Computation in accordance with the guidance provided here will serve as the backup for completion of a DD Form 1106 or an economic analysis.

4.3 Economic justification. For DoD-owned equipment designated for continued ownership, the primary justification for accomplishing replacement or modernization projects are the economic and technical benefits to be obtained by: (a) introducing advanced manufacturing processes to enhance productivity; (b) alleviating equipment obsolescence; and (c) making the Government-owned segment of the production base more responsive to industrial preparedness requirements. The "Industrial Plant Equipment Replacement Analysis Work Sheet," DD Form 1106, prescribed in DLAM 4215.1-M, AR 700-43, NAVSUP PUB 5009 and AFM 78-9 or the instructions of DoD Instruction 7041.3 (reference (M) "Economic Analysis and Program Evaluation for Resource Management") may be used to perform the economic analysis of proposed DoD investments. Economic justification is needed for additional NC IPE (for existing workload) even when no existing equipment is replaced. For new workload follow chapter 3 to select the two best alternatives. The economic justification will determine which alternative has the lowest uniform annual cost.

4.3.1 Abbreviated economic analysis (AEA).

a. An abbreviated economic analysis (AEA) may be used in lieu of a "formal" EA whenever the investment cost is less than $200,000. The objective of the AEA is to fulfill the requirements for justification, serve as a useful management tool, and reduce the administrative workload to a minimum.

b. With respect to the project submission, the most frequently used EA is the one that compares the proposed alternative to the status quo. In this case the AEA follows the techniques and precepts of the formal economic analysis but in a condensed form.

c. The AEA is required when the project is to acquire additional NC IPE or initially invest in NC IPE without eliminating any existing conventional IPE providing the investment does not exceed $200,000. Appendix E provides a suggested format and example of the abbreviated EA.

4.3.2 DD Form 1106 Industrial Plant Equipment Replacement Analysis Worksheet. When numerically controlled equipment is replacing conventional and NC-equipment the DD Form 1106 should be used to perform the economic analysis.

4.3.3 Examples of DD Form 1106 use for NC IPE justification. The DD Form 1106 can be used to justify the replacement of two or more conventional machines with NC IPE and explore the alternative of upgrading existing NC IPE by rebuild and retrofit. Appendix C provides an example of using the DD Form 1106 to replace two conventional machines. Appendix F provides instructions and examples of exploring the alternative to rebuild and retrofit or replace with a new NC machine. Appendix D covers the ranking of projects by utilization of ROI to analyze competing investment opportunities. Ranking may be by amortization, ROI, saving/investment ratio or, priority (urgency) on projects supported by DD Form 1106 or an economic analysis.

4.4 Sources of supply. Prior to procurement, the Defense Industrial Plant Equipment Center (DIPEC) general reserve must be screened to determine whether the customer requirement can be satisfied by allocation of a machine from the general reserve. When the requirement cannot be satisfied with an item from the general reserve, DIPEC completes Section V of the DD Form 1419 Non-Availability Certificate or issues a MILSTRIP Supply Status Code “CW”. Either of these documents serves as a Certificate of Non-Availability.

4.4.1 Allocation from DoD reserve. Numerically controlled machines in the general reserve that match the customer’s requirements provided on the DD Form 1419, MILSTRIP requisition, DD Forms 1348-6 and 1348-M or MILSTRIP message format are offered for reallocation. Numerically controlled machines allocated to the customer are completely rebuilt to like-new condition, retrofitted with a new control, and equipped with the latest state-of-the-art electrical axis drive system. The customer having a requirement for additional features not on the machine such as rotary milling table or electrical spindle drive is required to pay for the cost involved in providing these features.

4.4.2 New machine procurement. New machine procurement is the authorized source of supply when a Non-Availability Certificate is issued by DIPEC. DIPEC cites the applicable military specification to be used in procurement of the item requested on the DD Form 1419. Procurement specifications are such that the requiring activity can specify the options desired and thereby satisfy his capacity and performance requirements.

4.4.3 Upgrade by rebuild and retrofit. Early numerically controlled machines that have supported manufacturing since installation do not have the capabilities available on new machines of the same type. Advanced features available on the numerical control and use of modern electrical axis drive systems make these new machines more productive, quieter and more energy efficient than the early NC machines that used hydraulic motors for axis and spindle drive. The Defense Industrial Plant Equipment Center will provide the technical and contractual support to rebuild and retrofit your machines to provide the latest state-of-the-art capabilities and features on a reimbursable basis. Technical requirements prepared by DIPEC for the rebuild and retrofit of numerically controlled machines include modernization of the axis drives by the installation of modern servo motors, solid-state drives and electric spindle motors. The rebuilt machine is retrofit with the latest numerical control that in most cases enhances the capabilities of the machine. The rebuilt and retrofitted machine has new machine life expectancy, accuracy and the performance capabilities of a new machine of the same type. The cost for the typical rebuild and retrofit is 45 to 60 percent of replacement cost. To obtain contractual support from DIPEC, contact Defense Industrial Plant Equipment Center, DIPEC-S, Memphis, TN 38114-5297.

4.5 Justification of computers and systems. The introduction of numerically controlled machines into the manufacturing process opens opportunities to develop productivity enhancing systems that are outside the manufacturing environment and utilize computers to make manufacturing support work less labor intensive. The productivity improvement obtainable from the use of computer equipment is directly correlated to the specification for the system. Since these computers and systems are for support of manufacturing they fall under the category of industrial resources and require justification on the basis of benefits and costs.

4.5.1 Justification documents. The costs and benefits identified to computer systems supporting manufacturing shall be documented and used as the basis for preparing an economic analysis. Economic analyses for computer hardware, peripherals and software required shall be prepared in accordance with paragraph 4.3.

4.5.2 Present method cost data. The source of data for developing cost related to the existing method for providing manufacturing support is the cost accounting system supplemented with data from the work measurement and performance effectiveness evaluation system. Present method cost data also serves as the basis for post operation analysis.

4.5.3 Vendor’s data. Vendors of computers are the best source of information regarding the productivity improvement you can expect from the system specified. Vendors are also well qualified to assist you in developing the system specification best suited to the situation within your activity.

4.6 Justification of digital readout systems (DRS). A digital readout system is a productivity enhancing attachment for the machine on which it is fitted. The productivity improvement on machines fitted with a digital readout system is such that the DRS cost can be recovered in less than one year and the investment is these systems can be justified under the Fast Payback System or the Quick Return on Investment Program. Policy and procedures issued by the services governing investments recoverable in a short time period should be followed in justifying these systems.

CHAPTER 5

POST ANALYSIS

5. Post analysis of industrial equipment modernization program. DoD Directive Number 4275. 5 DoD Instruction 5010 36 and guidance provided by the military departments establish post in investment accountability. The FAR in 52.245-16 and Department of the Army Pamphlet 700-23 prescribe that DD Form 1651 be used to evaluate industrial equipment modernization program projects. The DD Form 1651 is the appropriate form for reporting the results of the post investment analysis of industrial equipment placed in operation as the result of acquisitions supported by DD Forms 1106 and economic analyses. A follow-up analysis of the actual savings realized from operation of numerically controlled machines and computer based manufacturing support systems provides a closed loop management system. The post analysis of results obtained from operations lends credibility to the selection and justification phases of establishing operations. Personnel, knowing that justification document cost estimates will be compared to actual operational results, have sufficient time to develop the necessary data collection system.

5.1 Basis for comparison. The DD Form 1106, Economic Analysis or Abbreviated Economic Analysis, covering the improvement project is the basis for comparing results obtained from utilizing numerically controlled IPE and computer aided manufacturing systems. In the case where an economic analysis is used, the basis for comparison is the second best alternative.

5.2 Productivity enhancement measurement. The ideal system for gathering data relevant to the post analysis of productivity enhancing equipment and systems is prescribed in DoDI 5010.34, SUBJECT: Productivity Enhancement, Measurement and Evaluation Guidelines and Reporting Instructions. The most important measure sought in the post analysis is the Productivity improvement ratio (PIR) actually realized in the first year of operations compared to the projected PIR.

5.3 DD Form 1651 preparation. The DD Form 1651 is organized to present the estimated cost for old and new equipment and the actual cost for old and new equipment. The estimated cost data is extracted from the justification document and actual cost is taken from records kept by the activity during the prescribed operational period. Data elements listed in Section 8 of the form are identical to those in Section 8 of the DD Form 1106. Figure 5-1 is a completed DD Form 1651.

a. The DD Form 1651 will be prepared by the using activity within two months after the first year of use. When technical difficulties are encountered during the first year that do not permit operation of the new items for a period of nine months out of the first year following installation, the circumstances preventing utilization will be explained along with the DD Form 1651 covering the period utilized. A DD Form 1651 covering a full year of operation that immediately follows the year in which difficulties were experienced shall be prepared. Each form shall be identified as the first or second submission.

b. In those cases where the actual cost reduction is less than 85 percent of the savings projected on the DD Form 1106, a detailed explanation of the reason for the deviation will be provided.

A copy of the approved DD Form 1106 or economic analysis will be attached to the DD Form 1651.

5.4 Reporting. The completed DD Form 1651 with justification documents provides information required to prepare the Document Format, Productivity Enhancing Capital Investments Analysis Data required by DoD Instruction 5010.36.

5.5 Automated analysis and management system. The Air Force Logistics Command (AFLC) has developed an Automated Economic Anaylsis and Equipment Inventory Management System. The AFLC will make the system documentation available to DoD components interested in implementing the system. Those interested in application of the AFLC system should contact:

Headquarters Air Force Logistics Command
ATTN : HQ AFLC/MAXF
Wright Patterson AFB, OH 45433

The Air Force Automated Economic Analysis and Equipment Inventory Management System can be utilized to perform much of the work required to select, justify and analyze production equipment.

INDUSTRIAL EQUIPMENT MODERNIZATION PROGRAM - POST ANALYSIS REPORT	DATE 29 Jan 1985	FORM APPROVED BUDGET BUREAU NO. 22-R 0271
1. ACTIVITY ABC Arsenal	2. LOCATION Davenport, IA	3. EQUIPMENT LOCATION FUNCTION Industrial Machine Shop BLDG NO. 123
4. DCASR/DOD REP	5. CONTRACT N00164-79-B-0045	6. SUPPLEMENT NO. N/A
7. EQUIPMENT DATA		
a. DESCRIPTION Lathe, Turret, Saddle, Cross Sliding Turret, Numerically Controlled	b. MANUFACTURER Jones & Lamson Co., Div. of Waterbury Farrel	c. MODEL NO. 4515-B-TNC-4 d. QUANTITY Ø1
e. PRODUCTION EQUIPMENT CODE 3416-3627-2534	f. DOD NUMBER 3416-38698	g. UNIT COST $ 303,977
h. DATE RECEIVED May 1981	i. DATE INSTALLED October 1983	j. TOTAL COST $ 306,500
k. DATE ACCEPTED November 1981	l. DATE RELEASED TO PRODUCTION November 1983	m. SERVICE LIFE - YEARS 23

8. COMPARATIVE OPERATING COST ANALYSIS FOR EQUIVALENT OUTPUT *(Estimated vs Actual)*

FACTOR	a. ESTIMATED COST *(DD Form 1106)*		b. ACTUAL COST *(End of Year) (Est)*	
	OLD EQUIPMENT (1)	NEW EQUIPMENT (2)	OLD EQUIPMENT (Est) (1)	NEW EQUIPMENT (Est) (2)
a. MACHINE LOAD HOURS	3,960 HRS	1,414 HRS	14,153 HRS	1,163 HRS
b. DIRECT LABOR FY84 Actual $11.54	$ 31,600	$ 11,286	$ 163,326	$ 13,421
c. INDIRECT LABOR	33,496	11,963	Ø	Ø
d. FRINGE BENEFITS FY84 Actual $1.38	10,902	3,894	19,531	1,605
e. MAINTENANCE FY84 Actual $23.50	687	161	1,325	352
f. POWER	Ø	Ø	Ø	Ø
g. SCRAP/REWORK	1,580	158	8,166	817
h. TOOLING Actual Acquisition	6,320	2,257	6,320	19,000
i. SAVINGS/OTHER OPERATIONS ASSY	Ø	Ø	Ø	Ø
j. OTHER COSTS $12.92 FY84 Actual Inspection Cost	5,585	1,117	6,718	1,344
k. TOTAL OPERATING COSTS	$ 90,170	$ 30,836	$ 205,386	$ 36,539
l. NET OPERATING COSTS FAVORING NEW EQUIPMENT *(K Col a(1) or b(1) minus K Col a(2) or b(2))*		$ 59,334		$ 168,847

m. PRODUCTIVITY INCREASE RATIO *(Actual)* 12.1:1 *(Forecast DD Form 1106)* 2.8:1	o. ESTIMATED SAVINGS NEXT YEAR $ 175,000
n. 5785345-0001 16 November 1976	p. ESTIMATED SAVINGS TOTAL 2 YEARS $ 343,847

9. DISPOSITION OF REPLACED EQUIPMENT

a. EQUIPMENT REPLACED *(Item 5a, DD Form 1106) (Show DOD TAG No's)* Lathe, Turret, Ram, Universal, Manual DoD No. 3416-37679 Lathe, Turret, Saddle, Cross Sliding Turret DoD No. 3416-37677	b. DATE DOD 1342-S ISSUED 1062 c. DATE DOD 1342-S TO BE ISSUED

10. REMARKS

8c. Indirect labor costs were incorrectly identified on DD Form 1106; there are no indirect labor costs saved.

8m. Productivity increase ratio variance--production rate of new machine was under-estimated on DD Form 1106.

DD FORM 1 FEB 65 1651

Figure 5-1

CHAPTER 6

INSURING THE SUCCESS OF YOUR CAM INSTALLATION

6. Insuring the success of your CAM installation. It is no secret that some NC installations have been failures. Such experiences have been expensive, unpleasant, and have often been distorted. Usually, a technical reason was blamed when, in almost all instances, it could be traced to inadequate planning and/or to improper administration. The key to good NC management lies in prior planning so that an installation becomes productive in a minimum amount of time and with as little fanfare as possible. It is an absolute imperative that planning start when a favorable disposition is made towards the NC concept, long before the equipment order is signed. Implementing the following guidelines will help insure a very rewarding experience both to you as an individual, and to your plant. While no guarantee to success can be made by implementing the following guidelines, the risk can be minimized.

6.1 Inform and involve your people. It is an absolute must that as soon as a favorable modernization program decision is made, everyone affected should be informed of what changes are taking place, what will be expected, when the equipment will arrive, what the relationships will be toward the equipment, what opportunities will be created and the challenges that will have to be met. In all honesty, the people should be informed that NC is not just another machine tool; it is a whole new method of operation. It is largely a systems concept involving changes in operating methods, skill requirements, tooling, fixtures and maintenance. For example, there will be a programming function. Programing will relate to shop management, machine operation, planning and methods, product design, and finance.

a. All of these areas should be explored and they should be thoroughly discussed with the people involved. This can be done in such a way that people will look forward and welcome the new opportunities and the new challenges that NC will offer. Perhaps no other single step is as important as obtaining the cooperation of the people involved.

b. Failure to involve people and to adequately inform them will almost certainly bring about resentment, frustration, lack of cooperation, antagonism, or deliberate sabotage in extreme cases.

c. In any successful NC installation there has been thought and planning given to the concept with proper procedures developed to accommodate the NC machine.

6.2 Select and train personnel. An NC installation, even in the most modest form, is a capital Investment. The NC machine tool involves three important people--the person who will program it, the man who will maintain it, and the one who will operate it. All three of these people should receive prior training. Although machine maintenance may be under contract and programming may be done by an outside source, it is vitally important that selected arrangements are made before the machine arrives. Usually, the training courses are either furnished by, or made in cooperation with, the machine tool vendor. Ideally, there will be workpiece programs written, the operator will have been trained and the maintenance man will be familiar with his duties by the time the NC machine arrives. The vital key is the word beforehand. Many NC machine tool vendors have suggested schedules drawn up showing how far in advance training and other preparatory events should take place. It would be wise to work with them.

6.3 Consideration of future development. The recent trend is to integrate computer systems into the manufacturing plant to reduce manual labor, expedite actions and improve productivity. It is obvious that with the changed relationships among personnel and departments brought about by NC and with the use of the computer, NC is not just another machine tool. Thus, when the machine tool is purchased, try to think of what future manufacturing requirements will be, how the future will be organized, and the opportunities a new and improved manufacturing technology can open up. Therefore, keep an open mind and do not buy with the idea of acquiring just another machining spindle. Do not institute limitations which will restrict or inhibit future growth and development.

6.4 Plan for adequate tooling and part programming. Inadequate tooling can completely kill the efficiency of an NC operation. NC machines can often execute programs far faster than one man can prepare them--especially if he is writing them manually. Therefore, think about these things. If a minicomputer or some other computer package would be advisable, consider this and bring it in as part of the NC installation. The tooling packages and systems should be settled prior to delivery of the machine. In addition, such things as digitizing equipment, files, accessories and so on can have a very significant bearing on the success of an NC installation. A little bit of sound planning here will pay off very well in the working efficiency.

6.5 Get adequate machine and control unit features. A well programmed NC machine tool will be cutting the workpiece a very high percentage of the time. Therefore, the machine tool itself should have adequate drives, ways, and features that can stand up under sustained use. The control unit should have those features necessary to keep the machine functioning. For example, tool offsets may be one of the wisest investments that can be made in the way of control unit options. Before the machine is purchased, the NC coordinator should sit down with the supplier and review the various options and features and what they offer. It is far easier to have them built into the equipment than to make a field installation sometime in the future. Use of the military specification covering the NC machine required will insure the control has adequate features.

6.6 Know the actual machine capabilities. Control unit manufacturers claim that the electronic resolution of their units may be within 0.000050 or 0.000100 inch. Although this may be true, it is by no means a fact that the machine tool can produce to these accuracies. There are servos, lead screws, beds, ways, columns, spindles and tooling, made of metal and subject to physical component tolerances. All of them play a role in determining the final machining capability which, from the user's standpoint, is the one parameter of primary concern. Therefore, it behooves the user to know exactly what can be obtained in the way of accuracy. The same holds true for all machine features. Table size and travel are not always the same. Not all machine functions are digitally programmable. The machine may be equipped with a tool changer but it should be known what kind and what size tools can be mounted in the changer. In essence, it is important to know all machine and control features and what legitimately can be expected from them. When speaking of working tolerance, it is even important to know how it is defined. This is so essential that the National Machine Tool Builders Association has a comprehensive paper on the meaning of tolerance and its determination. If critical tolerance is a vital factor, it would pay to obtain and study this paper. Use of the military specification covering the required NC machine will insure that the desired performance requirements are satisfied.

6.7 Set goals for NC performance. A numerically controlled machine tool represents an investment of money, effort and talent. NC should have some challenging but realistic goals which can be met when the machine arrives and when everyone is low on the learning curve. The machine tool should not be relegated to odds and ends work. A good system of machines, programs and administrative backup can do far more work than normally expected. There should be a well defined effort to constantly expand the uses for the NC machine tool and make best use of its inherent advantages that lead to new opportunities which NC and enlarged computer-aided concept is creating.

6.8 Determine environmental and utility requirements. Because of its electronic control unit, some NC machines are sensitive to certain types of environment. Some control units will malfunction if there are wide electrical voltage variations. For this reason, a voltage regulator may be required. There is the question of foundations, air and other support utilities. These should all be checked out with the builder beforehand.

6.9 Implement NC into the entire production process. While NC will bring about changes in methodology, NC should not be considered as a totally separate entity. It should be integrated into overall production routine. Process and methods people should be thoroughly versed in NC capability to plan for its advantages. Even the product designer should realize that NC machining will give him more latitude in his work. He and the programmer should integrate their knowledge and efforts so that the input from design to programming is kept minimum, while yielding maximum results. Drafting and engineering will probably want to revise their procedures, if necessary, to comply with programming and machine tool operating requirements. Otherwise, the programmer may have the laborious task of trying to program from incremental drawings in the absolute coordinate system. The NC concept becomes more profitable as it is integrated into normal shop routine.

6.10 Rely on trained personnel. NC has a lot of built-in safety and protective features, but it cannot cope with gross mismanagement or untrained operators. One programmed collision can do many dollars worth of damage. Operation of NC machine tools should be restricted to those who have had adequate training and have a positive, willing attitude.

6.11 Follow the manufacturer's advice. Remember, no NC equipment manufacturer wants to have an unsuccessful Installation. It can hurt him as much as it does the person who is not making satisfactory progress. Therefore, manufacturers of NC equipment are most interested in seeing that your people have the proper training and know-how to make the installation successful. They have gone to great pains to prepare manuals, organize training programs, offer consulting services and advice that go with the machines. Be sure to avail yourselves of these. Because of the manufacturer's own self-interest, he will do everything in his power to give you a very important backup resource to make sure that your NC installation works. Be sure to utilize this resource when you need help with NC.

6.12 Dissemination of information on the subject of NC/CAM. Personnel within those activities that are using or intend to use NC or CAM at their plant need to keep up with developments in the field and provide training to those personnel having responsibilities to select, maintain, program and operate the machines and systems involved.

a. Trade journals. Periodicals covering the manufacturing industry contain articles and advertising material that keep personnel informed on developments in application of technology to increase productivity. Excellent periodicals for this purpose are: Modern Machine Shop, Machine and Tool Bluebook, Manufacturing Engineering and Commline. Most of these periodicals are free to those having responsible positions in manufacturing plants.

b. NC/CAM Workshop for DoD Components. The annual NC/CAM Workshop sponsored by DIPEC is for the purpose of disseminating current information on developments in the field of applying technology to improve productivity of manufacturing operations. The workshop is usually held during the first half of November. Proceedings of the workshop are published and a copy is available to each individual attending. For information regarding the workshop contact, Defense Industrial Plant Equipment Center, DIPEC-SSM, Memphis, Tennessee 38114-5297.

c. Manufacturers. Training for part programmers and electronic and mechanical maintenance personnel is provided by the machine tool manufacturer and is usually conducted at the manufacturer's plant.

d. Government training. The U. S. Army Management Engineering Training Activity (AMETA), DRXOM-DO, Rock Island, IL 61299 offers courses in computer aided manufacturing, numerical control part programming and manufacturing cost estimating for modernization projects. The current AMETA Course Catalog lists and describes courses currently available to DoD personnel.

Custodians:
Army - AL
Navy - SH
Air Force - 99

Preparing activity:
DLA - IP

Project FSG 34GP-0063

Review activities:
Army - AV, SM
Navy - AS, YD
Air Force - 84
DLA - GS

User activities:
Army - AL
Navy - SH
Air Force - 99
NC Coordinators (See Distribution List)

APPENDIX A

NUMERICALLY CONTROLLED MACHINES

A.1 Numerically controlled machines. In a broad sense, a numerically controlled machine operates by means of a numerical control system consisting of a numerical control unit, axis drive servo, control components, axis leadscrew, servo motors and encoders. The control unit operates motion and functions of the machine in accordance with alphanumeric data that is provided to the control by some form of input media. The entire set of coded data necessary for the machine and control system to automatically produce a part is the part program. The standard specified for coding the part programs used for DoD owned numerically controlled machines is Electronic Industries Association Standard RS-274, "Interchangeable Variable Block Data Format For Positioning, Contouring, and Contouring/Positioning Numerically Controlled Machine." Machine axis and motion nomenclature specified for DoD owned machines is EIA Standard RS-267, "Axis Motion Nomenclature for Numerically Controlled Machines."

A.2 Machining centers. Federal Supply Class 3408, "Machining Centers," refers to a multipurpose numerically controlled machine tool for the complete and automatic machining of parts requiring multiple operations such as milling, drilling, tapping, boring, and reaming, having an integral tool storage device and an integral means for positioning various faces of the workpiece. It must have facilities for automatic interchanging of tools in the spindle so as to provide the tools required for three various operations. Excluded from this class are multipurpose numerically controlled machine tools, such as boring-drilling-milling machines, which require manual tool changes and manual manipulation of the workpiece to present a different face to the spindle.

A.2.1 Combined operations. Machining centers have been widely accepted because of their capability to combine operations that required several conventional machines. Combining operations by utilizing a machining center reduces the number of set ups, material handling moves and production planning steps.

A.2.2 Vertical spindle machining center. Three-axis, vertical spindle, multipurpose boring, drilling, and milling machines, equipped with a tool changer, that offer a rotary positioning or contouring table are considered to be machining centers in FSC 3408. Machining centers in this category can also be optionally eauipped with a pallet shuttle system. Figure A-1 shows a three-axis vertical spindle machininq center with the optional pallet shuttle. The pallet shuttle is the feature that enables integration of these machininq centers into flexible systems or cells.

A.2.3 Horizontal spindle machining center. Three-axis, horizontal spindle machining centers with a positioning rotary table provides a stand-alone, multipurpose machining capability. These machining centers are capable of performing work on at least four sides of the workpiece. When equipped with the optional pallet shuttle, these machining centers can be integrated into a flexible manufacturing system or cell. Figure A-2 is the three-axis, horizontal spindle machine with the rotary positioning table. The machine is not equipped with the optional pallet shuttle.

A.2.4 Four and five-axis machining centers. Four and five-axis, horizontal spindle maching centers provide capabilities that maximize the operations that can be performed with one set up. The manipulation of the spindle with a rotary contouring head or manipulation of the workpiece with a rotary tilting table enables machining that would require multiple fixturing, machining five sides of the workpiece and multiple axis contouring with one set-up. The capability to machine sides of the workpiece is not available on four axis machining centers. Some four-axis machining centers provide a 90-degree spindle attachment that enables machining five sides of the workpiece. The fourth axis on the machine in figure A-3 is a positioning and rotary contouring table. The fifth axis is a tilting rotary table capable of orienting the work piece at any position ranging from vertical to horizontal in relation to the longitudinal axis. The fourth axis on the machine is figure A-4, is a rotary positioning and contouring table. The fifth axis is a rotary contouring head that enables spindle positioning or rotation from 15 degrees above the horizontal to 15 degrees aft the perpendicular for a total movement of 120 degrees.

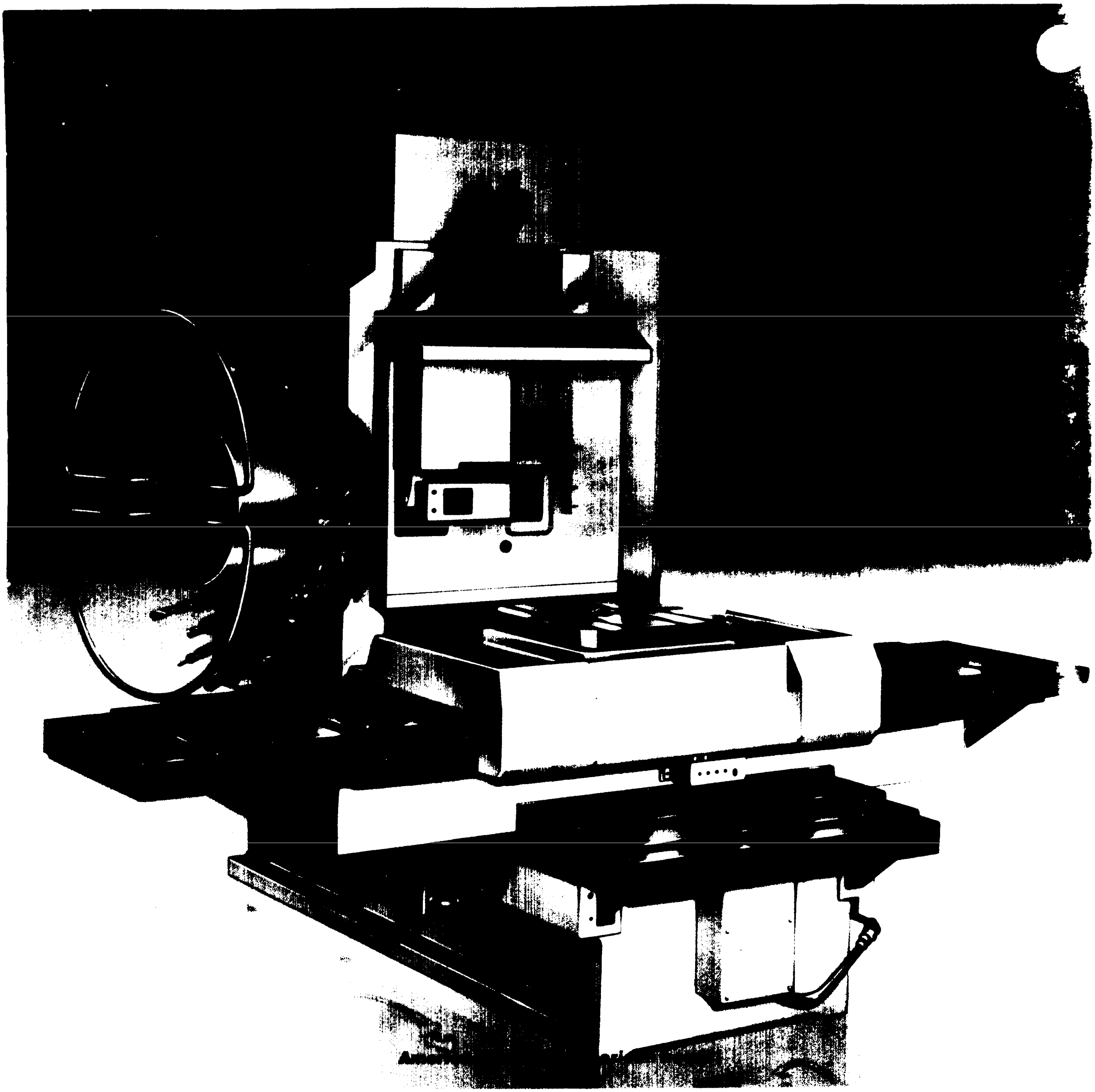


Figure A-2. Horizontal spindle machining center with rotary positioning table. Three axes numerically controlled. (Burgmaster Houdaille).

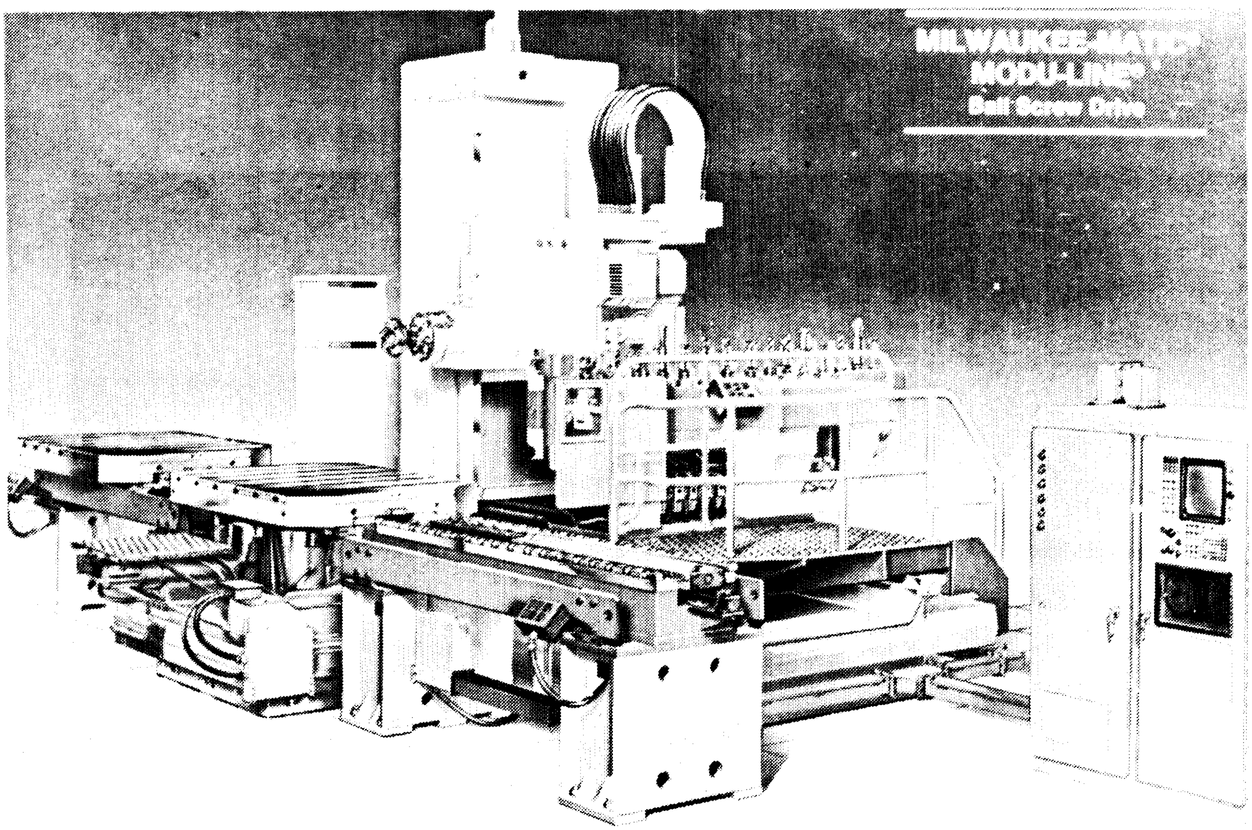


Figure A-3. Five-axis machining center, five axes numerically controlled. (Kearney & Trecker)

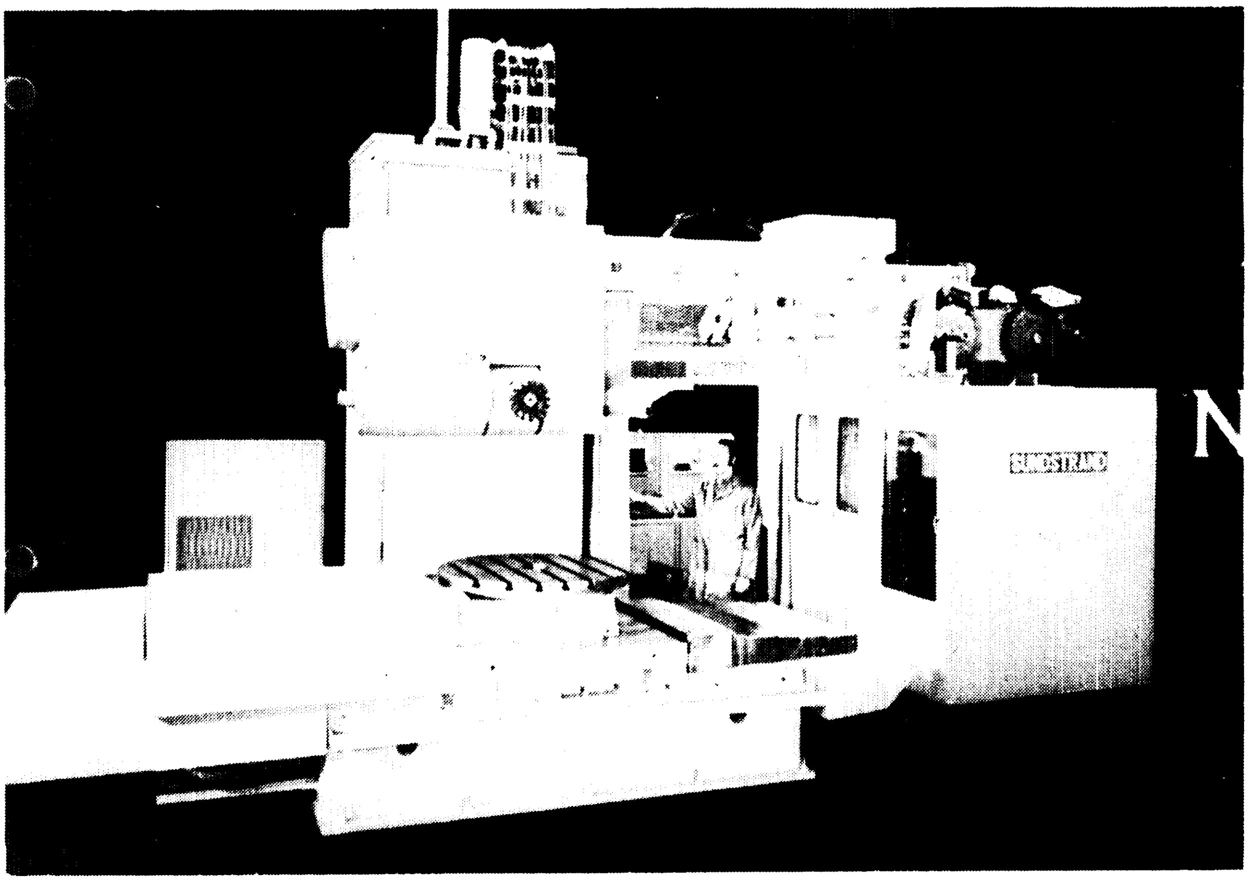


Figure A-4. Five-axis machining center, horizontal spindle, rotary positioning and contouring table and rotary contouring head. Five axes numerically controlled. (Sundstrand Division/ White Consolidated Industries)

A.2.5 Machining center numerical control requirements. Minimum requirements for the numerical control utilized on machining centers purchased by the DoD are stated in the military specification covering the particular machining center. In the following paragraphs the notation (see 6.2.1) appears and makes reference to the procurement requirements of the procuring activity. Using the procurement requirements enables the procuring activity to specify requirements that are not satisfied by the specification. The following paragraphs state the typical requirements for a numerical control fitted to a machining center.

A.2.6 Numerical control. The machining center shall have a fully automatic, solid-state, soft-wired, integrated circuit type numerical control. The machine control unit (MCU) shall provide automatic control of machine functions, operating modes, four-axis feedrate control for type I machines and five-axis feedrate control for type II machines, spindle speed and direction of spindle rotation and other part program directed functions for machining centers of the type specified herein. The axes shall be identified in accordance with EIA Standard RS-267. The control shall have linear and circular interpolation and be capable of simultaneous control of four axes for type I machines and five axes for type II machines. Control features shall include a programmable interface, buffer storage, fixed cycles, part program storage, part program and buffer edit capability, and control diagnostics. The MCU shall direct machine functions from part program data stored in memory, manually input or directly input from the input media specifies herein. The control shall initiate a halt or an error signal should a fault condition occur in the control. All necessary executive diagnostic and interface program routines shall be furnished in the form of one-inch, eight-channel binary coded decimal punched tape or eiqht-inch flexible disk as appropriate for input media specified" (see 6.2.1 for controls having volatile memory). The control unit shall conform to EIA Standard RS-281. A line voltage of ±10 percent from normal shall not adversely affect the numerical control function. The control shall be capable of functioning in ambient temperatures ranging from 50°F to 120°F and relative humidities ranging from 5 percent to 95 percent non-condensing. The control shall automatically shut down when internal operating temperature exceeds safe operating temperature. Control resolution shall be 0.0001 inch or 0.001 mm for each linear axis and not more than 0.001 of a degree for each rotary axis. When binary cutter location (BCL) data is specified (see 6.2.1) the numerical control shall have the necessary hardware and software to perform all geometry dependent functions which are ordinarily performed by the postprocessor.

A.2.6.1 Type I MCU. The type I MCU shall provide full contouring control of the machine's three linear and one rotary axes of motion for performing drilling, tapping, boring, reaming, and contour milling operations through simultaneous movement of each axis.

A.2.6.2 Type II MCU. The type II MCU shall provide full contouring control of the machine's three linear and two rotary axes of motion for performing drilling, tapping, boring, reaming, and contour milling operations through simultaneous movement of each axis.

A.2.6.3 Data input.

A.2.6.3.1 Punched tape data input. Unless otherwise specified (see 6.2.1) the input media for the control shall be one-inch, eight-channel punched tape. The data input format and codes shall comply with EIA Standards RS-274, RS-358 and RS-447, or when specified (see 6.2.1), RS-244 shall apply in lieu of RS-358. The control shall be equipped with a photoelectric tape reader capable of holding, feeding and reading tape prepared in the format specified at a rate not less than 150 characters per second. Unless otherwise specified (see 6.2.1), the tape reader shall be supplied with standard feed and take-up spoolers 5-1/4 inches in diameter. The tape reader shall be housed in a dust-free area of the numerical control cabinet and shall be easily accessible for cleaning and tape handling. The control shall have a tape error detection capability to continuously check for the following errors:

a. Odd parity per EIA RS-244
b. Even parity per EIA RS-358
c. Misaligned sprocket holes
d. No sprocket holes

Any of the above errors shall halt machine functions and illuminate an error light or a message on the data display screen to indicate a fault condition.

A.2.6.3.2 Flexible diskette data input. When 32 Bit Binary Cutter Location (BCL) Exchange Input for Numerically Controlled Machines is specified (see 6.2.1), the input media shall be an eight inch flexible diskette recorded in accordance with A.2.6.3.2.1.1. The input data format shall comply with EIA Standard RS-494. Functions 10.1, 10.2 and 10.3 of Section 10, EIA-RS-494 shall apply. Manufacturers providing functions or features that can not be addressed by command codes currently covered by EIA-RS-494 shall apply to the Electronic Industries Association, IE-31 Committee on Numerical Control Systems and Equipment for an extension of the standard codes to cover the new features or functions. The control shall be equipped with an eight-inch flexible diskette reader. The reader shall have the capability to perform a cyclic redundancy check of the input data and be capable of reading not less than 15,000 characters per second.

A.2.6.3.2.1 Flexible diskette format. When an eight-inch flexible disk is specified as the input media to the numerical control, it shall be a single-density recording on one side using a soft-sectored format. The disk shall be divided into 77 distinct locations on the single-side disk. Tracks shall be assigned numbers from 00 through 75. Track 00 shall be nearest to the edge of the disk and track 76 nearest the center. Tracks 00, 74, 75 and 76 shall not be used. There is an index hole in the jacket and the disk that shall be used for timing functions when a beam of light passes through it. Recording shall be accomplished by rotating the disk inside its jacket exposing the disk at the read/write head slot cut in the jacket. Data shall be recorded only on the side of the disk that is exposed to the read/write head. Each track shall be divided into 26 addressable sectors which contain 128 bits. All sectors shall be identified by the file starting sector number with track 00, sector 1, designated as O. The first part program shall be located at sector lE hexadecimal corresponding to track 1, sector 5. Where two byte numbers are referenced the high order byte shall be recorded first and the low order last. The data stored in a sector is called a record. Track 1, sectors 1 through 4 shall contain the program directory of up to 16 part program names in ASCII. Each file shall be packed on the disk in the same order as its directory entry. Unused directory entries shall point to the next available sector after the last file and contain the 30-character ASCII space characters. The last sector of each file shall be padded with end-of-file (EOF) records (8000 0000). Diskette addressing shall comply with the requirements of table IV.

A.2.6.4 Data display. A cathode ray tube (CRT) capable of displaying at least 250 characters simultaneously shall be provided. Unless otherwise specified (see 6.2.1), the display shall, as a minimum, display the following data:

a. Four digit block sequence number.
b. Active block of stored data.
c. Actual position of each axis.
d. Feedrate and override condition.
e. Control and system error messages.

A.2.6.5 Control system modes of operation. The operational modes of the NC control shall include manual, automatic, single block, MDI, sequence number search and optional stop.

A.2.6.7 Departure control. The maximum departure permitted by a single command in either incremental or absolute mode shall be not less than plus or minus 99.9999 inches or 999.999 mm. The control shall be capable of automatically controlling the acceleration and deceleration of the slides. The resolution of slide movement in either direction shall not be more than 0.0001 inch or 0.001 mm.

A.2.6.8 Absolute/incremental input. The control shall have absolute/incremental input capability. This mode shall be selected by a preparatory “G” code or setpoint initialization switch which may be switched during the part program. Not applicable if BCL data input is specified (see 6.2.1).

A.2.6.9 Switchable inch/metric input. The control system shall provide switchable inch/metric input capability.

A.2.6.10 Part program storage. Unless otherwise specified (see 6.2.1), part program storage shall be in either solid-state or bubble-type memories. Unless otherwise specified (see 6.2.1), the MCU shall be capable of storing in memory the content of not less than 250 feet of postprocessed part program tape data. Not required if BCL data input is specified (see 6.2.1).

A.2.6.11 Standby battery power. Unless otherwise specified (see A.4.6.10), standby battery power be provided for controls having volatile memory, to hold the fully loaded memory for a period of not less than 70 hours when the primary power source fails.

A.2.6.12 Part program edit. A program edit capability shall be provided to allow block Insertion, deletion or modification of any part program in the part program memory. Data related to part program edit shall be input by the manual data input provided on the control panel. Edited program data entered into program memory shall be automatically acted upon, in the sequence designated, whenever the part program is cycled.

A.2.6.13 Feed rate override. A feed rate override control shall be provided to allow manual adjustment of the programmed feed rate from zero to not less than 120 percent of the programmed rate in either continuous adjustment or in steps of not more than 10 percent. The feed rate override control shall have a position that allows return of feed rate to that programmed.

A.2.6.14 Spindle speed override. A spindle speed override shall be provided to allow manual adjustment of spindle speed in either continuous adjustment or in steps of not greater than 10 percent each. The spindle speed override control shall control not less than the range of override percentages between 60 percent and 120 percent of programmed speed. The spindle speed override control shall have a position that allows return of speed to that programmed.

A.2.6.15 Sequence number search. The control shall have the capability to permit the operator to search for any desired sequence number.

A.2.6.16 Mirror image. The machine shall be capable of producing either right or left hand from the same tape data through the inversion of X and Y axis. Inversion of each axis shall be by keyboard or switch entry. Mirror image shall not affect the directional sense of manual controls. Reverse settings shall be displayed on the data display.

A.2.6.17 Preparatory function (G-Codes). The preparatory function codes of the control shall be in accordance with EIA Standard RS-274. If the BCL data format is specified (see 6.2.1), codes in EIA-RS-494 shall be applied.

A.2.6.18 Miscellaneous functions (M-Codes). The miscellaneous function codes of the control shall be in accordance with EIA Standard RS-274. If the BCL data format is specified (see 6.2.1), Codes in EIA-RS-494 shall be applied.

A.2.6.19 Block delete. The control shall have a block delete feature to permit bypassing of blocks of programmed data.

A.2.6.20 Buffer storage. The control shall have buffer storage for transferring command data from the tape reader or flexible disk reader to internal storage without delaying the next incoming command and without interrupting the machine functions. The internal storage shall store multiple blocks of data until required by the controlling devices.

A.2.6.21 Block-by-block read. The control shall have a block-by-block read function to provide for reading information one block at a time.

A.2.6.22 Tool length offsets. The control shall have a tool length offset feature to permit adjustments to the programmed tool length by means of manual data input. The tool length offset feature shall have a range of not less than the following:

a. Inch system ± 0.0001″ to ±1.0000″
b. Metric system ±0.001mm ±25.400mm.

A.2.6.23 Cutter compensation. Cutter compensation shall be provided to compensate for cutter diameters differing from those utilized in programming. The cutter compensation shall have a range of not less than the following:

a. Inch system ±0.0001″ to ±1.0000″
b. Metric system ±0.001mm to ±25.400mm

A.2.6.24 Fixture compensation. A fixture compensation feature shall be provided to permit compensation for fixture position errors.

A.2.6.25 Reversal error compensation. Reversal error compensation shall be provided for each axis of motion to compensate for drive gear backlash when slide reversal occurs. A means shall be provided to input new compensation values when required.

A.2.6.26 Axis calibration. Error compensation shall be provided to correct repeatable errors determined to exist due to leadscrew and feedback inaccuracies. A means shall be provided to input new error compensation values when required.

A.2.6.27 Additional features. Unless otherwise specified (see 6.2.1), the following additional numerical control features shall be provided:

a. Four-quadrant programming
b. Incremental and continuous jog for each axis
c. Leading zero suppression or decimal point programming
d. Inches per minute (IPM)/Millimeters Per Minute (MMPM),
e. programming in all modes of operation
e. Tape edit keylock

A.2.6.28 Operator control panel. Unless otherwise specified (see 6.2.1), The control unit shall have a control panel which provides at least the following control functions: Emergency Stop; Cycle Start; Optional Stop; Mode Selection; Feed Hold; Feedrate Override; Spindle Speed Override; Jog; Jog Direction; and EOF Stop.

A.2.6.28.1 Pendant control. When specified (see 6.2.1) a pendant control shall be furnished in lieu of an operator control panel. The pendant control shall be connected to the machine to enable the operator to control machine functions while in close observation position. Unless otherwise specified (see 6.2.1), the pendant control shall be capable of the same functions as stated for the operator control panel in paragraph A.2.6.28.

A.2.6.29 Reference zero. The control unit shall have a reference zero to move each axis to a reference limit switch to establish synchronization and reset all registers to zero.

A.2.6.30 Set zero. The control unit shall have a "set zero" feature to permit the specified axis register to be reset to zero establishing preset axis location as zero.

A.2.6.31 Program tryout. The control shall have a program tryout feature to permit new part programs to be read through the control without machine motions.

A.2.6.32 Operational software. Operational software shall be resident in the control and shall contain all logic necessary to effectively operate the machine tool. The software shall provide for meaningful diagnostics relating to the utilization of the control, machine tool, part program, and operator's actions. The MCU executive interface and diagnostic programs for those controls having volatile memory shall be provided in the form of one-inch, eight-channel punched tape complying with EIA-RS-227 or eight-inch flexible disk as specified (see 6.2.1).

A.2.6.33 On-line system diagnostics. The MCU shall be capable of performing a constant monitoring function of various activities and conditions of the control and machine. The diagnostic system shall communicate appropriate fault messages to the operator by means of the CRT or universal display. Unless otherwise specified (see 6.2.1), the on-line diagnostic capability shall determine the following fault conditions and provide appropriate error messages on the digital display.

-Memory parity fail
-Axis servo failure
-Axis feedback loop fail
-Feed limit
-Axis range limit
-Program error
-Reader read error
-Air filter clogged
-Console overheat
-Motor overload
-Servo failure
-Incomplete tool change cycle

A.2.6.33.1 Maintenance diagnostics system. Maintenance diagnostics software shall be furnished as non-volatile memory, punched tape or eight inch flexible disk to provide for diagnostic checking of the machine control unit. The diagnostic software shall test, exercise, and display failures, at least to board level.

A.2.6.34 Peripheral equipment interface. The control shall be equipped with an interface complying with EIA-RS-232.

A.2.6.35 Axis jog. The control panel or pendant shall have manual controls for accomplishing both single and continuous, low and high speed jog movements of the slides for each controlled axis in both the plus and minus direction.

A.2.6.36 Auxiliary functions. Unless otherwise specified (see 6.2.1), the MCU shall respond to the following program commanded auxiliary functions: interpolation, fixed cycles, and dwell. Unless otherwise specified (see 6.2.1), miscellaneous functions shall include program stop, optional program stop, end of program, spindle CW, spindle CCW, spindle off, coolant on-off, tool change, end of program (rewind), and program re-start. System preparatory and miscellaneous functions shall be coded in accordance with EIA-RS-274.

A.2.6.37 Canned cycles. The following canned cycles shall be provided:

a. Drilling
b. Boring
c. Tapping

A.2.6.37.1 Macro program cycles. The following flexible macro program cycles shall be provided:

a. Milling
b. Drilling
c. Boring
d. Tapping

A.2.6.38 Tape punch unit. When specified (see 6.2.1), the system shall have a tape punch unit for producing punched tapes from edited programs of tape being input and from programs stored in data memory. The unit shall have a plug receptacle and circuitry that is compatible with the tape punch output of-the system, punching both paper and mylar tapes of dimensions characteristics and code in accordance with 3.4.16.3. The punching speed of the unit shall be not less than 75 characters per second.

A.2.6.39 Postprocessor. Unless otherwise specified (see 6.2.1), the system shall be furnished with a postprocessor program(s) to be utilized in off-line, computer-assisted preparation of part programs. The postprocessor shall be provided for converting specified tape information (see 6.2.1) to the form and format required to operate the machine tool and control. The postprocessor shall be written for use on the type computer specified (see 6.2.1). Documentation sufficient to implement and utilize the postprocessor shall be provided for computer compatibility verification and validation at least 30 days prior to delivery of the machining center.

A.2.6.40 Graphics software. When specified (see 6.2.1), graphics software shall be provided which will allow communication between the specified (see 6.2.1) user graphics system and the machine control unit.

A.3 Electrical erosion machines. Federal Supply Class 3410 includes electrical discharge machines, electrochemical machines and electrolytic grinding machines. Numerical controls are available on electrical discharge and wire-cut electrical discharge machines. These machines are capable of producing precision parts of very intricate and complex configurations from any electrically conducting metal regardless of its hardness.

A.3.1 Electrical discharge machine (EDM) principles. Electrical discharge machines provide two axes of motion to Position or continuously move the workpiece beneath the ram which is perpendicular to the workpiece and holds the electrode. The ram is capable of vertical movement so as to maintain the appropriate arc gap between the electrode and the workpiece. Machining occurs when a high frequency series of electrical arc discharges vaporizes material in the workpiece. The electrical arc discharges occur in an electrolyte which insulates the electrode, solidifies the vaporized metal, flushes away the solidified particles and acts as a coolant (see figure A-5).

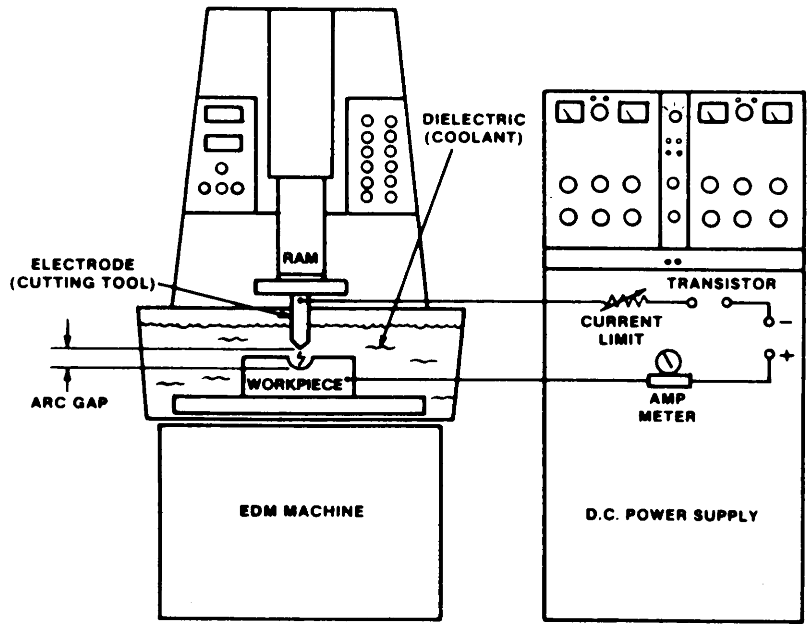


Figure A-5. Electrical Discharge Machining (Elox Division/Colt Industries)

A.3.2 Numerically controlled EDM. Numerically controlled EDMs having three linear axes of motion (x, y, and Z) and a fourth optional axis of rotary motion provided by a rotary table or a rotary indexing device for the electrode. Numerical control has provided the capability to precisely control orbiting, power applied to the electrode and simultaneous two-axis discharge. The application of numerical control to EDM has improved the EDM process by reducing electrode wear, prevention of DC arcs, enabling side machining instead of plunge-machining and improving the finish of the machined surface to 8 RMS (using metallic electrodes). A ram type EDM is shown in figure A-6.

A.3.3 Wire-cut EDM principles. Wire-cut EDM is an electrical discharge erosion process that utilizes a traveling wire as electrode. The wire is copper, brass or other metallic material in diameters between 0.003″ and 0.012″. The wire erodes a narrow slot through the workpiece in accordance with the path established by motion of the table. The dialectic used for wire-cut electrical discharge machining is deionized water. Deionized water is an efficient insulator. Since a supply of deionized water is necessary for operation, adeionizere is provided on these machines to deionize ordinary tap water. As on the electrical charge machines utilizing machined electrodes there is a power supply to provide DC power to the electrode.

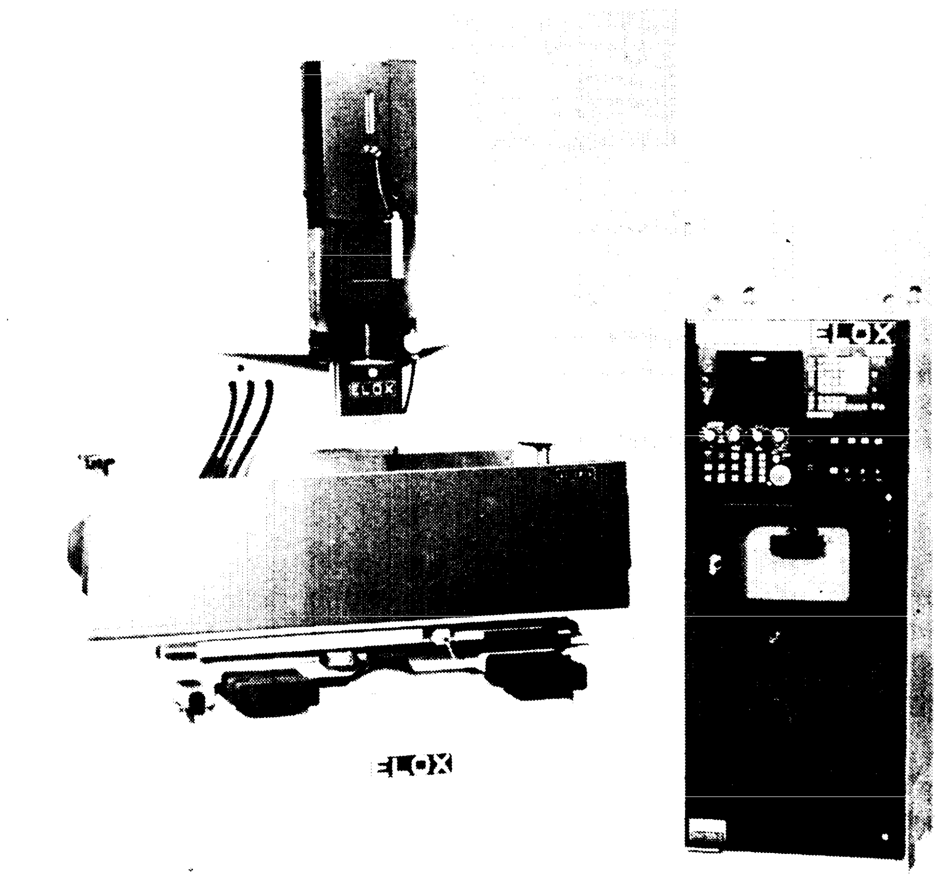


Figure A-6. Three or four-axis EDM, numerically controlled (Elox Division/Colt Industries)

A.3.4 Numerically controlled wire cut EDM. The numerical control for the wire-cut EDM is a four-axis system where X and Y constitute table motion and V and U axes designate motion of the wire. Automatic manipulation of the wire guides orients the wire at an angle required to machine a taper in the workpiece. The wire-cut EDM can cut complex shapes and is capable of cutting parts that cannot be produced by any other machining method, figure A-7 shows a four-axis, wire-cut EDM.

Figure A-7. Four-axis wire-cut EDM, numerically controlled (Elox Division/Colt Industries)

A.3.5 Numerical control system. The numerical control system shall be of the soft-wired, programmable, minicomputer type (CNC) designed to be selectively operated by punched tape, memory or manually by the operator through manual data input. Information stored in memory may be changed by adding, altering or deleting at the discretion of the programmer without alteration or modification to the control. The machine shall be a full four-axis programmable, automatic tape control system. The system shall be capable of continuous path, two-axis (X and Y) linear and circular interpolation with two-axis (U and V), continuous wire offset at the programmed angle. The control shall accept program data and translate this data into positioning and feed motion command signals, as well as initiate the programmed auxiliary and fixed cycles. A axis drives shall accept the translated signals and move the machine slides to the programmed positions with the control selecting and monitoring wire feed rate, axis feed rate and path of axis movements as well as the sequence and timing of all operations. All drives shall provide smooth, accurate and immediate response to control commands. The control shall insure that the machine functions occur in the proper order and initiate protective action should a faulty condition occur.

The control shall utilize solid-state, transistorized or integrated circuitry and modular construction. Plug-in circuit boards shall be coded to facilitate identification and location in the system.

The control shall be constructed in accordance with the applicable requirement of EIA-RS-281, NFPA-79. Axis and motion nomenclature shall conform to EIA-RS-267.

Control input resolution of 0.00001 inches or better shall be provided. Means shall be provided to assure precision, repeatability and performance under normal operating conditions to the accuracies defined in table II.

A.3.5.1 Controlled functions. The following functions shall be controlled by nunerical control:

a. All contouring axis vector feed rates and departure

b. All positioning axis

c. Wire feed and tension

d. Coolant control

e. Electrical discharge power

A.3.5.2 Electrical discharge power.

a. Minicomputer or microprocessor with power fail memory save features must retain memory 24 hours.

b. Fully buffered 300 CPS tape reader with take-up reels.

c. Display, CRT, 480 character, capable of displaying the following:

(1) Position display of each axis
(2) The entire block of active data
(3) All modal functions
(4) Complete wire information
(5) Power settings
(6) Full diagnostics

d. Control cabinet - NEMA 12 sealed against dust, dirt oil. etc. The cabinet shall be air conditioned, if reguired, in order to operate in ambient temperatures from 50°F to 120°F with relative humidity up to 90 percent.

e. Feedback - closed loop system.

A.3.5.3 Programming and operating requirements.

a. EIA or ASCII, switchable.

b. Inch/Metric switchable, or by "M" code.

c. Incremental or absolute modes, plus/minus programming, 0.00001 inch resolution.

d. Single block maximum departure ±999.99999 inches and 99999.999 mm.

e. Full floating zero.

f. Block delete, slash(/) code.

g. Miscellaneous functions.

h. Preparatory functions.

i. Wire diameter compensation 0-9.99999 inches.

j. Mirror image, X and Y axes.

k. Feedrate override 0-150 percent.

l. Sequence number search and display.

m. Dry run.

n. Single block operation.

o. Travel reverse for short circuits.

p. Automatic edge finder.

q. Automatic center of hole finder.

r. Automatic wire alignment to vertical.

s. Workpiece parallelism compensation.

t. Corner recessing and rounding.

u. Program rotation, scaling, and mirror image.

v. Part program storage and edit.

A.4 Boring machines. Federal Supply Class 3411 covers jig boring machines; boring, drilling and milling machines; vertical boring and turning machines, and vertical turret lathes. Machines in this class are capable of precision machining under high-thrust conditions. Horizontal spindle boring, drilling and milling machines equipped with a tool changer. Rotary positioning or contouring table and optional pallet shuttle are high precision machining centers in FSC 3408 and have the same functional capability as machining centers in the class. If combined operations and precise machining capability is required, the precision machining center in FSC 3408 should be acquired. The requirement for more precise machining than can be provided by horizontal spindle, table-type milling machines in FSC 3417 can be satisfied by a horizontal spindle, boring, drilling machine in this class.

A.4.1 Single-column, jig boring machine. A vertical spindle, single column, table-type boring, drilling and milling machine has the same general configuration as a vertical spindle, single-column, table-type milling machine in FSC 3417. The application of jig boring machines is to perform boring, drilling and milling to very precise tolerances. These machines are primarily used for manufacturing tools, jigs and fixtures and the fabrication of parts requiring tolerances beyond the capability of FSC 3417 milling machines. Jig boring machines are typically available with a numerical control capable of controlling three or four axes. Three axis controls operate the longitudinal table motion (X axis), table cross travel (Y axis) and vertical travel of the spindle saddle (Z axis) optional two-axis. On the three axis controls are available to control the X and Y axes with the Z axis under manual control. Four axis controls operate the X, Y and Z axes and vertical travel of the boring quill (W-axis) (see figure A-8).

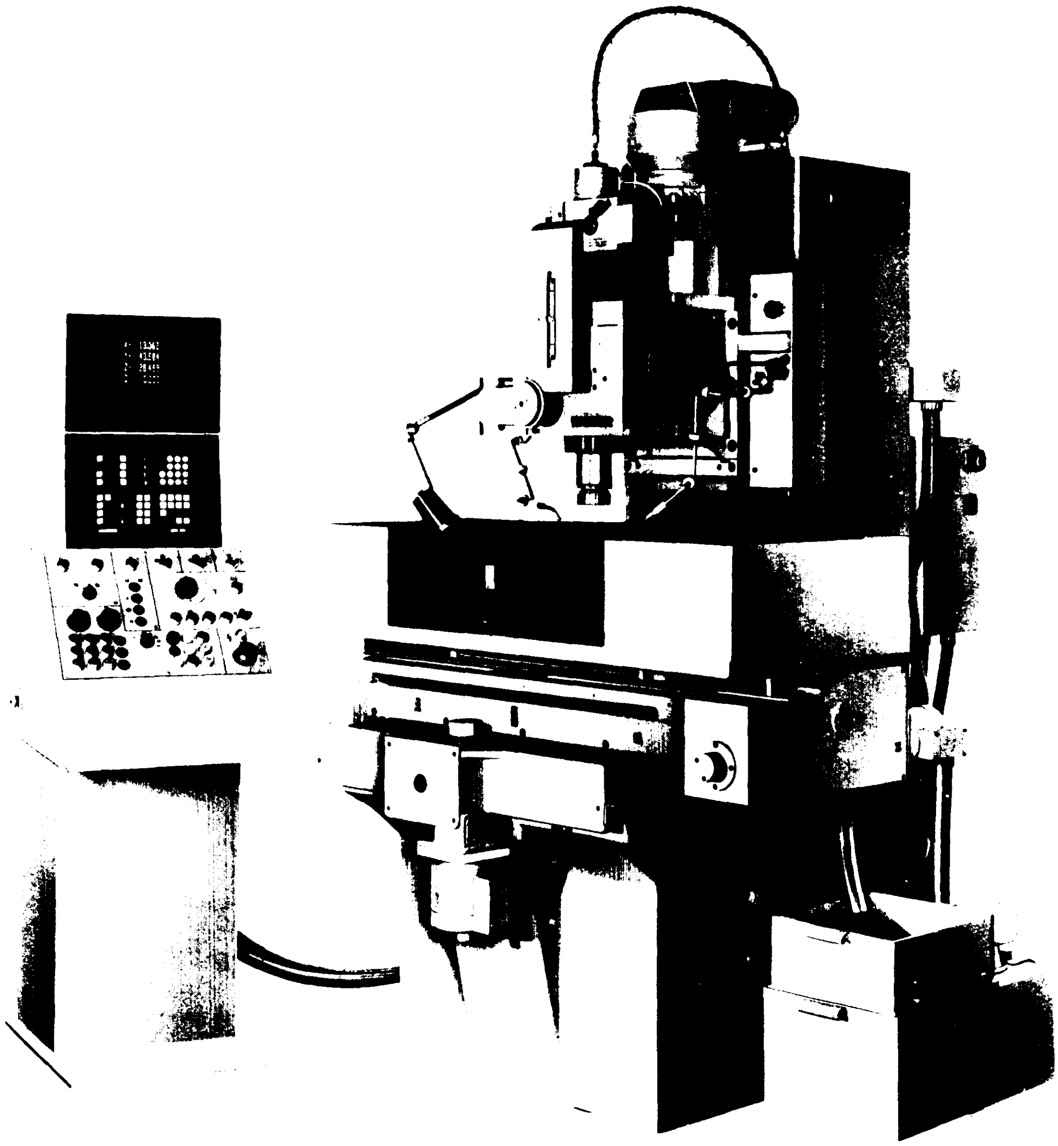


Figure A-8. Four-axis jig boring machine, numerically controlled. (American SIP Corporation).

A.4.2 Double-column, bridge-type jig boring machine. A vertical spindle, double-column, fixed or traveling cross rail, boring, drilling, and milling machine having the same general configuration as the bridge-type milling machine in FSC 3417. Application considerations stated for the jig boring machine in paragraph A.4.1 apply to this type machine. These machines are typically available in three and four-axis, numerically controlled versions. The three-axis numerical control operates the longitudinal travel of the table (X-axis), cross travel of the boring head or head carrier on the cross rail (Y-axis), and vertical travel of the spindle quill (Z-axis). The four-axis control operates the X, Y and Z axes as stated and additionally controls vertical traverse of the cross rail or the boring head on ways of the head carrier (W-axis). See figure A-9.

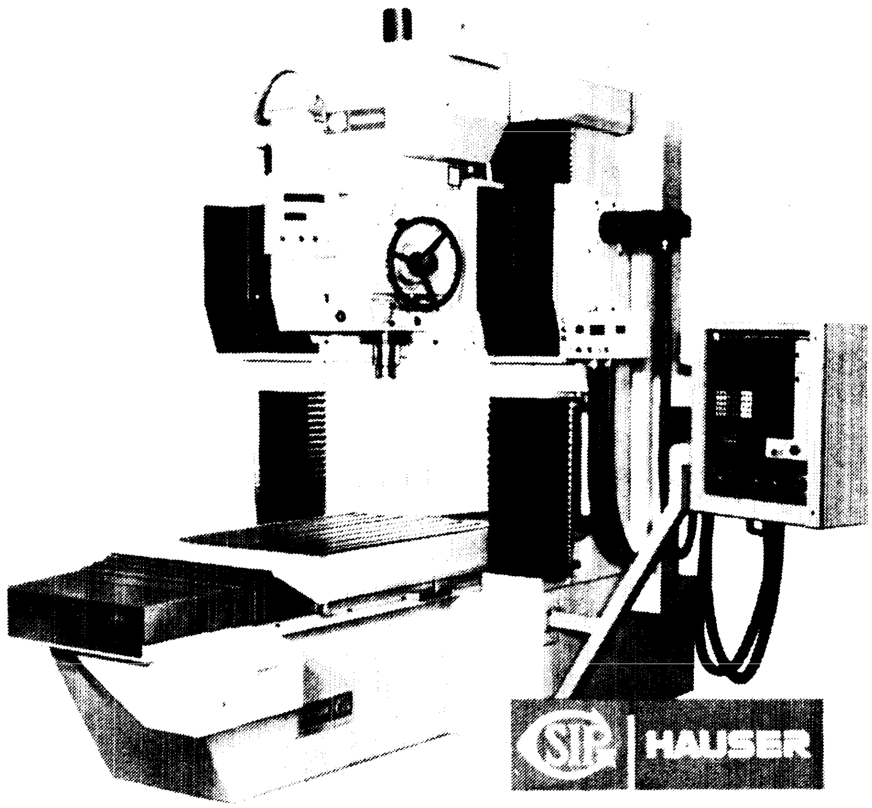
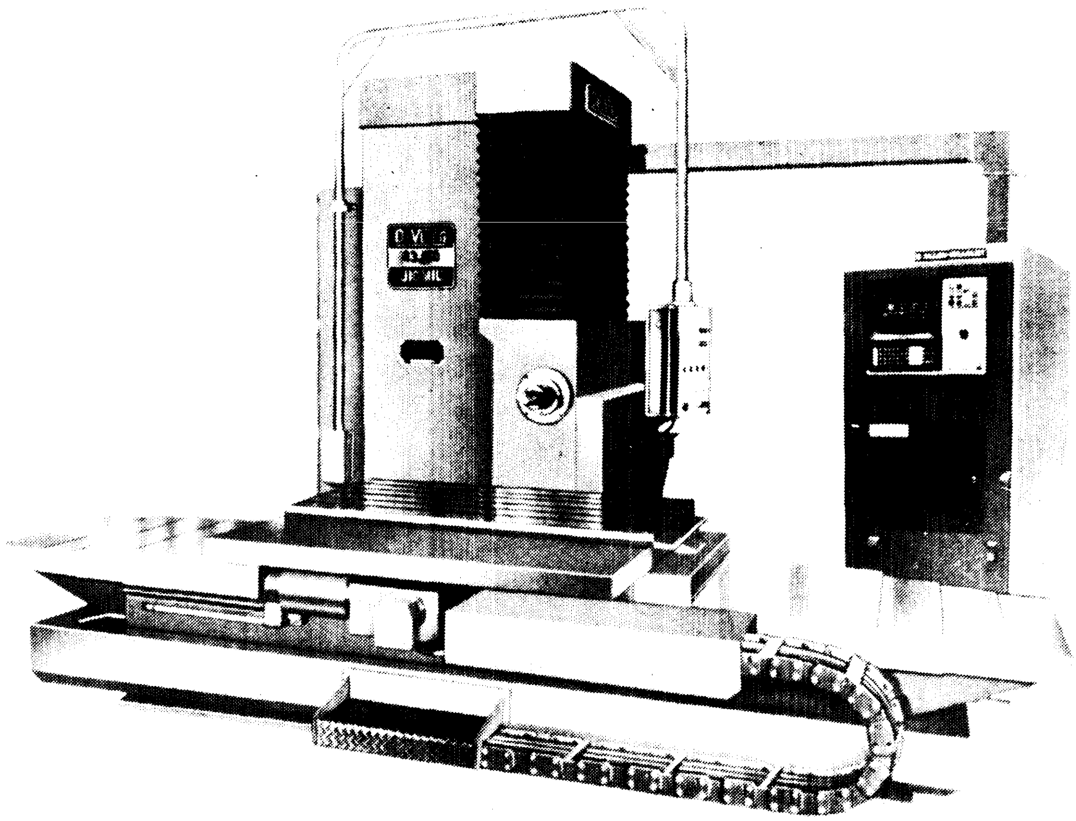


Figure A-9. Four-axis, numerically controlled jig boring machine featuring a traveling cross rail. (American SIP Corporation)

A.4.3 <u>Boring and milling machine, precision, horizontal spindle, table-table.</u> Machines in this category are capable of boring, drilling milling, and tapping operations and have the same general configuration as the milling machine, horizontal profiler, traveling column in FSC 3417. these machines are applicable to a wide variety of rough and finish boring, heavy milling, fast drilling and tapping operations and have the capability to produce workplaces to very precise limits of accuracy. Machine functions are automatically controlled by the numerical control unit. Basic machine motions under numerical control are table movement horizontal (X-axis), spindle head vertical travel (Y-axis), spindle bar travel horizontal (in and out, Z-axis) and table horizontal spindle in and out, (W-axis). Figure A-10, boring machine equipped with a 4-inch spindle bar and 60 inches of horizontal travel and vertical spindle travel of 50 inches.



Fiqure A-10. Four-axis, numerically controlled boring machine, precision, horizontal spindle, table-type. (DeVlieg Machine Company)

A.4.4 Productivity enhanced boring and milling machine. The addition of a tool changer to a numerically controlled boring and milling machine enhances the productivity of the machine by eliminating manual tool changes. This makes it possible to perform multiple machining operations with one set up in a minimum time. See figure A-11.

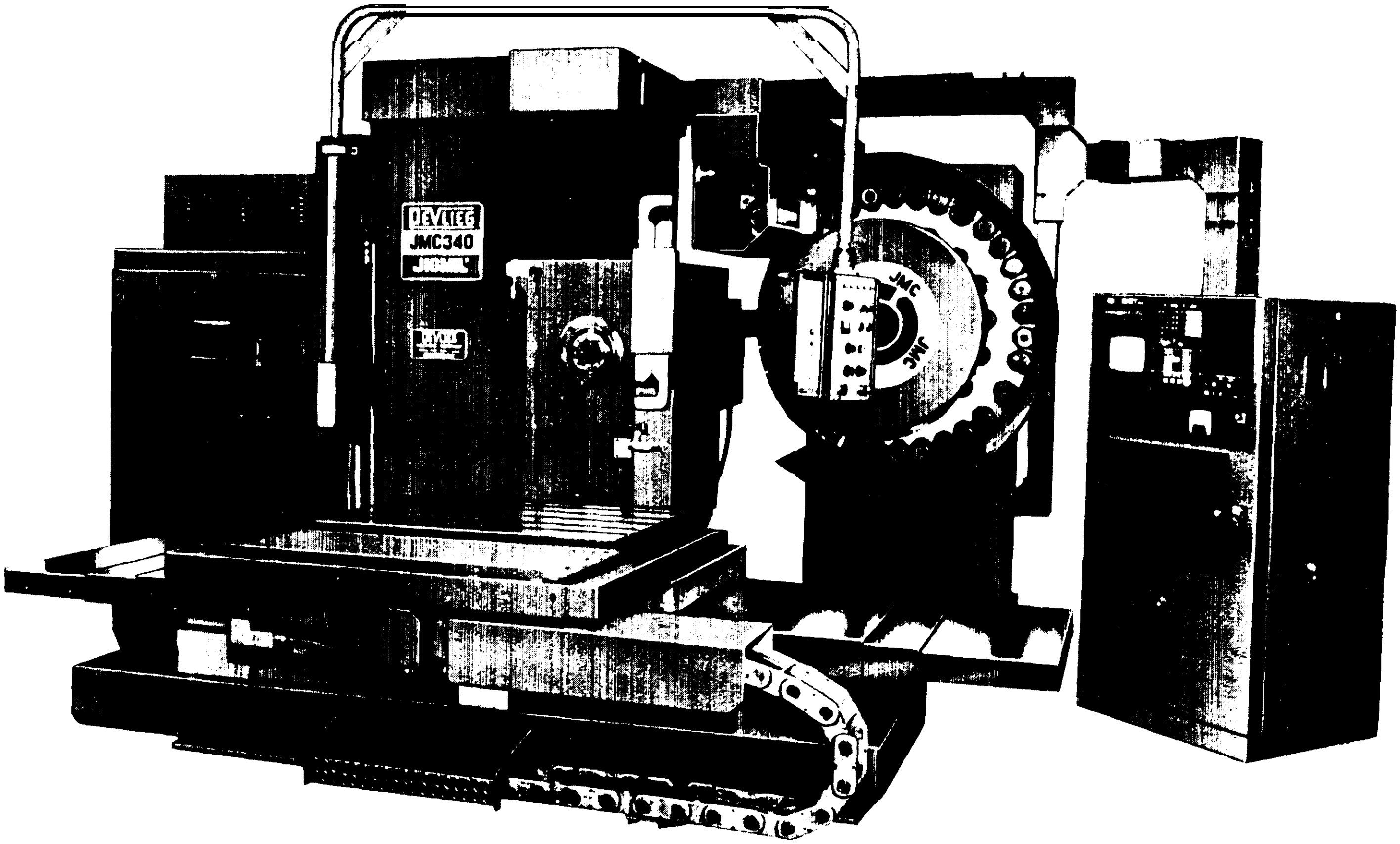
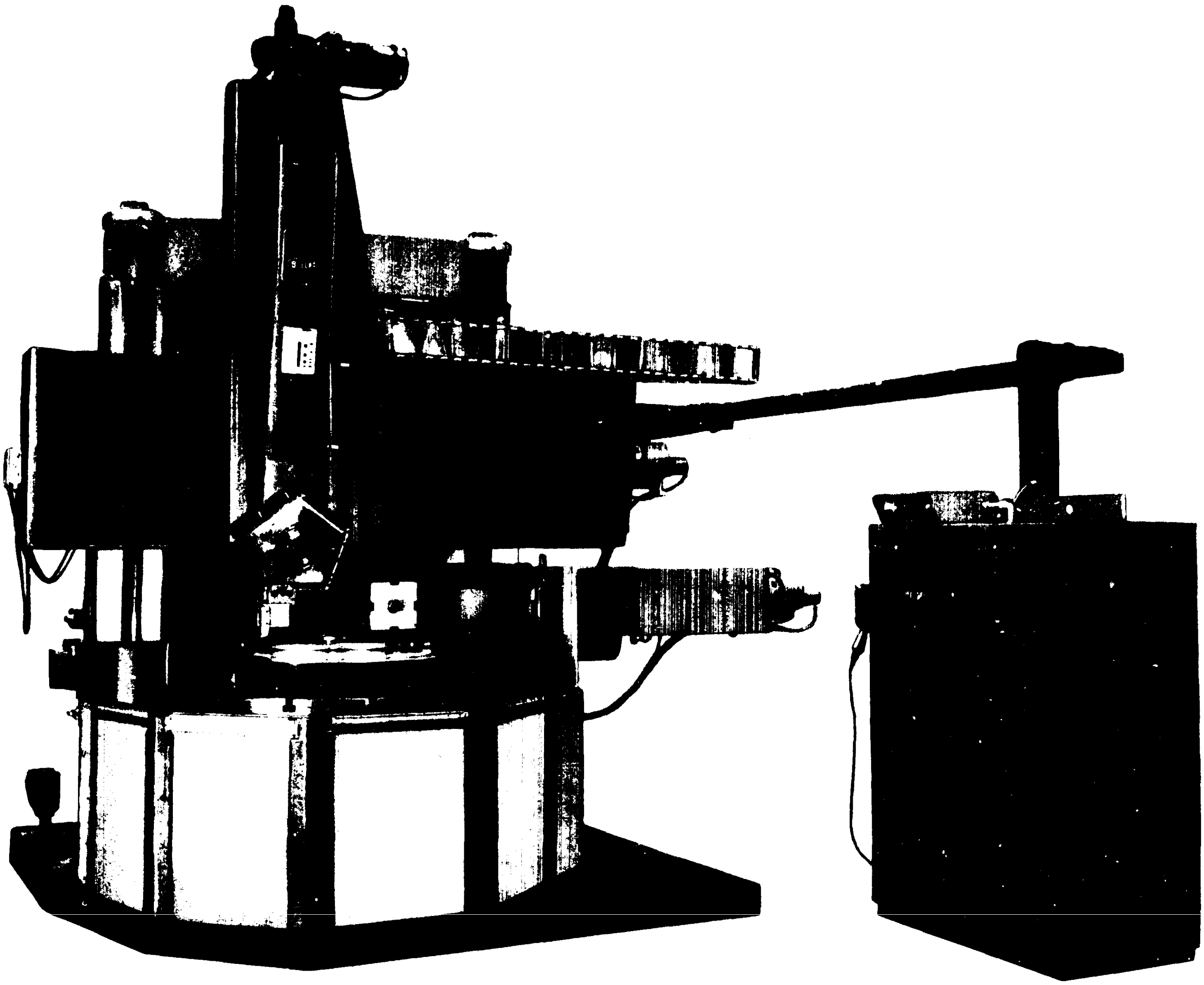


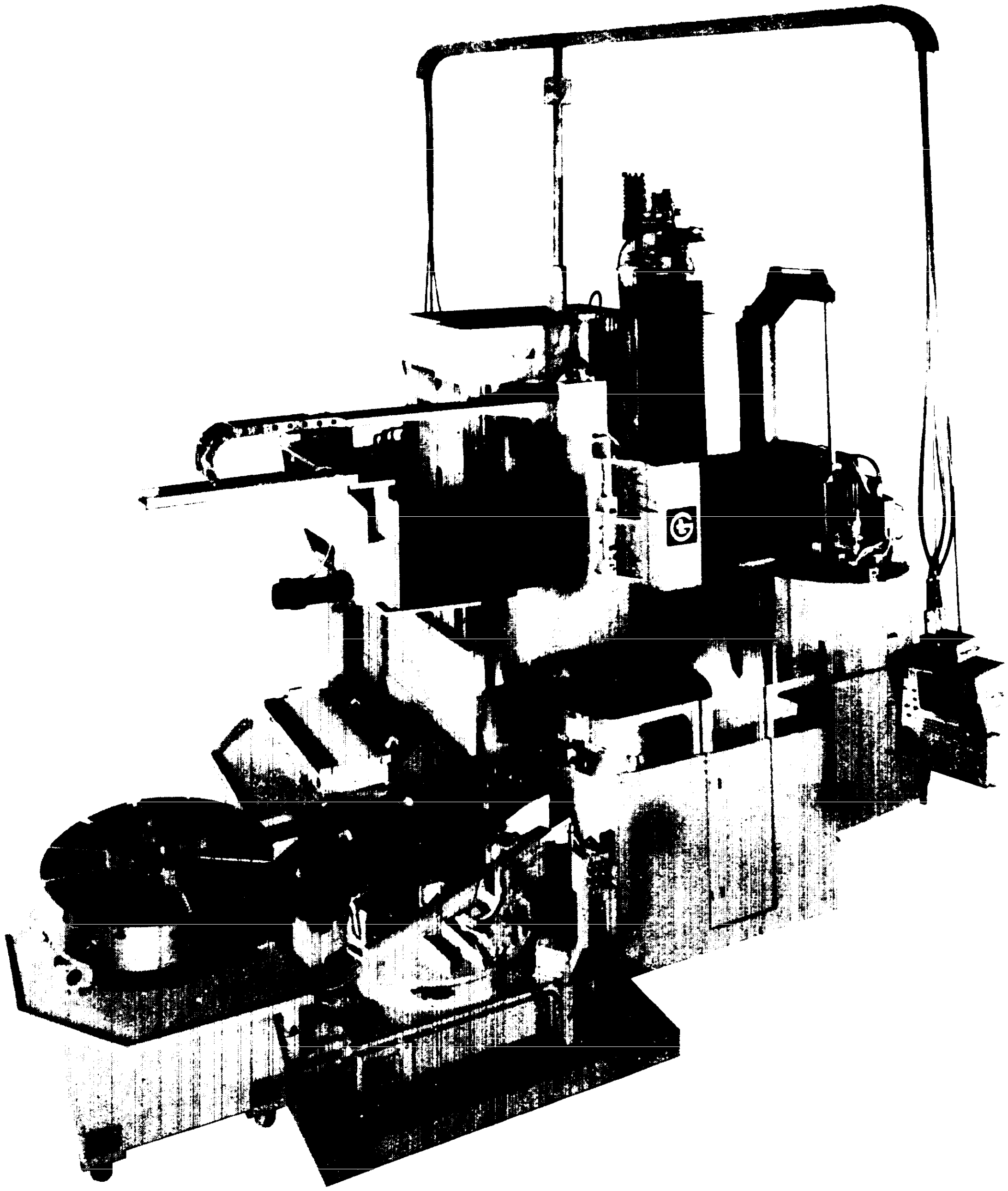
Figure A-11. Four-axis, numerically controlled boring and milling machine with automatic tool changer (DeVlieg Machine Company).

A.4.5 Vertical boring and turning machines. Boring machines covered in previous paragraphs perform machining by turning the cutting tool while it moves along the feed path. Such machining is accomplished on a workpiece that is held securely in position. Machining performed by vertical boring and turning machines is accomplished by rotating the workpiece against the cutting tool held in position and moving it along the direction of feed. Vertical boring mill is a term commonly used for turning machines featuring a vertical spindle and bed. These machines, when equipped with a tool changing, turret are marketed as vertical turret lathes. When a side head is provided on a vertical turret, lathe, the similarity to lathes in FSC 3416 is more evident because the side head performs the same as a lathe carriage.

A.4.5.1 Vertical turret lathe. The vertical turret lathe is equipped with a rail head which carries a precision turret head having multiple faces which can carry two tool blocks per face. A side head is also available which can be equipped with an indexing turret. The numerical control operates spindle speed and direction of rotation, indexing of the rail head and side head turrets, cross travel of the side head (X-axis), vertical travel of side head (Y-axis), vertical travel of cross rail (W-axis), and cross travel of the rail head (U axis). Manufacturers offer optional tool changers and pallet shuttles for vertical turret lathes enabling these machines to be integrated into automated manufacturing systems or cells. See figures A-12 and A-13.



Fiqure A-12. Four-axis, numerically controlled vertical turret lathe (Bullard/White Consolidated Machine Tool Group).



Fiqure A-13. Two-axis, numerically controlled vertical turning machine with tool changer and pallet shuttle. (Giddings & Lewis Machine Tool Company)

A.4.5.2 Vertical boring mill. The vertical boring mill is typically a large workpiece turning machine capable of heavy roughing cuts and machining to accurate finishes. Vertical boring mills are available as two and four-axis, numerically controlled machines. The most common configuration is the two-axis version having a ram-type rail head. The four-axis version has a ram or turret head and a side head. These machines are available with an automatic tool changer. See Figure A-14.

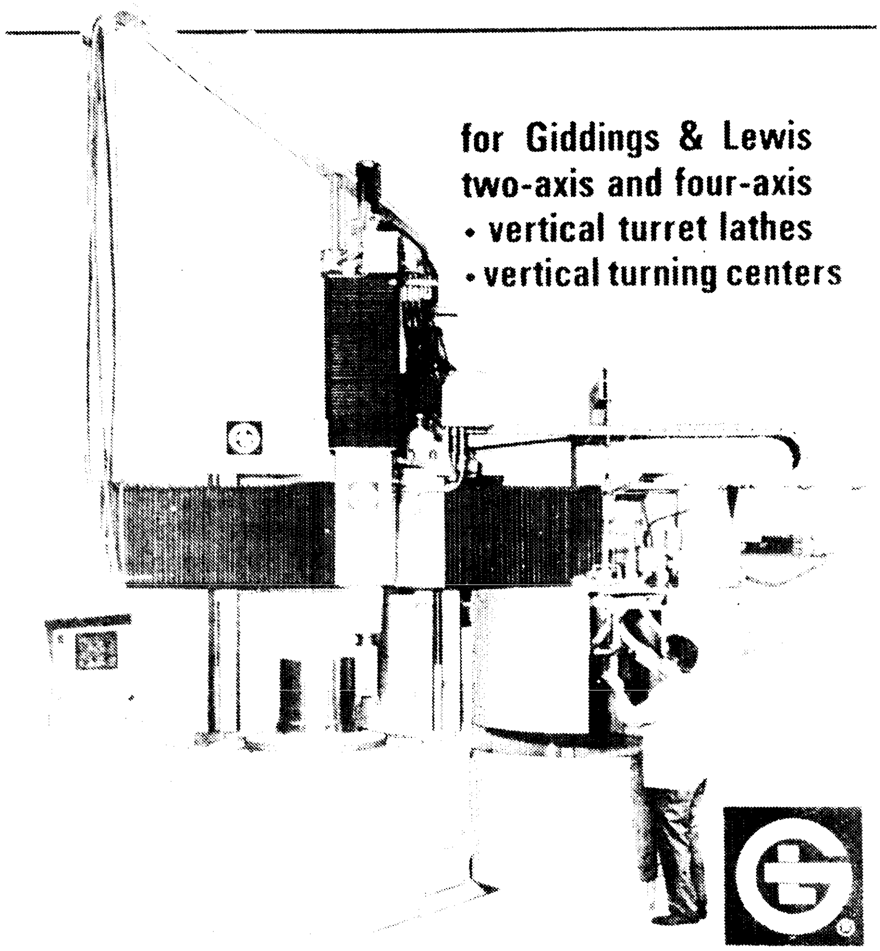


Figure A-14. Two-axis, numerically controlled vertical boring mill with automatic tool changer. (Giddings & Lewis Machine Tool Company).

A.4.6 Numerical control for lathes. The numerical control requirements for four-axis, vertical turret lathes in FSC 3411 and horizontal lathes in FSC 3416 stated in the following paragraphs are typical of those included in military specifications.

A.4.6.1 Numerical control system. The numerical control shall be a solid-state, soft-wired, integrated circuit type. The control shall provide automatic control of machine functions, operating modes, four-axis control of X, Z, U and W feed rates, spindle speed and direction of spindle rotation. The axes shall be identified in accordance with EIA Standard RS-267. The control shall have linear and circular interpolation. The control shall be capable of threadcutting by direct control of axis motion and spindle rotation. Control features shall include buffer storage, part program storage, program edit capability and control diagnostics. The NC unit shall direct machine functions from part program data in memory storage, punched tape, flexible disk and manual data input. The control shall initiate a halt or an error signal should a fault condition occur in the control. All necessary executive program routines shall be furnished in the form of one-inch, eight-channel, binary coded decimal punched or tape eight- inch flexible disk for controls having volatile memory. The control unit shall conform to EIA Standard RS-281. Control electrical equipment shall function on 460 volts, 3 phase, 60 Hertz power supply. A line voltage variation of ±10 percent from normal shall not adversely affect the NC system function. The control shall be capable of functioning in ambient temperatures ranging from 50° F to 120° F and relative humidities ranging from 5 percent to 95 percent. The control shall automatically shut down when internal operating temperature exceeds safe operating temperature. Control resolution shall be 0.0001 inch or 0.001 mm for each linear axis and not more than 0.001 of a degree for each rotary axis. When binary cutter location (BCL) data is specified (see 6.2.1) the numerical control shall have the necessary hardware and software to perform all geometry dependent functions which are ordinarily performed by the postprocessor.

A.4.6.2 Data input.

A.4.6.2.1 Punched tape data input. Unless otherwise specified (see 6.2.1) the input media for the control shall be one-inch, channel-punched tape. The data input format and codes shall comply with EIA Standards RS-274, RS-358 and RS-447, or when specified (see 6.2.1), RS-244 shall apply in lieu of RS-358. The control shall be equipped with a photoelectric tape reader capable of holding, feeding and reading tape prepared in the format specified at a rate not less than 150 characters per second. Unless otherwise specified (see 6.2.1), tape reader shall be supplied with standard feed and take-up spoolers 5-1/4 inches in diameter. The tape reader shall be housed in a dust free area of the numerical control cabinet and shall be easily accessible for cleaning and tape handling. The control shall have a tape error detection capability to continuously check for the following errors:

a. Odd parity per EIA RS-244
b. Even parity per EIA RS-358
c. Misaligned sprocket holes
d. No sprocket holes

Any of the above errors shall halt machine functions and illuminate an error light or a message on the data display screen to indicate a fault condition.

A.4.6.2.2 Flexible diskette data input. When 32 Bit Binary Cutter Location (BCL) Exchange Input for Numerlcally Controlled Machines is specified (see 6.2.1), the input media shall be an eight-inch flexible diskette recorded in accordance with A.4.6.2.2.1. The input data format shall comply with EIA Standard RS-494. Manufacturers providing functions or features that cannot be addressed by command codes currently covered by EIA-RS-494 shall apply to the Electronic Industries Association, IE-31 Committee on Numerical Control Systems and Equipment for an extension of the standard codes to cover the new features or functions. The control shall be equipped with an eight-inch flexible diskette reader. The reader shall have the capability to perform a cyclic redundancy check of the input data and be capable of reading not less than 15,000 characters per second.

A.4.6.2.2.1 Flexible diskette format. When an eight-inch flexible disk is specified as the input media to the numerical control it shall be a single-density recording on one side using a soft sectored format. The disk shall be divided into 77 distinct locations on the single-side disk. Tracks shall be assigned numbers from 00 through 76. Track 00 shall be nearest to the edge of the disk and track 76 nearest to the center. Tracks 00, 74, 75 and 76 shall not be used. There is an index hole in the jacket and the disk that shall be used for timing functions when a beam of light passes through it. Recording shall be accomplished by rotating the disk inside its jacket exposing the disk at the read/write head slot cut in the jacket. Data shall be recorded only on the side of the disk that is exposed to the read/write head. Each track shall be divided into 26 addressable sectors which contain 128 bits. All sectors shall be identified by the file starting sector number with track 00, sector 1, designated as O. The first part program shall be located at sector lE hexadecimal corresponding to track 1, sector 5. Where two byte numbers are referenced the high order byte shall be recorded first and the low order through 4 shall contain the program directory of up to 16 part program names in ASCII. Each file shall be packed on the disk in the same order as its directory entry. Unused directory entries shall point to the next available sector after the last file and contain the 30 characters ASCII space characters. The last sector of each file shall be padded with end-of-file (EOF) records (8000 0000). Diskette addressing shall comply with the requirements of table IV.

A.4.6.2.3 Manual data input. A manual data input (MDI) unit shall be furnished to permit manual entry of alphabetical, numerical, and special characters necessary for control of all programmable machine functions. The manually input data shall be immediately displayed on the data display to permit data verification. The MDI shall be capable of entering a block of data into memory upon command.

A.4.6.3 Data display. A data display shall be provided which must be either a cathode ray tube (CRT) or a universal alphanumeric display capable of displaying not less than 250 characters simultaneously. The CRT or universal alphanumeric display shall display, as a minimum, the following:

a. Four digit block sequence number
b. Active block of stored data
c. Next block of stored data
d. Actual position of each axis
e. Feedrate and override condition
f. Control and system error messages
g. Spindle speed and override condition

A.4.6.4 Control system modes of operation. Modes of operation shall include increment offset, manual, auto, single, MDI, sequence number search and reference stop.

A.4.6.5 Departure control. All drives shall provide immediate, accurate and smooth response to control commands. To avoid travel overshoot and undercut, the control shall be capable of controlling the automatic acceleration and deceleration of the slides. The maximum linear and rotary departure by a single command for any mode of departure shall be not less than 99.9999 inches or 999.999mm. The smallest programmable increment of movement of the slides in either direction shall be not more than 0.0001 inch or 0.001 mm.

A.4.6.6 Absolute/incremental input. Absolute/incremental input capability shall be provided. The mode shall be selected by a preparatory "G" code which may be switched during the tape program. Not applicable to BCL controls.

A.4.6.7 Automatic tape code recognition. When one-inch tape is the input media the control shall have the capaility to automatically recognize and read punch tape with either EIA RS-244 or RS-358 (ASCII) character codes.

A.4.6.8 Switchable inch/metric input. The control system shall provide switchable inch/metric input capability.

A.4.6.9 Part program storage. The machine control unit shall be capable of simultaneously storing in memory the executive proqram and the contents of not less than 500 feet of postprocessed part proqram tape data.

A.4.6.10 Standby battery power. Standby battery power shall be provided for controls having volatile memory to hold the size memory provided at full load for a period of not less than 500 feet of postprocessed part program tape data.

A.4.6.11 Editing. A full edit capability shall be provided. The tape edit system allow for the correction, addition or deletion of any part of the part program (tape) stored in the control unit. The edit information shall be stored in the control memory and shall be automatically acted upon, at the proper time, whenever the part program is cycled. Edit information shall be input through the use of the MDI keyboard.

A.4.6.12 Feed rate override. A feed rate override control shall be provided to allow manual adjustment of the programmed feed rate from zero to not less than 120 percent of the programmed rate in either continuous adjustment or in steps of not more than 10 percent. The feed rate override control shall have an "OFF" position that halts all slide motions.

A.4.6.13 Spindle speed override. A spindle speed override shall be provided to allow manual adjustment of spindle speed in either continuous adjustment or in steps of not greater than 10 percent each ranging from 60 percent to 120 percent of the programmed spindle speed.

A.4.6.14 Sequence number search. The control shall provide a means to permit the operator to search for the desired sequence number.

A.4.6.15 Mirror image. The machine shall be capable of producing either right or left-hand parts from the same tape data through the use of inversion switches for each axis. Inversion of each axis shall be by keyboard or switch entry. The system shall display reverse settings and shall be visible to the operator. Mirror image shall not affect the directional sense of manual controls.

A.4.6.16 Preparatory function (G-Codes). The preparatory function codes of the control shall be in accordance with EIA Standard RS-274. Not applicable to BCL controls.

A.4.6.17 Miscellaneous functions (M-Codes). The miscellaneous function codes of the control shall be in accordance with EIA Standard RS-274. Not applicable to BCL controls.

A.4.6.18 Block delete. The control shall have a block delete feature to permit bypassing of blocks of programmed data.

A.4.6.19 Buffer storage. The control shall have buffer storage for transferring command data from the tape reader to internal storage without delaying the next incoming command and without interrupting the machine functions. The internal storage shall delay or store multiple blocks of data until required by the controlling devices.

A.4.6.20 Block-by-block read. The control shall have a block-by-block read function to provide for reading information one block at time.

A.4.6.21 Tool length offset. The control shall have a tool length offset feature to provide the capability to make adjustments to the programmed tool length by means of manual data input. The tool length offset feature shall have a range of not less than the following:

a. Inch system ±0.0001" to ±1.0000"
b. Metric system ±0.001 mm to ±25.400mm

A.4.6.22 Threadcutting. Threadcutting capability to generate accurate threads in the X, Z, U, and W axes set shall be provided. The threadcutting capability shall include the option to generate straight, tapered or variable lead threads in either axes set and produce finish threads.

a. Inch system ±0.0001" to ±1.0000"
b. Metric system ±25.400 mm

A.4.6.23 Tool radius compensation. Tool radius compensation shall be provided which will permit the part prgram to specify the furnished contour of the workpiece rather than the tool radius center-line path.

A.4.6.24 Lead reversal error compensation. Lead error and reversal error compensation shall be provided to permit data stored in memory to compensate lead screw errors and backlash present in each axis of motion.

A.4.6.25 Additional features. The following additional numerical control features shall be provided:

a. Four quadrant programming
b. Incremental and continuous jog for each axis
c. Decimal point programming
d. Inches per minute (IPM) Millimeters Per Minute (MMPM), programming in all modes of operation
Tape edit keylock
Software resident in the control to accomplish threadcutting as specified in 3.49.21
g. Capability to operate in the constant surface feet mode

A.4.6.26 Operator control panel. The control unit shall have a control panel which provides at least the following control functions: Emergency Stop; Cycle Start; Optional Stop; Mode Selection; Feed Hold; Feedrate Override; Spindle Speed Override; Jog; Jog Direction and EOB Stop.

A.4.6.26.1 Portable control. A portable control shall be provided and connected to the machine to enable the operator to control machine functions while in close observation position. The portable control shall be capable of axes feed start, axes feed stop, axes feed and spindle stop, spindle start, block stop, emergency stop, automatic and manual selection, job and jog direction of X, Z, U, W axes and spindle.

A.4.6.27 Reference zero. Means shall be provided to move each axis to a reference limlt switch to establish synchronization and reset all registers to zero.

A.4.6.28 Set zero. The control unit shall have a "set zero" feature to permit the specified axis register to be reset to zero with no slide motions.

A.4.6.29 Absolute axis offset. The control unit shall have a "set zero" feature to permit the specified axis register to be reset to zero with no slide motions.

A.4.6.30 Tape tryout. The control shall have a tape tryout feature to permit new part programs to be read through the control without machine motions.

A.4.6.31 Canned cycles. Canned cycles as specified by the procuring activity shall be provided (see 6.2.1).

A.4.6.32 Programmable macro functions. The control shall have the capability to store user generated functions that can be called by a single command.

A.4.6.33 Operational software. Operational software shall be resident in the control and shall contain all logic necessary to effectively operate the machine tool. The software shall provide for meaningful diagnostics and comments relating to the utilization of the controls, machine tool, part program and operator's actions.

A.4.6.34 Maintenance diagnostics system. Maintenance diagnostics software shall be furnished to provide for diagnostic checking of the machine control unit. The diagnostic software shall test, exercise and display failures at least to board level.

A.4.6.35 Postprocessor. The postprocessor routine shall be a complete program including documentation of all pertinent information covering all machines and control unit characteristics that are required to produce an operating tape by computer-assisted part programming. The postprocessor shall be compatible with the part programming language specified by the procuring activity (see 6.2.1) for use on computer model specified (see 6.2.1). The postprocessor is not required for controls operated by BCL data.

A.5 Grinding machines. Federal Supply Class 3415 covers machines that perform machining by passing cutting edges at speeds of 60 to 70 miles per hour against the surface of the workpiece. Small chips are removed from the surface of the workpiece resulting in a smooth surface finish. The cutting tool is a grinding wheel made of abrasive particles (cutting edges) and bonding material formed in the general shape of a disc. Grinding is commonly considered as a finishing operation, but in some shops it is the complete machining process. Nearly every part produced goes through the grinding process. Surfaces can be ground to precision tolerances with greater ease and in less time than they can be machined to the same tolerance with a single point tool. Also precision ground pieces have a better surface finish than can be achieved by machining with a single-point tool. Grinding requires ten horsepower to remove one-cubic inch of cast iron or steel per minute from the surface of a part. Grinding machines are available to perform cylindrical, centerless, jig and surface grinding. The configuration and components provided on these machines are as appropriate to enable performance of specialized grinding operations. Grinders are available as manual, automatic and numerically controlled machines. Numerically controlled grinding machines are appropriate for the low volume production of many different parts.

A.5.1 Center-type grinding machines. Center-type grinding machines can be provided with attachments and accessories that enable them to perform plain, plunge, shoulder and taper grinding on cylindrical parts. The center-type grinder features a traversing table having thereon a spindle and tailstock which holds and rotates the workpiece. Movement of the table on its ways is the X axis. A wheelhead mounted on a cross slide is the X axis to provide controlled motion of the grindinq wheel (cutting tool). Rotary positioning of the grinding wheel is provided so that tapers may be ground. Automatic size control is provided by electronic or other in-process gaging to adjust positioning of the grindinq wheel to compensate for wheel wear. (See figures A-15, A-16 and A-17).

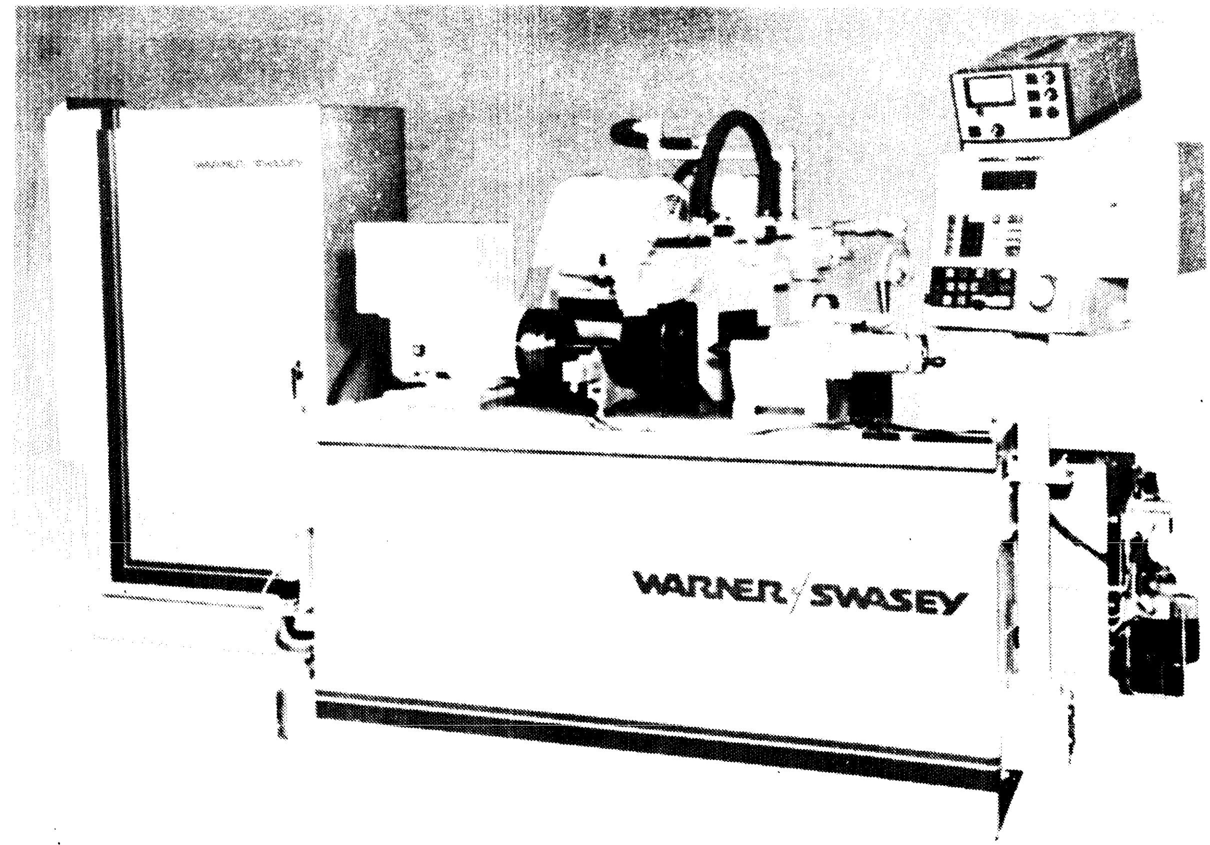


Figure A-15. Two-axis, center-type grinder, between centers or chucking (Warner & Swasey Grinding Division/a Cross & Trecker Company).

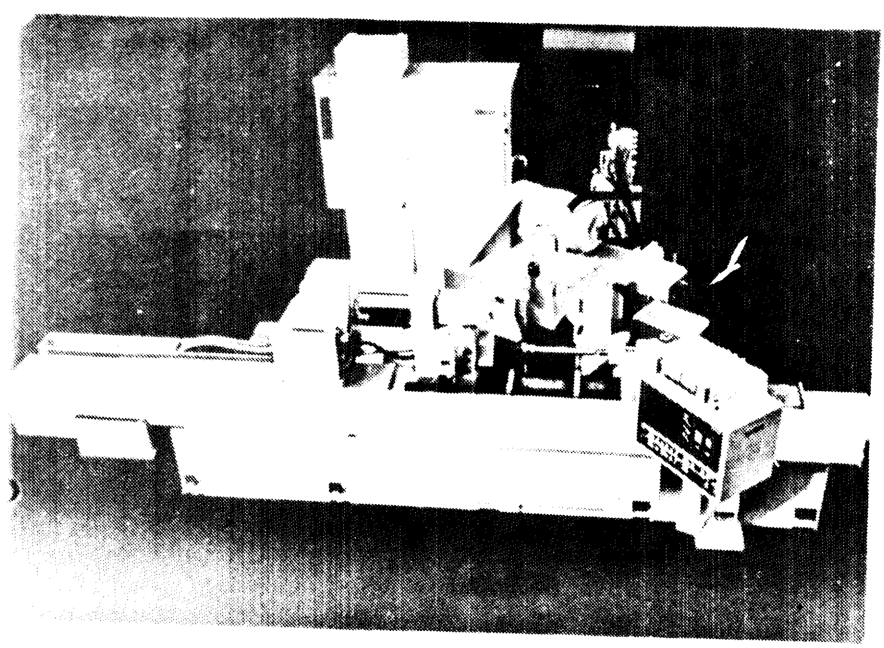


Figure A-16. Center-type, two-axis, step grinder for multiple diameter shaft grinding (Cincinnati Milacron).

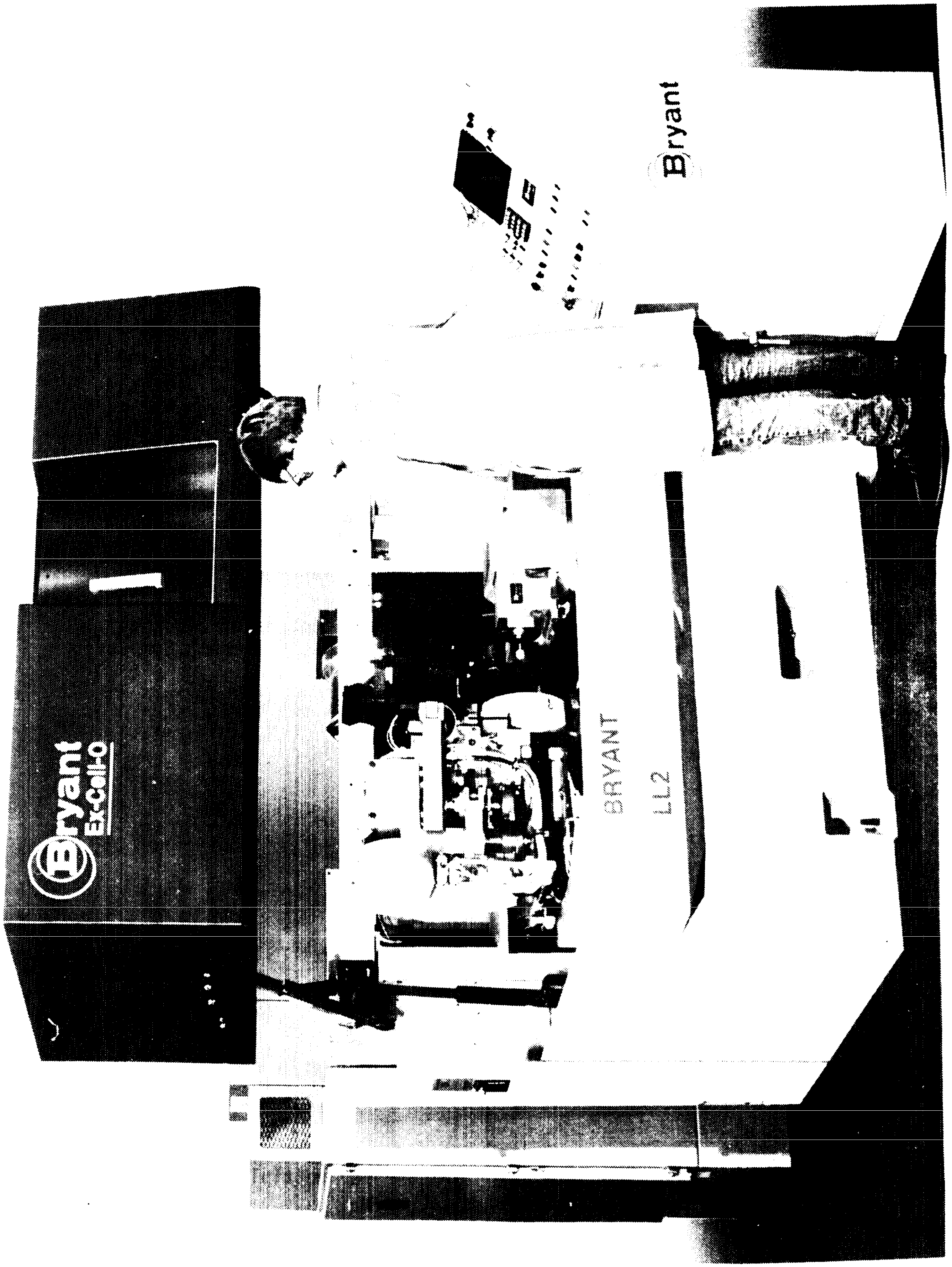


Figure A-17. Chucking grinder, two axis, for grinding inside and outside diameters (Bryant Grinder Corp. a Subsidiary of Ex-Cell-O Corp.)

A.5.2 Centerless grinding machines. The centerless grinder is applicable to the precision grinding of round steel bars or cylindrical parts where the workpiece rotates between a grinding wheel and a regulating wheel. The workpiece rests on a workrest blade located directly at the point of grinding. The axis of the regulating wheel is arranged so that it can be tilted at an angle in relation to the grinding wheel. Revolutions per minute of the regulating wheel and angle of the regulating wheel determine the feed rate of the cylindrical part traversing the grinding wheel. Numerically controlled machines of this type are capable of processing a wide variety of parts at a high level of productivity. See figure A-18.

A.5.3 Surface grinder. The jig grinder is a vertical spindle, table type surface grinder having construction and operating features that enable precision grinding of complex parts. Horizontal travel of the table is the X axis and cross travel of the table is the Y axis. Vertical travel of spindle is the Z axis. Orbiting of the grinding head is the C axis. An optional rotary table for rotating or angular positioning of the workpiece is the C axis. A four-axis, numerically controlled jig grinder is capable of grinding continuous path contours, inside and outside diameters and tapers. See figure A-19.

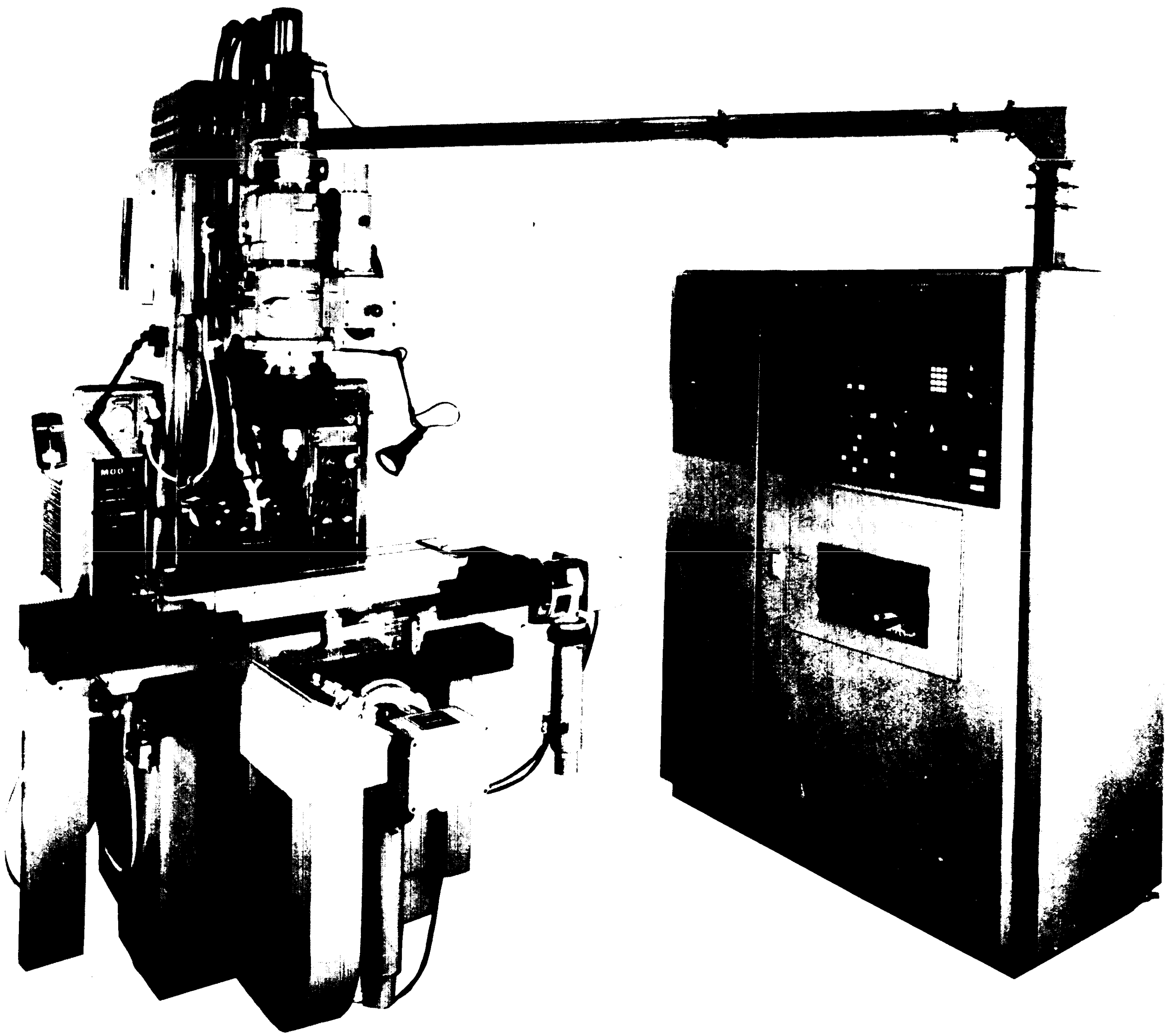


Figure A-19. Three-axis, jig grinding machine. (Moore Special Tool Company)

A.5.4 Numerical control for grinders. Numerical controls used on grinders are primarily the manual data input type that can be programmed automatically when the machine is operated manually to produce the first part. The part program can he recorded on a magnetic tape or card and used to produce the part. Off-line programming is optional and is some instances is preferable to programming the parts on the floor. Minimum requirements for the numerical control for grinding machines acquired for DoD use are included in the following.

A.5.4.1 Numerical control. The numerical control shall be solid-state, soft-wired, integrated circuit type. The machine control unit (MCU) shall provide automatic control of machine functions, operating modes, two axis (X and Z) positioning and feed motion, workhead speed and direction of rotation for each grind surface, rapid traverse rates, axis dwell times, dress type, dress rates, dress frequency, and shall initiate action should a machine fault occur. The two axes (X and Z) shall be identified in accordance with EIA Standard RS-267. The control shall have linear interpolation and be capable of two axis simultaneous control. Control features shall include a programmable interface, buffer storage, fixed cycles, part program storage, part program and buffer edit capability, and control diagnostics. The MCU shall accept part program data entered either in an absolute or incremental mode from a keyboard (manual data input-MDI) or from an external input device compatible with the external storage media (cassette tape cartridge, magnetic card, etc.) of the type specified (see 6.2.1). The control unit shall conform to EIA Standard RS-281. A line voltage of ±10 percent from normal shall not adversely affect the numerical control function. The control shall be capable of functioning in ambient temperatures ranging from 50°F to 120°F and relative humidities ranging from 5 percent to 95 percent non-condensing. The control shall automatically shut down when internal operating temperature exceeds safe operating temperature. Control resolution shall be 0.000025 inch for each linear axis.

A.5.4.1.1 Data display. A cathode rate tube (CRT) or multi-line alphanumeric display, capable of displaying at least 250 characters simultaneously, shall be provided. Unless otherwise specified (see 6.2.1), the display shall, as a minimum, display the following data:

a. Block sequence number
b. Actual and command position of each axis
c. Feedrate and/or override condition
d. Control and system error messages

A.5.4.1.2 Control system modes of operation. The operational modes of the NC control shall include manual, automatic, single block, MDI, sequence number search and optional stop.

A.5.4.1.3 Switchable inch/metric input. The control system shall provide switchable inch/metric input capability.

A.5.4.1.4 Part program memory. Unless otherwise specified (see 6.2.1), the part program shall reside in either solid-state or bubble-type memories. Unless otherwise specified (see 6.2.1), the MCU shall be capable of storing in memory the content of not less than 250 instructions for part program data.

A.5.4.1.5 Standby battery power. Unless otherwise specified (see 6.2.1), the part program shall reside in either solid-state or bubble-type memories. Unless otherwise specified (see 6.2.1), the MCU shall be capable of storing in memory the content of not less than 250 instructions for part program data.

A.5.4.1.6 Part program edit. A program edit capability shall be provided to allow block insertion, deletion or modification of any part program in the part program memory. Data related to part program edit shall be input by the manual data input provided on the control panel. Edited program data entered into program memory shall be automatically acted upon, in the sequence designated, whenever the part program is cycled.

A.5.4.1.7 Feed rate override. A feed rate override control shall be provided to allow manual adjustment of the programmed feed rate from zero to not less than 120 percent of the programmed rate in either continuous adjustment or in steps of not more than 10 percent. The feed rate override control shall have a position that allows return of feed rate to the originally programmed.

A.5.4.1.8 Sequence number search. The control shall have the capability to permit the operator to search for any desired sequence number.

A.5.4.1.9 Block delete. The control shall have a delete feature to permit bypassing one or more instructions of programmed data.

A.5.4.1.10 Segmental read. The control shall have a function to provide for reading information one segment at a time.

A.5.4.1.11 Automatic cycle. When specified (see 6.2.1), the control shall have the capability of running in automatic cycle. Once programmed, the control shall automatically run for an infinite number of parts.

A.5.4.1.12 Reversal error compensation. Error resulting from reversing the direction of the leadscrew shall be minimized by the use of appropriate mechanical devices designed to eliminate, as much reversal error as possible. Electronic compensation within the control unit may be used to reduce the effects of reversal error. Means shall be provided to adjust the anti-backlash device and to input new compensation valves, if applicable, to correct for wear and usage during the life of the machine. The backlash eliminator/compensation system shall provide sufficient accuracy to meet the tolerances given in table II.

A.5.4.1.13 Axis calibration. Error compensation shall be provided to correct repeatable errors determined to exist due to leadscrew and feedback inaccuracies. A means shall be provided to input new error compensation values when required.

A.5.4.1.14 Additional features. Unless otherwise specified (see 6.2.1), the following additional numerical control features shall be provided:

a. Incremental and continuous jog for each axis
b. Leading zero suppression or decimal point programming
c. Inches per minute (ipm)/millimeters per minute (mmpm), programming in all modes of operation
d. Data edit keylock

A.5.4.1.15 Operator control panel. Unless otherwise specified (see 6.2.1), the control unit shall have a control panel which provides at least the following control functions: Emergency Stop; Cycle Start; Optional stop; Mode Selection; Feed Hold; Feed rate Override; Spindle Speed Override; Jog; Jog Direction; and EOB Stop.

A.5.4.1.15.1 Pendant control. When specified (see 6.2.1), a pendant control shall be furnished in lieu of an operator control panel. The pendant control shall be connected to the machine to enable the operator to control machine functions while in close observation position. Unless otherwise specified (see 6.2.1), the pendant control shall be capable of the same functions as stated for the operator control panel in paragraph 3.4.16.15.

A.5.4.1.16 Reference zero. The control unit shall have a reference zero to move each axis to a reference limit switch to establish synchronization and reset all registers to zero.

A.5.4.l.17 Set zero. The control unit shall have a “set zero” feature to permit the specified axis register to be reset as zero establishing present axis location as zero.

A.5.4.1.18 Program tryout. The control shall have a program tryout feature to permit new part programs to be read through the control without machine motions.

A.5.4.1.19 On-line system diagnostics. The MCU shall be capable of performing a constant monitoring function of various activities and conditions of the control and machine. The diagnostic system shall communicate appropriate fault messages to the operator by means of the CRT or other display. Unless otherwise specified (see 6.2.1), the on-line diagnostic capability shall determine the following fault conditions and provide appropriate error messages on the digital display:

- Axis feedback loop fail
- Illegal program entry
- Axis travel limits exceeded
- Low hydraulic pressure
- Axis servo motor failure
- Control console overheat
- Axis servo drive on/off
- Lubrication fault
- Guard door open
- Worn wheel
- Program error
- Feed limit

A.5.4.1.20 Maintenance diagnostics system. Maintenance diagnostics software shall be furnished as non-volatile memory or as specified (see 6.2.1) to provide for diagnostic checking of the machine control unit. The diagnostic software shall test, exercise, and display failures, at least to chip level.

A.5.4.1.21 Peripheral equipment interface. When specified (see 6.2.1), the control shall be equipped with an interface complying with EIA-RS-232.

A.5.4.1.22 Axis jog. The control panel or pendant shall have manual controls for accomplishing both single and continuous, low and high speed jog movements of the slides for each controlled axis in both the plus and minus direction.

A.5.4.1.23 Auxiliary functions. Unless otherwise specified (see 6.2.1), the MCU shall respond to the following program commanded auxiliary functions: interpolation, fixed cycles, and dwell. Unless otherwise specified (see 6.2.1), miscellaneous functions shall included program stop, optional program stop, end of program, coolant on-off, end of program (rewind), and program re-start.

A.5.4.1.24 Canned cycles. Canned cycles shall be provided as specified (see 6.2.1).

A.6 Lathes. Federal Supply Class 3416 covers lathes other than vertical turret lathes in FSC 3411. All lathes, regardless of type, operate on the same basic principle; the workpiece is revolved by power against a cutting tool that removes metal. The metal removing process includes cutting internal or external threads on the workpiece. Lathes are available for turning work between centers and work held only in the chuck or spindle. Long cylindrical workplaces provide additional support by a steady rest. Bar type lathes have the capability to produce parts from raw bar stock that is fed through the spindle. Bar type lathes have a fixture to hold the raw stock behind the spindle steady while it is being rotated for the machining process.

A.6.1 Cylindrical turning lathe. Lathes in this category are for the purpose of turning cylindrical work between centers. Numerical control enables the machining of contours and cutting of external threads. Two axes are under numerical control. Cross travel of saddle is the X axis. Horizontal traverse of the saddle is the Y axis. Spindles speed and direction of rotation, feed rates, positioning and continuous path control of X and Y axes, indexing of the tool turret, threadcutting and positioning of the tailstock are under numerical control. See figure A-20.

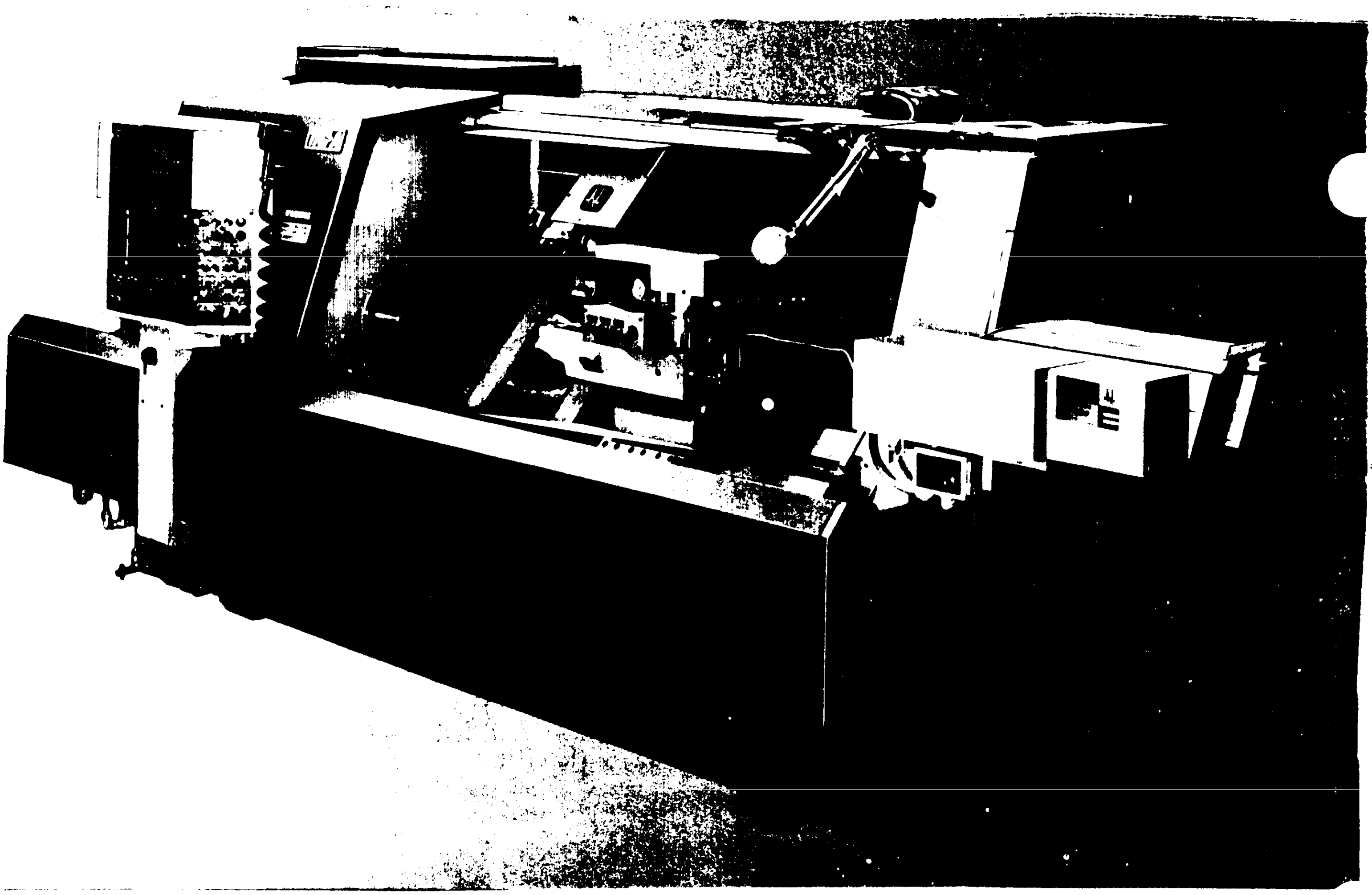


Figure A-20. Two-axis, cylindrical turning lathe. (Jones & Lamson/ Waterbury Farrel Division of Textron Inc.)

A.6.2 Chucking lathe. Lathes in this category are applied to machining of inside and outside surfaces. Numerical control enables the machining of internal and exterior surfaces, internal and external contouring, facing, and the generation of interior and exterior threads. Cross traverse of the saddle is the X-axis and horizontal saddle traverse is the Y-axis. Indexing of the turret is controlled as a machine function. Spindle speed and direction of rotation, feed rates, positioning and continuous path control of X and Y axes, indexing of the turret, and threadcutting are under numerical control. See figure A-21.

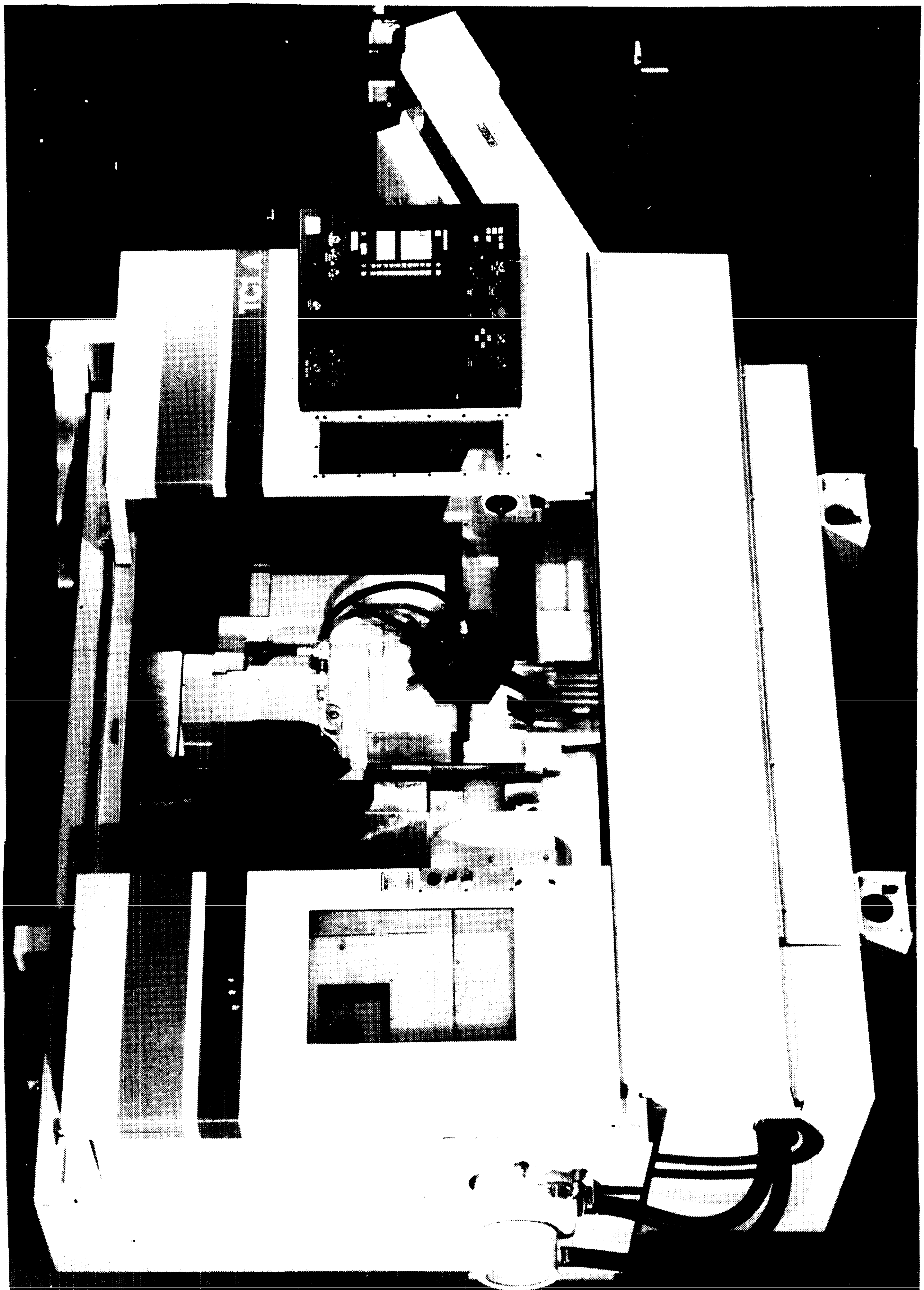


Figure A-21. Two-axis, chucking lathe, vertical bed, two turrets, numerically controlled (Monarch Sidney)

A.6.3 Combination bar and chuck lathe. Lathes having the capability to perform bar and chucking work feature two multiple-station turrets, one for end working and one for turning. The operations performed by this lathe are the same as those for the chucking lathe in paragraph A.6.2 with the addition of automatic bar feed. See figure A-22.

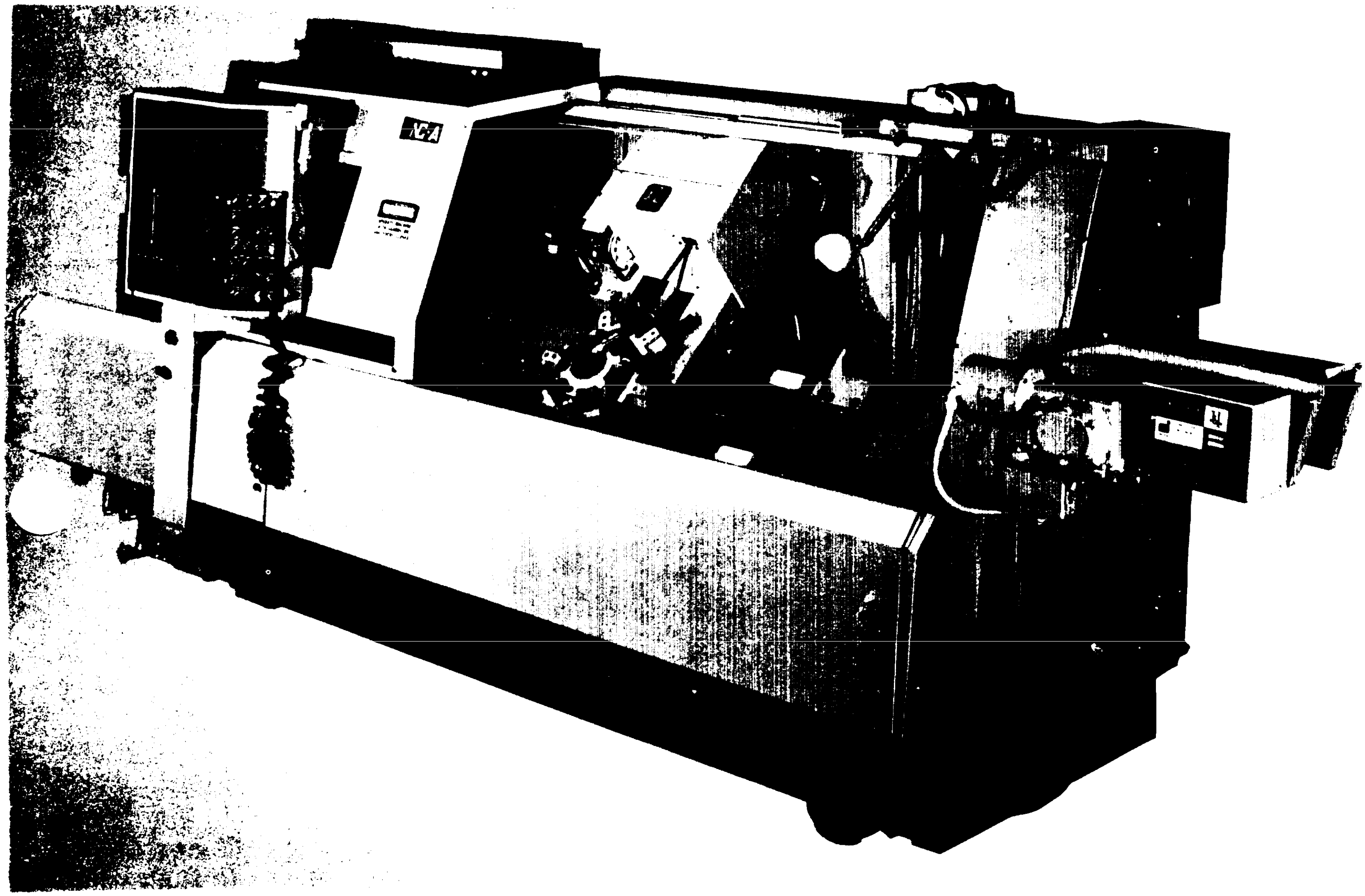
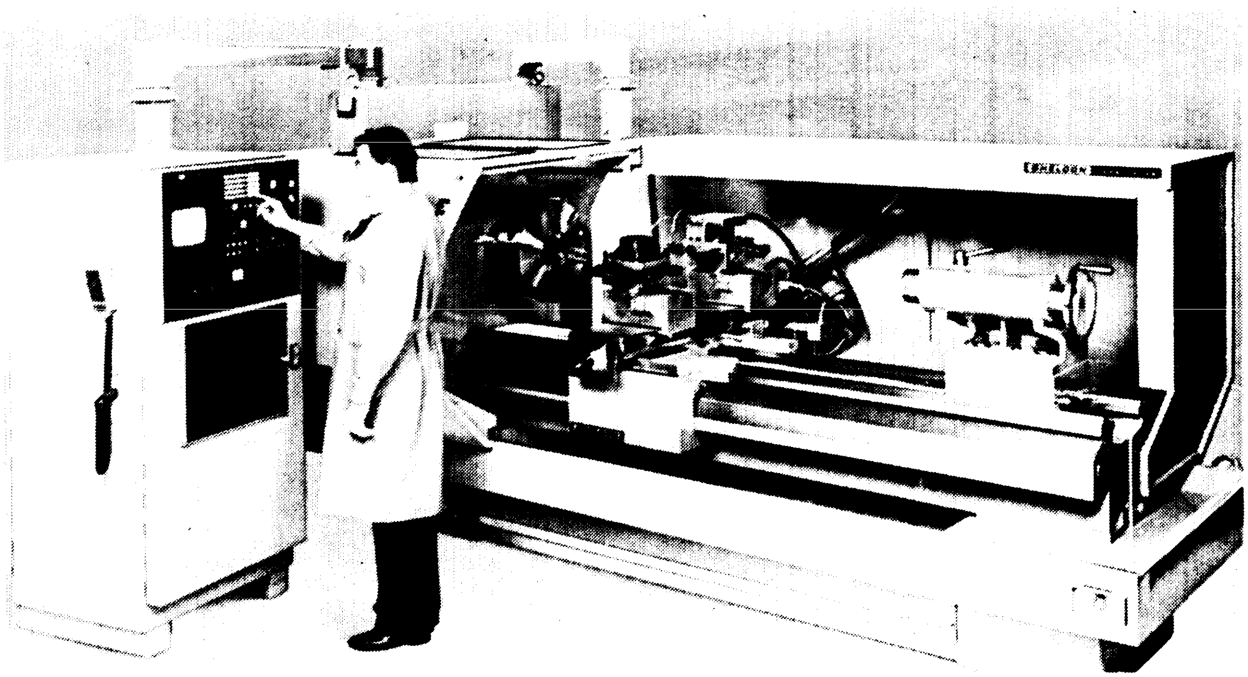


Figure A-22. Two-axis, combination bar and chuck lathe. (Jones & Lamson/ Waterbury Farrel Division of Textron Inc.)

A.6.4 Universal turning lathe. The universal lathe provides the capability to perform bar, chucklng and shaft work. Numerical control features on this lathe are the same as for the machines in paragraphs A.6.l and A.6.2 with the addition of numerical controlled bar feed. See figure A-32.



Fiqure A-23. Two-axis, Universal lathe. (Sheldon Machine Company)

A.6.5 Numerical control requirements for lathes. Numerical control requirements for lathes in FSC 3416 are the same as those stated in paragraph A.4.6.

A.7 Milling machines. Federal Supply Class 3417 covers milling machines that are appllicable to a variety of machining operations. In addition to those operations operations that can be classified as milling, utilizing milling cutters, other operations, such as slotting, drilling, boring, reaming, and tapping that utilize tools identified for use on other machine tools, can be performed by milling machines. Milling machines are capable of combined operations and can replace the capability of some boring and drilling machines wherever the capacity of the milling machine can accommodate the work formerly performed thereon. Principles for operation of milling machines are the same as those applicable to operation of drilling, reaming, tapping, and precision boring. An essential consideration when selecting a milling machine to perform combined operations is the positioning accuracy and repeatability of the machine and its control system.

A.7.I Knee-type milling machine. The typical knee-type milling machine has a vertical spindle fitted to the column and a saddle that traverses vertically on ways of the column. The saddle provides ways for horizontal and cross travel of the table. Vertical travel of the saddle is the W-axis, horizontal travel of the table is the X-axis and cross travel of the table is the Y-axis. The four axis version provides for vertical travel of the spindle quill or spindle head as the Z-axis of motion. Knee-type milling machines are primarily used to machine small parts. Large workplaces having significant weight can be more accurately machined on a bed type milling machine so as to avoid deflection of the table that will occur when a heavy workpiece is oriented to one side of the table. Manual data input or conversationally programmed control is offered by most manufacturers of these machines. See figure A-24.

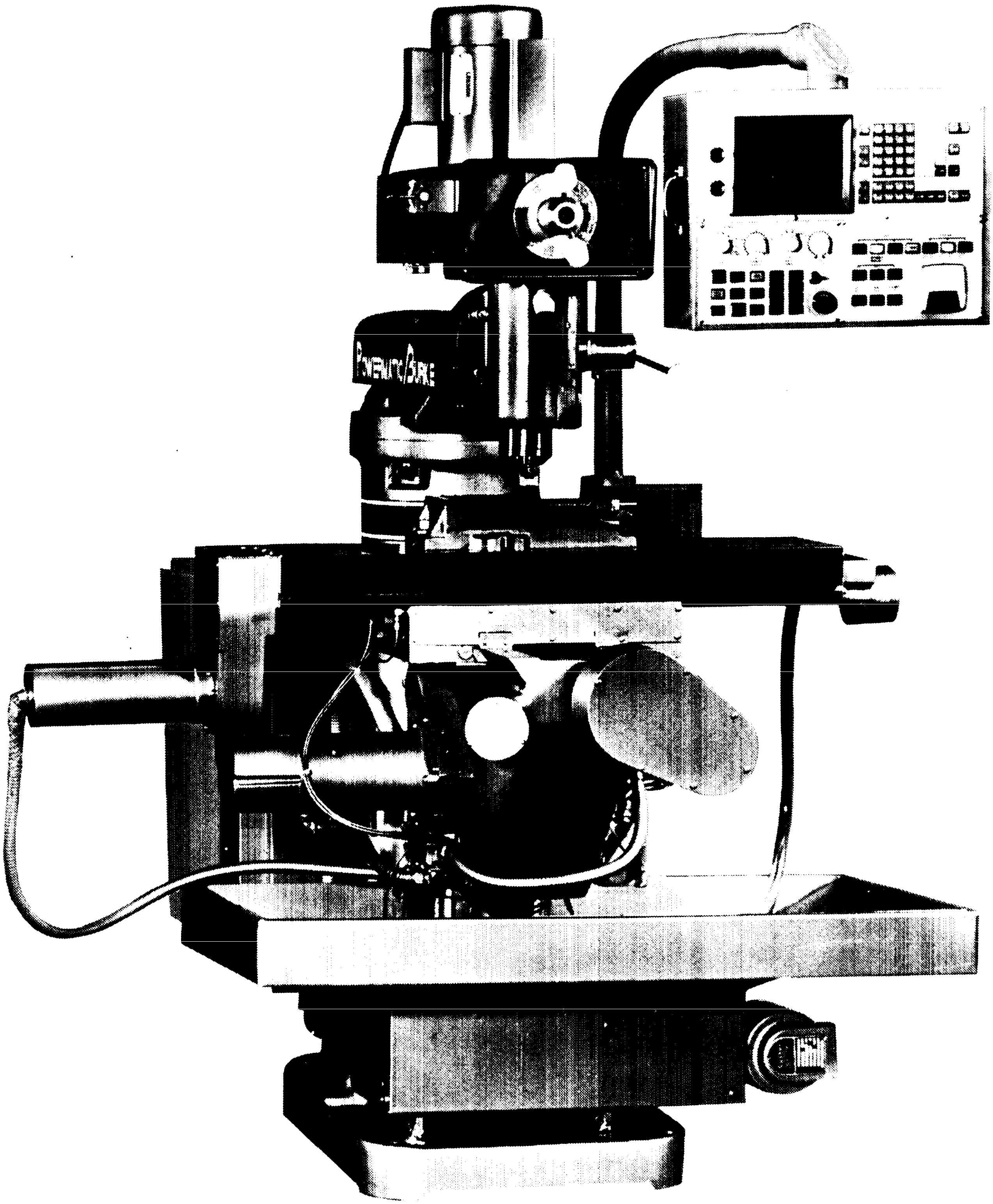


Figure A-24. Three-axis, knee-type, vertical spindle milling machine (Burke Division Powermatic Houdialle).

A.7.2 Bed-type milling machines. A vertical or horizontal spindle milling machining having a table that is fully supported on ways that are machined or fitted to the foundation of the machine. As numerically controlled machines, the configuration can be three to five axes. Nomenclature for the three-axis machine is; X axis for horizontal travel of the table, Y axis for cross travel of the table, Z axis for vertical travel of the spindle. The four-axis version includes the X, Y and Z axes plus a B axis that provides rotary motion of spindle to orient it at an angle to the perpendicular. The five-axis version adds an optional dividing head to the four-axis configuration, providing an A axis of rotary motion. Numerical controls fitted to these machines are capable of simultaneously controlling all axes, feeds and speeds, direction of spindle rotation and machine functions. Four and five-axis versions are capable of multi-axis contouring work required to produce complex

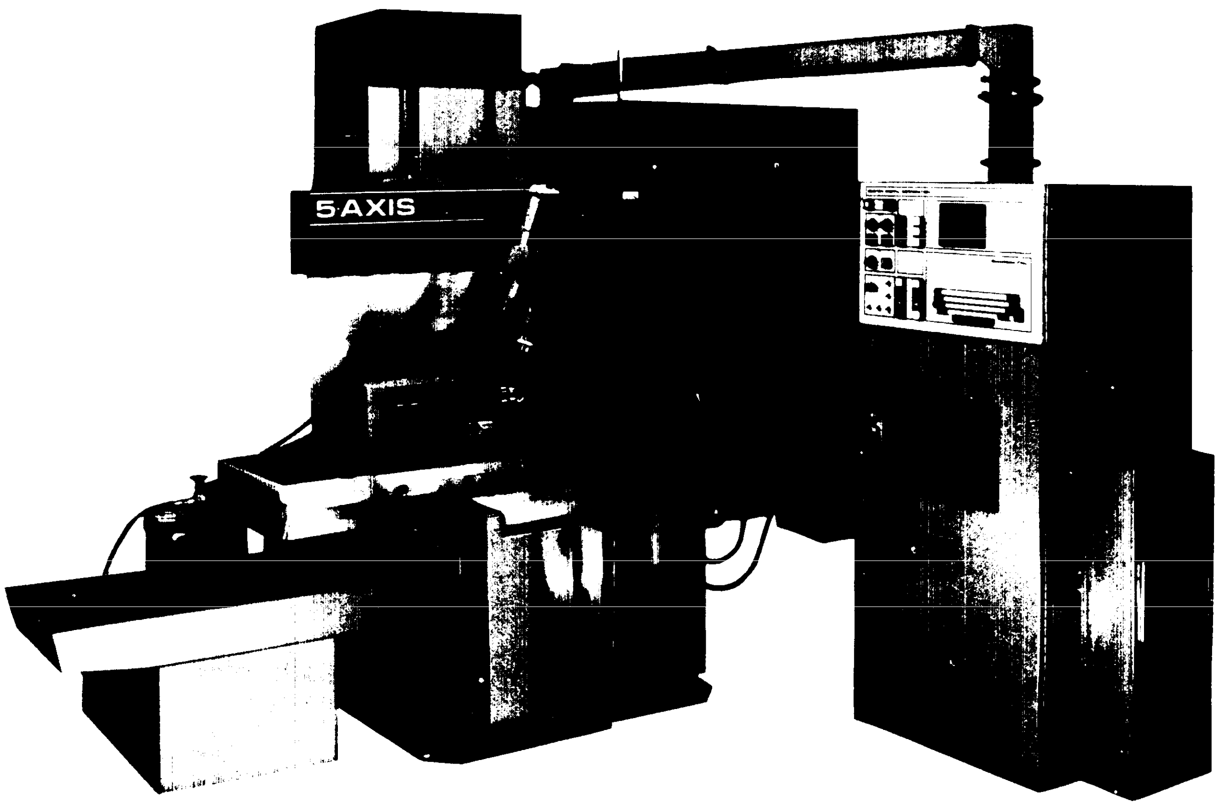


Figure A-25. Five-axis, bed-type, vertical spindle, contouring milling machine. (Boston Digital Corporation)

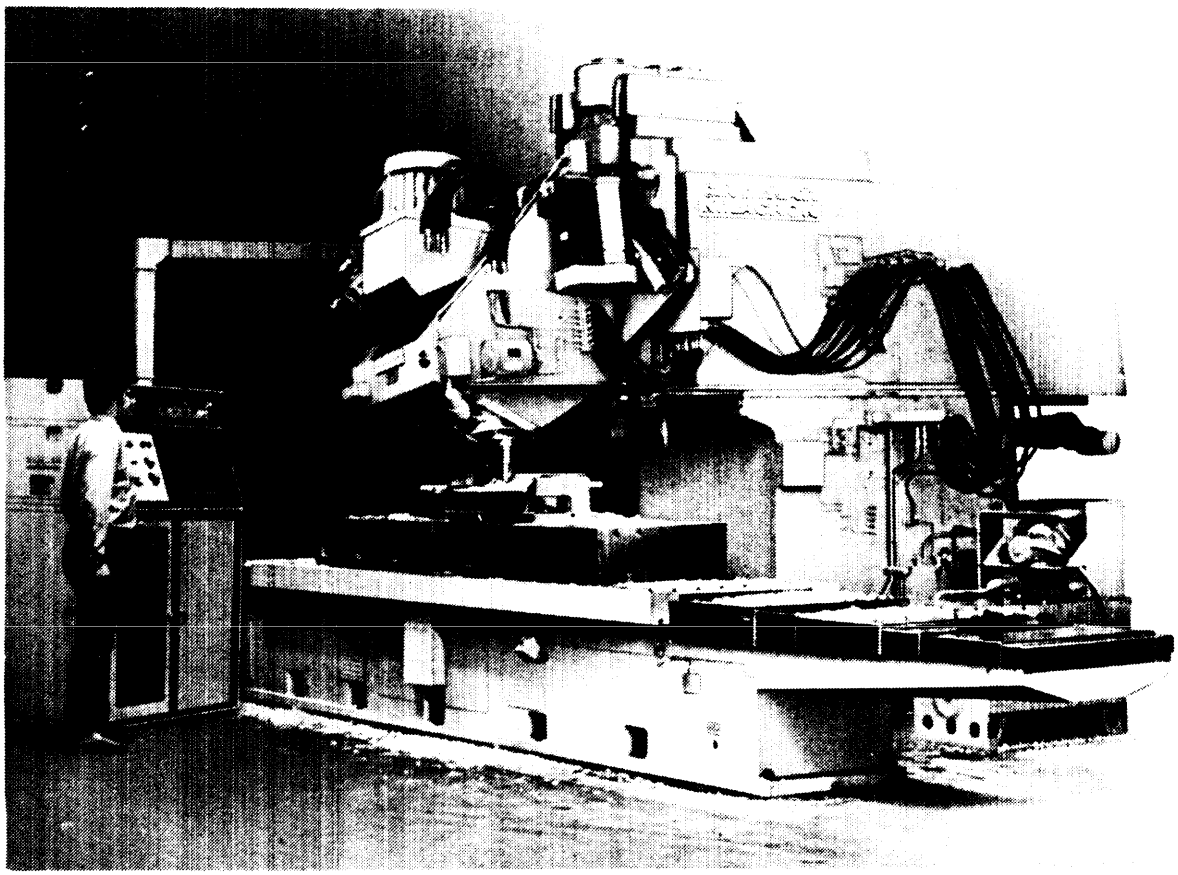


Figure A-26. Five-axis, bed-type, profile milling machine having two directions of spindle tilting, A and B axes. (Cincinnati Milacron)

A.7.3 Milling machine numerical controls. Milling machines in FSC 3417, boring, drilling, and milling machines in class 3411 and jig boring machines in FSC 3411 require features in the following paragraphs for a computer numerical control or manual data input control. The manual data input control provides the capability to perform complex machining operations, can be programmed in a central office and eliminates the necessity for a postprocessor.

A.7.3.1 Computer numerical control (CNC). Unless otherwise specified (see 6.2.1), the milling machine will be equipped with a fully automatic, solid-state, soft-wired, integrated circuit type numerical control. The numerical control shall provide automatic control of machine functions, operating modes, spindle speeds, direction of rotation and simultaneous control of the machine's three-linear axes in linear and helical interpolation. The control shall also be provided with circular interpolation capabilities. Machine axes shall be identified in accordance with EIA-RS-267. Line voltage fluctuation of ±10 percent from the normal operating voltage shall not adversely affect the operation of the CNC. Unless otherwise specified (see 6.2.1), the control shall be provided for connection to a 115-volt AC, 60 HZ, single phase power source. The control shall be capable of operating in an outside ambient temperature of 50-110 degrees F at 5-95 percent non-condensating relative humidity. The control shall be automatically shut down when the maximum operating temperature is reached. Program resolution shall be 0.0001 inch or 0.001 mm for each linear axis. The mechanical and electrical design of the control shall comply with EIA-RS-281 construction standards. The control shall be capable of accepting input data in the form and format specified by the ordering activity.

A.7.3.1.1 Punched tape data input. Unless otherwise specified (see 6.2.1), the input media for the control shall be one-inch, eight-channel punched tape complying with EIA-RS-227.

A.7.3.1.1.1 Tape reader. When one inch tape is the specified input media, the control shall be equipped with a photoelectric tape reader capable of holding, feeding and reading tape prepared in the format specified at a rate not less than 150 characters per second. Unless otherwise specified (see 6.2.1), the tape reader shall be supplied with standard feed and take-up spoolers 5-1/4 inches in diameter. The tape reader shall be housed in a dust proof enclosure mounted in a control cabinet and shall be easily accessible for cleaning and tape handling. The control shall have a tape error detection capability to continuously check for the following errors:

a. Odd parity per EIA RS-244
b. Even parity per EIA RS-358
c. Misaligned sprocket holes
d. No sprocket holes

Any of the above errors shall halt machine functions and illuminate an error light or a message on the data display screen to indicate a fault condition.

A.7.3.2 Flexible diskette data input. When 32 Bit Binary Cutter Location (BCL) Exchange Input for numerically controlled machines is specified (see 6.2.1), the input media shall be an eight-inch flexible diskette recorded in accordance with A.7.3.2.1. The input data format shall comply with EIA Standard RS-494. Manufacturers providing functions or features that are not currently covered in EIA-RS-494 shall apply to the Electronic Industries Association, IE-31 Committee on Numerical Control Systems and Equipment for an extension of the standard codes to cover the manufacturer's features or functions. The control shall be equipped with an eight-inch flexible diskette reader. The reader shall have the capability to perform a cyclic redundancy check of the input data and be capable of reading not less than 15,000 characters per second.

A.7.3.2.1 Flexible diskette format. When an eight-inch flexible disk is specified as the input media to the numerical control it shall be a single density recording on one side using a soft-sectored format. The disk shall be divided into 77 distinct locations on the single-side disk. Tracks shall be assigned numbers from 00 through 76. Track 00 shall be nearest to the edge of the disk and track 76 nearest the center. Tracks 00, 74, 75 and 76 shall not be used. There is an index hole in the jacket and the disk that shall be used for timing functions when a beam of light passes through it. Recording shall be accomplished by rotating the disk inside its jacket exposing the disk at the read/write head slot cut in the jacket. Data shall be recorded only on the side of the disk that is exposed to the read/write head. Each track shall be divided into 26 addressable sectors which contain 128 bits. All sectors shall be identified by the file starting sector number with track 00 sector 1, designated as O. The first part program shall be located at sector 1 E hexadecimal corresponding to track 1, sector 5. Where two byte numbers are referenced, the high-order byte shall be recorded first and the low order last. Track 1, sectors 1 through 4, shall contain the program directory of up to 16 part program names in ASCII. Each file shall be packed on the disk in the same order as its directory entry. Unused directory entries shall point to the next available sector after the last file and contain the 30-character ASCII space characters. The last sector of each file shall be padded with end-of-file (EOF) records (8000 0000) . Diskette addressing shall comply with the requirements of table II.

A.7.3.3 Program features.

A.7.3.3.1 Tape coding. The control shall accept punched tape programmed in accordance with EIA-RS-274. The control shall be capable of recognizing and automatically accepting coding in accordance with EIA-RS-244 or EIA-RS-358.

A.7.3.3.2 Leading zero suppression. The control shall be capable of suppressing leading zeros.

A.7.3.3.3 Selectable inch/metric input. The control system shall provide operator or program selectable inch/metric input capability.

A.7.3.3.4 Absolute/incremental input. The control shall have switchable absolute/incremental input capability.

A.7.3.3.5 Departure control. The maximum departure permitted by a single command in either incremental or absolute mode shall be not less than plus or minus 99.9999 inches or 999.999mm. The control shall be capable of automatically controlling the acceleration and deceleration of the slides. The resolution of slide movement in either direction shall not be more than 0.0001 inch or 0.001 mm.

A.7.3.3.6 Preparatory function (G-Codes). The preparatory function codes of the control shall be in accordance with EIA RS-274.

A.7.3.3.7 Miscellaneous functions (M-Codes). The miscellaneous function codes of the control shall be in accordance with EIA RS-274.

A.7.3.3.8 Additional features. Unless otherwise specified (see 6.2.1), the following additional numerical control features shall be provided:

a. Four quandrant programming.
b. Incremental and continuous jog for each axis.
c. Inches per minute (IPM)/Millimeter Per Minute (MMPM).
d. Vector feed rate.

A.7.3.4 Axis and tool management.

A.7.3.4.1 Tool length offsets. The control shall have a tool length offset feature to permit adjustments to the programmed tool length by means of manual data input. The tool length offset feature shall have a range of not less than the following:

a. Inch system ±0.0001" to ±1.0000".
b. Metric system ±0.001 to ±25.400 mm.

A.7.3.4.2 Cutter compensation. Cutter compensation shall be provided to compensate for cutter diameters differing from those utilized in programming. The cutter compensation shall have a range of not less than the following:

a. Inch system ±0.0001" to +1.0000”.
b. Metric system ±0.001 to ±25.400 mm.

A.7.3.4.3 Fixture compensation. A fixture compensation feature shall be provided to permit compensation for fixture position errors.

A.7.3.4.4 Reversal error compensation. Reversal error compensation circuitry shall be provided for a selectable dimension correction to be added automatically to the command dimension to each linear axis reversal to compensate for mechanical lost motion.

A.7.3.4.5 Lead error compensation. Lead error compensation software shall be provided to permit compensating for the lead errors of each axis ball screw.

A.7.3.4.6 Auxiliary functions. Unless otherwise specified (see 6.2.1), the MCU shall respond to the following program command auxiliary functions: interpolation, "fixed cycles, and dwell. Unless otherwise specified (see 6.2.1), miscellaneous function shall include program stop, end of program, spindle CW, spindle CCW, spindle off, coolant on-off, tool change; end of program (rewind), and program re-start. System preparatory and miscellaneous functions shall be coded in accordance with EIA RS-274.

A.7.3.5 Operator interface and controls.

A.7.3.5.I Data display. A cathode ray tube (CRT) capable of displaying at least 250 characters simultaneously, shall be provided. Unless otherwise specified (see 6.2.1), the display shall, as a minimum, display the following data:

a. Four digit block sequence number
b. Active block of stored data
c. Actual position of each axis (may be a LED display on the control unit)
d. Control and system error messages

A.7.3.5.2 Control system modes of operation. The operational modes of the NC control shal1 include manual, automatic, single block, MDI, and sequence number search.

A.7.3.5.3 Manual data input. A manual data input (MDI) unit shall be furnished to permit manual entry of alphabetical, numerical, and special characters necessary for control of all programmable machine functions. The manually input data shall be immediately displayed on the data display to permit data verification. The MDI shall be capable of entering a block of data into memory upon command.

A.7.3.5.4 Block delete. The control shall have a block delete feature to permit bypassing of blocks of programmed data.

A.7.3.5.5 Block-by-block read. The control shall have a block-by-block read function to provide for reading information one block at a time.

A.7.3.5.6 Sequence number search. The control shall have the capability to permit the operator to search for any desired sequenced number.

A.7.3.5.7 Part program edit. A program edit capability shall be provided to allow block insertion, deletion or modification of any part program in the part program memory. Data related to part program edit shall be input by the manual data input provided on the control panel. Edited program data entered into program memory shall be automatically acted upon, in the sequence designated, whenever the part program is cycled.

A.7.3.5.8 Feed rate override. A feed rate override control shall be provided to allow manual adjustment of the programmed feed rate from zero to not less than 120 percent of the programmed rate in either continuous adjustment or in steps of not more than 10 percent.

A.7.3.5.9 Spindle speed override. A spindle speed override shall be provided to allow manual adjustment of spindle speed in either continuous adjustment or in steps of not greater than 10 percent each. The spindle speed override control shall control not less than the range of override percentages between 60 and 120 percent of programmed speeds.

A.7.3.5.1O Mirror image. The control shall be capable of producing either right or left-hand parts from the same input data through the inversion of X and Y axis. Inversion of each axis shall be keyboard, switch or programmed entry. Mirror image shall not affect the directional sense of manual controls. Reverse settings shall be displayed on the data display.

A.7.3.5.11 Axis jog. The control panel or pendant shall have manual controls for accomplishlng both single and continuous, low and high-speed jog movements of the slides for each controlled axis in both the plus and minus direction.

A.7.3.5.12 Reference zero. The control unit shall have a reference zero to move each axis to a reference limit switch to establish synchronization and reset all registers to zero.

A.7.3.5.13 Tape tryout. The control shall have a tape tryout feature to permit new part programs to be read through the control without machine motions.

A.7.3.5.14 Operator control panel. The control unit shall have a control panel which provides, unless otherwise specified (see 6.2.1), at least the following control functions: Emergency Stop; Cycle Start; Optional Stop; Mode Selection; Feed Hold; Feedrate Override; Spindle Speed Override; Jog; Jog Direction; and EOB Stop.

A.7.3.6 Miscellaneous control requirements.

A.7.3.6.1 Part program storage. Part program memory loadable from the data input media shall be provided. Unless otherwise specified (see 6.2.1), the part program memory shall be capable of storing not less than 100 feet of postprocessed part program tape.

A.7.3.6.2 Standby battery power. Unless otherwise specified (see 6.2.1), standby battery power shall be provided for controls having volatile memory, to hold the size memory provided at full load for a period of not less than 72 hours when the primary power source fails.

A.7.3.6.3 Operational software. Operational software shall be resident in the control and shall contain all logic necessary to effectively operate the machine tool. The software shall provide for meaningful diagnostics relating to the utilization of the controls, machine tool, part program, and operator's actions.

A.7.3.6.4 Prograrmmable interface. A software progqram for accommodating the soft-wired interface between the numerical control and machine shall be provided as part of the executive program or as a separate program.

A.7.3.6.5 Maintenance diagnostic systems. Maintenance diagnostics software shall be furnished in either the control as non-volatile memory or in the form of one-inch tape or eight-inch flexible disk, as required by the specified input media, to provide for diagnostic checking of the machine control unit. The diagnostic software shall test, exercise, and display failures, at least to board level.

A.7.3.6.6 Peripheral equipment interface. The control shall be equipped with an interface complying with EIARS-232.

A.7.3.6.7 Canned cycles. Unless otherwise specified (see 6.2.1), the following canned cycles shall be provided:

a. Drilling
b. Boring
c. Tapping
d. Bolt hole circle

Such cycles shall be called by G codes and shall be initiated when X, Y, Z and R plane data is entered plus data for the F, E and K words.

A.7.3.6.8 Operator portable or pendant control. When specified (see 6.2.1), an operator's control of the pendant or portable box type shall be provided for the CNC with features as specified by the procuring activity.

A.7.3.6.9 Postprocessor. Unless otherwise specified (see 6.2.1), the CNC shall be furnished with postprocessor program(s) to be utilized in off-line computer-assisted preparation of part programs. The postprocessor shall be provided for converting specified part program languaqe (see 6.2.1) to the form and format required for input to the CNC. The postprocessor shall be written for use with the computer specified (see 6.2.1). Documentation sufficient to implement and use the postprocessor shall be provided for computer compatibility verification and validation at least 30 days prior to delivery of the milling machine.

A.7.4 Manual data input (MDI) control. When specified (see 6.2.1), a MDI control shall be provided with the following minimum requirements.

A.7.4.1 Control unit. The control unit shall accept MDI to move the controlled elements of the position called for by the input data. The control unit shall be a fully automatic, solid-state, soft-wired, integrated circuit type design, to be selectively operated directly from manual input, from a program stored in memory and from a program pre-recorded on either punched tape, magnetic cassette tape, or flexible disk. The system shall provide automatic control of machine functions, operating modes, three linear axes feed rate control and other part program directed functions for milling machines of the type specified herein. The control unit and the related system components shall form a closed loop system. The control shall have linear and circular interpolation and be capable of simultaneous control of three linear axis. The axes shall be identified in accordance with EIA Standard RS-267. Control features shall include a programmable interface, buffer storage, fixed cycles, part program storage, buffer edit capability and control diagnostics. The control shall initiate a halt or error signal should a fault condition occur in the control. All necessary executive program routines shall be provided on a magnetic storage drive or punched tape for controls having volatile memory. The control unit shall conform to EIA Standard RS-281. All line voltage of ±10 percent from normal shall not adversely affect the control system function. The control shall be capable of functioning in any ambient temperature 60 to 105 degrees Fahrenheit and in relative humidity of 10 to 90 percent. The control shall automatically shut down when operating temperature exceeds safe operating temperature. Control resolution shall be not than 0.0001 inch or 0.001 mm.

A.7.4.2 Manual data input (MDI) keyboard. Programming shall be done at the machine with a CRT display leading the operator through programming steps by short inquires displayed in simple English. The operator shall be able to respond to the inquires by selecting: type of data block; type of operation, such as drill, tape, bore or mill; X and Y dimensions; Z up and Z down dimensions; feed rates for X, Y and Z; peck; the tool number and appropriate sub-routines. All of this information shall be entered through the keyboard and displayed as a part of the data block being programmed. It shall be possible to review each data block on the CRT display and instantly edit the same through simple keyboard entries. Part program(s) shall be accomplished from Data Block 1 through Data Block 250. A set-up data block, which can be varied independently from the part program, shall be used for table referencing, tool length offset, tool diameter and spindle speed corresponding to the tool choice.

A.7.4.3 Additional data input media. When specified, a secondary input device shall be provided to input data on either one-inch, eight-channel punched tape, magnetic tape cassette or flexible diskette (see 6.2.1). When one-inch, eight-channel punched tape reader is specified, the tape reader and control shall satisfy the requirements in 3.4.11.1.1.

A.7.4.3.1 Reader/recorder. When specified (see 6.2.1), the control shall be equipped with a reader/recorder for reading and recording either tape cassettes or flexible disks. When specified (see 6.2.1), a portable tape punch shall be supplied for punching one-inch, eight-channel tape. Recordin shall be accomplishing when the control is operated in the program record mode.

A.7.4.4 Data display. The data display shall be a cathode ray tube (CRT) capable of displaying the following:

a. Prompting message
b. Active block of stored data
c. Fault condition or programming error
d. Actual position of each axis (may be an LED display located on the control unit)

A.7.4.5 Planual/automatic modes. A means shall be provided to operate the machine manually through the control panel or automatically from a part program.

A.7.4.6 Departure control. The maximum departure permitted by a single command in either incremental or absolute mode shall be not less than plus or minus 99.9999 inches or 999.9 mm.

A.7.4.7 Absolute/Incremental programming. The control shall have switchable absolute/incremental programming capability.

A.7.4.8 Part program storage. Part program storage shall be either solid state or bubble memory control shall be capable of storing in memory a minimum not less than the equivalent of 50 feet of part program tape. Specify number of feet required, if different (see 6.2.1).

A.7.4.9 Standby battery power. Unless otherwise specified (see 6.2.1), standby battery power shall be provided for controls having volatile memory, to hold the size memory provided at full load for a period of not less than 72 hours when the primary power source fails.

A.7.4.1O Part program edit. A program edit capability shall be provided to allow block insertion, deletion, or modification of any part program memory. Edited program data entered into program memory shall be automatically acted upon, in the sequence designated, whenever the part program is cycled.

A.7.4.11 Peripheral equipment interface. The control shall be equipped with an interface complying with EIA RS-232 for peripheral equipment.

A.7.4.12 Inch/metric input. Operator or program selectable inch/ metric input capability shall be provided.

A.7.4.13 Data block search. The control shall have the capability to permit the operator to search for any desired data block within a selected part program.

A.7.4.14 Mirror image. The control shall be capable of directing the machine to produce right or left-hand parts from the same part program by means of a special function selector.

A.7.4.15 Feed rate override. A feed rate override shall be provided to allow adjustment of the programmed feed rate from zero to not less than 10 percent of the programmed rate in either continuous adjustment or in steps of not more than 10 percent increments.

A.7.4.16 Tool length offset. The control shall have a tool length offset feature to provide the capability to make adjustments to the programmed tool length. The tool length offset feature shall have a range of not less than the following:

Inch system ±0.0001″ to ±1.0000″
Metric system ±O.001 mm to ±25.4 mm

A.7.4.17 Cutter compensation. Cutter compensation shall be provided to compensate for cutter diameters differing from those utilized in programming. The cutter compensation shall have a range of not less than the following:

Inch system ±0.0002″ to ±1.0000″
Metric system ±O.002 mm to ±25.400 mm

A.7.4.18 Fixture compensation. A fixture compensation feature shall be provided to permit compensation for fixture position errors and for shifting program data in multi-fixture applications.

A.7.4.19 Reversal error compensation. Reversal error compensation software shall be provided to apply a determined linear correction value to the commanded position each time a screw reversal occurs. The linear correction value shall be equal to the linear value of lost mechanical motion in the motion screw thrust points.

A.7.4.20 Additional features. Unless otherwise specified (see 6.2.1), the following add itional numerical control features shall be provided:

a. Four quadrant programming
b. Incremental and continuous jog for each axis
c. Leading zero suppression or decimal point programming
d. Inches per minute (IPM)/millimeters per minute (MMPM) programming in all modes of operation

A.7.4.21 Reference zero. The control unit shall have a reference zero capable of being relocated to any point on each controlled axis.

A.7.4.22 Operational software. Operational software shall be resident in the control unit and shall contain all logic necessary to effectively operate the machine tool. The software be shall provided for meaningful diagnostics relating to the utilization of the controls, machine tool, part program, and operator's actions.

A.7.4.23 Programmable interface. A software progqram for accommodating the soft-wired interface between the control unit and the machine shall be provided as part of the executive program or as a separate program.

A.7.4.24 Maintenance diagnostics. Maintenance diagnostics software shall be furnished either in the control as non-volatile memory for diagnostic checking of the control unit. The diagnostic software shall test, exercise, and display failures, at least to board level.

A.7.4.25 Canned cycles. Unless otherwise specified (see 6.2.1), the following canned cycles shall be provided:

a. Drilling
b. Boring
c. Tapping
d. Bolt hole circle

Such cycles shall be called by codes and shall be initiated when X, Y, Z and R plane data is entered plus data for the F, E, and K words.

NOTE : MDI controls do not require a postprocessor.

A.8 Miscellaneous numerically controlled machines.

A.8.1 Welding machines Numerically controlled arc welding machines in FSC 3431 are composed of a power supply, manipulator and devices for holding and positioning the workpiece. The numerical control used on this system controls the power used for welding, arc on and off, operation of the manipulator for the welding head and operation of the workholding and positioning device. An arc welding machine of this configuration is shown in figure A-27.

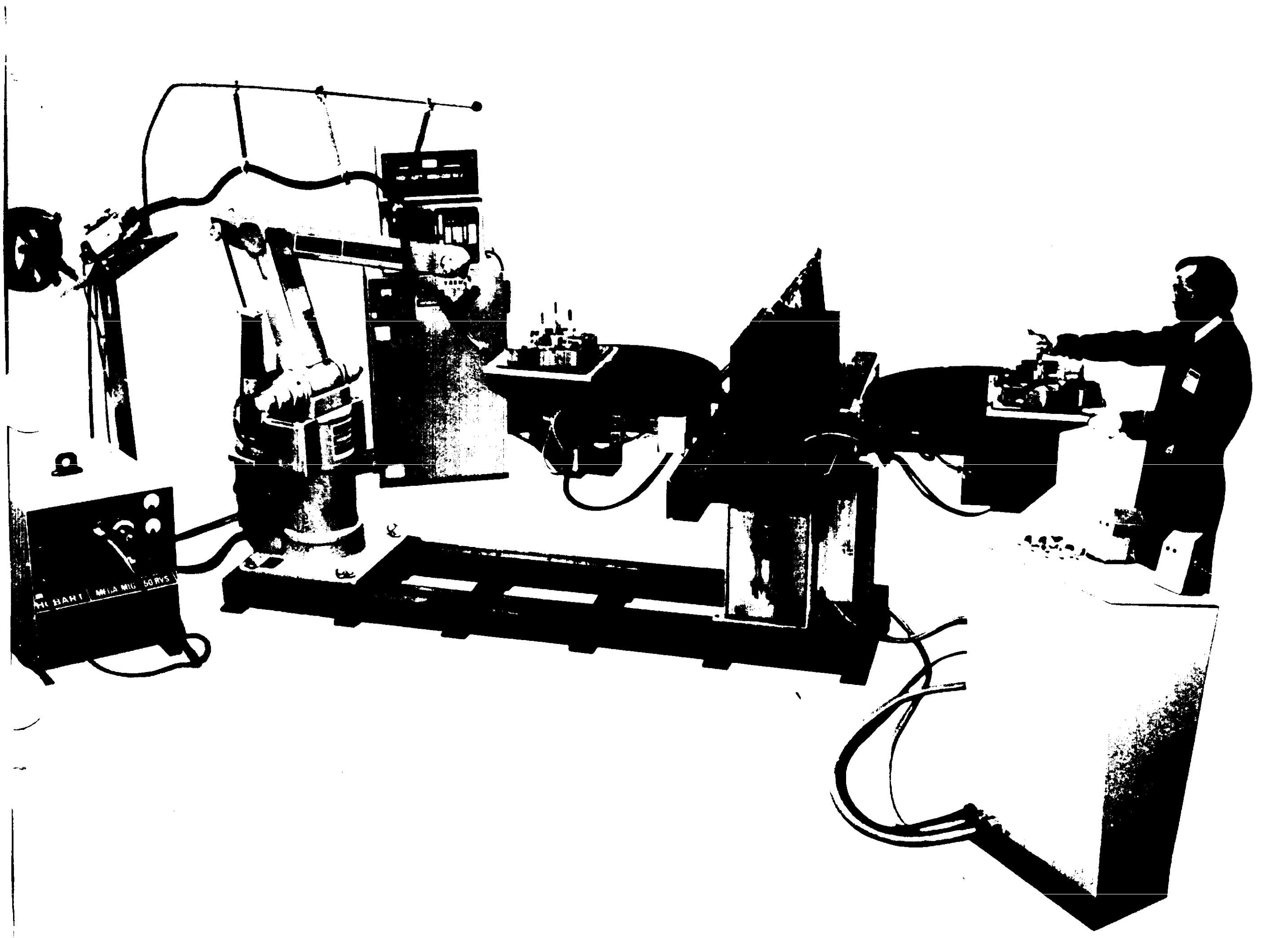


Figure A-27. Electric arc welder, numerically controlled, featuring an articulated robot for manipulation of the welding head and a five-axis workholding and positioner capable of rotation and tilting of the workpiece. (Hobart Brothers Company)

A.8.2 Gas welding, heat cutting and metalizing equipment. Federal Supply Class 3433 includes heat cuttling equipment that utilizes oxnyfuel or plasma to cut shaped parts from metal plates or sheets. The numerically controlled machine is a gantry robot that manipulates the path of one or more torches over the material blank in accordance with the part program. The numerical control applied to this machine controls the flame of the torch to influence the width of cut. Typically, metal cutting machine tool controls with uniquely tailored executive programs are used to control shape cutting machines. See figure A-28.

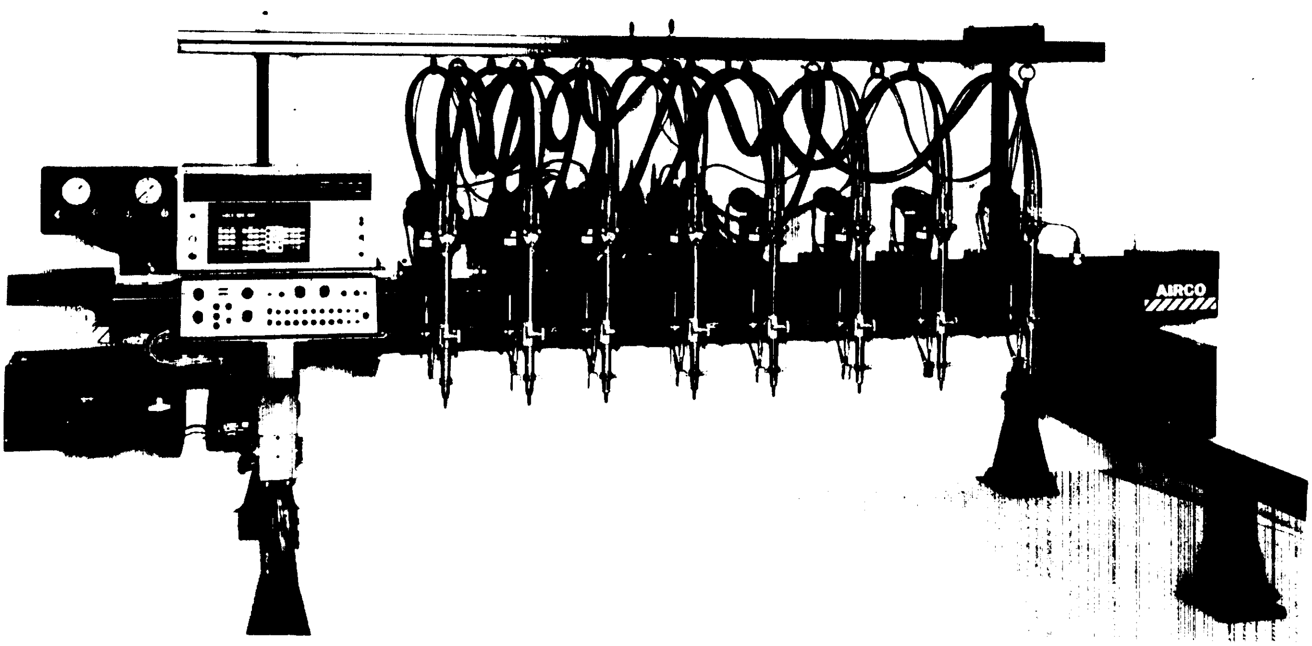


Figure A-28. Three-axis, gantry-type thermal cutting machine. (AIRCO Welding Products)

A.8.3 Bending and forming machines. The numerically controlled tube bending machines in FSC 3441 support the requirement to produce a wide variety of tube shapes and sizes. The numerical control used with such machines is tailored to operate the machine so as to bend the tube to the desired shape while maintaining the overall dimensional accuracy and dimensions between bends. See figure A-29.

A.8.4 Punching and shearing machines. Machines in FSC 3445 include numerically controlled turret punch presses. Typical of machines offered by vendors is the numerically controlled turret punch press for punching and nibbling operations shown in figure A-30. Material feed, clamping, tool selection and hit rate are under numerical control. Numerical control eliminates layout, minimizes material handling, reduces inventory scrap and rework and provides the most economical means to support low volume production.

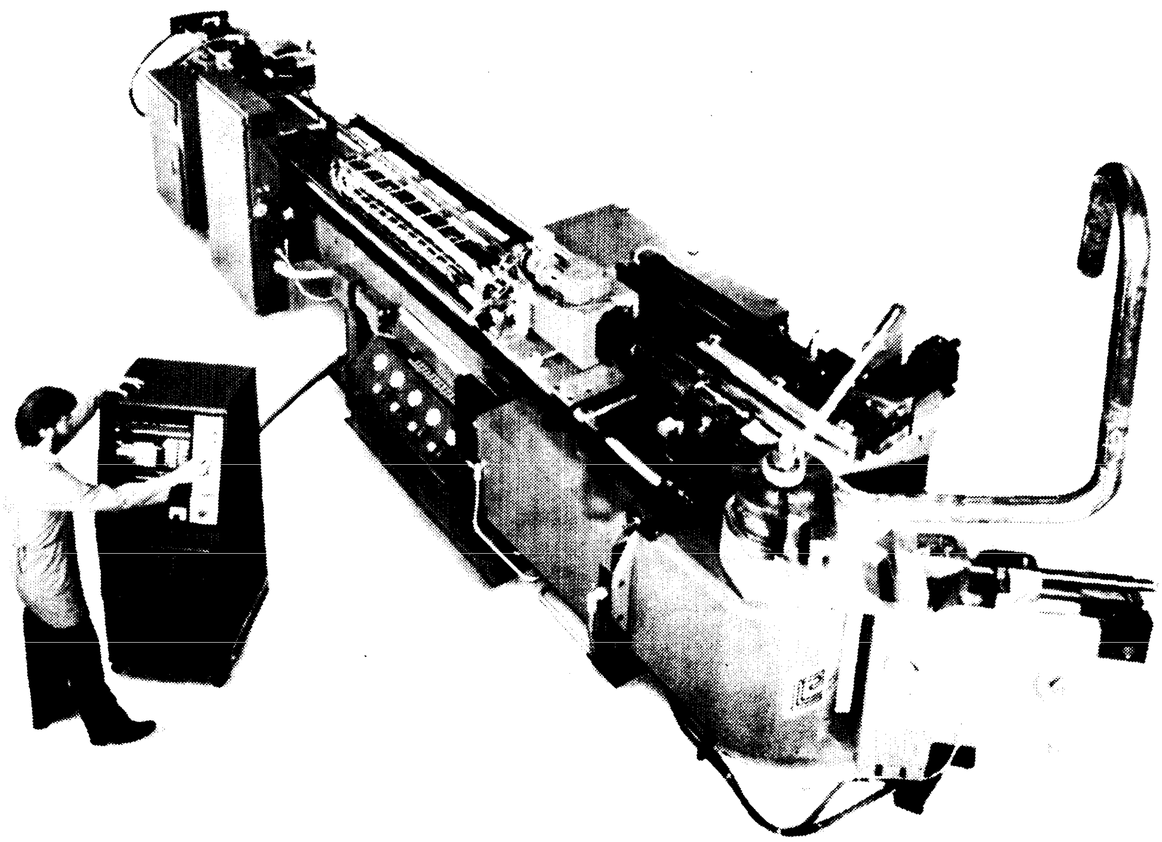


Figure A-29. Numerically controlled tube bender. (Eaton Leonard)

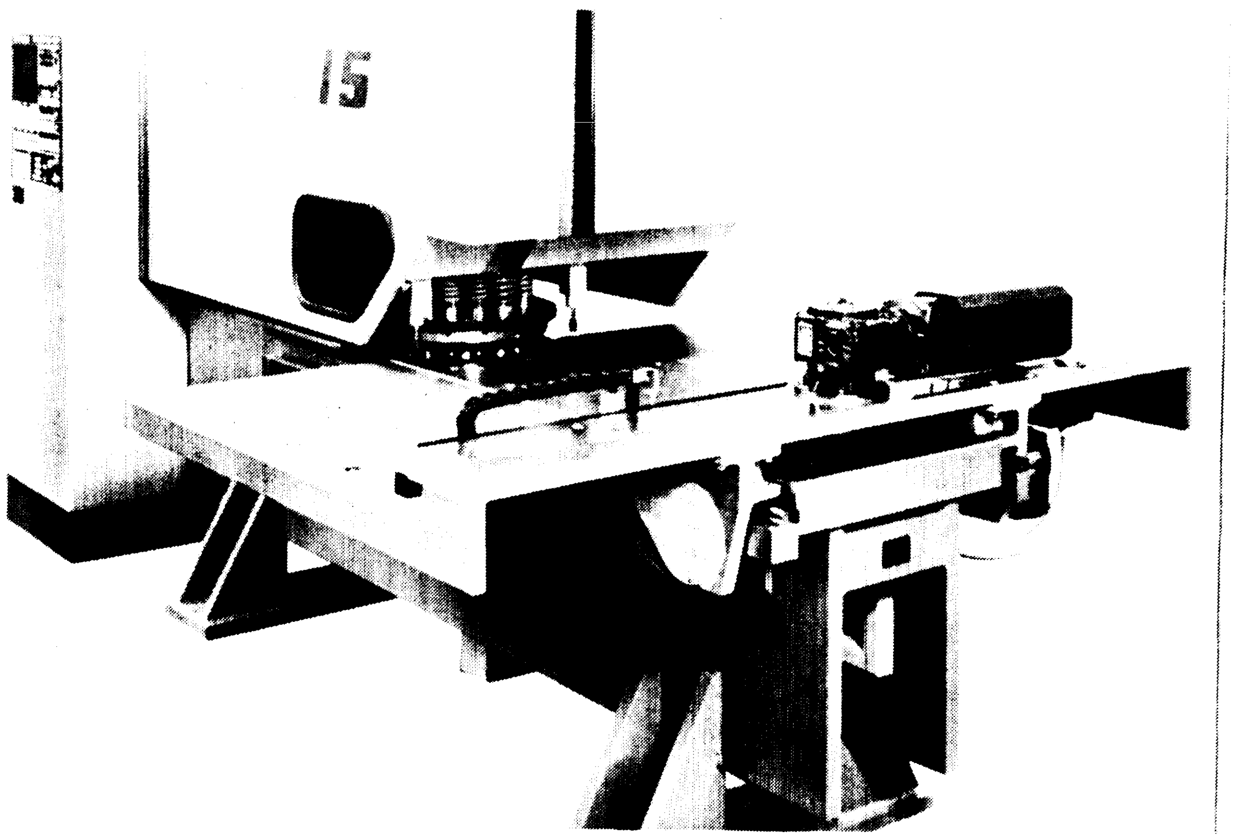


Figure A-30. Numerically controlled turret punch press (W. A. Whitney an Esterline Company)

A.9 Industrial robots. FSC 3695, miscellaneous special industry machinery, includes robots. Industrial robots were initially developed in the early 1960s. Since that time, the number and type of robots has been increasing at an accelerating rate. They are available in a wide range of configurations and capabilities. These include simple "pick-and-place" path units. Programmable controls, memory systems, and up to seven articulations provide industrial robots with a high degree of flexibility and adaptability to do many tasks involving manipulation of objects and tools. Robots are about as fast as a man on a short-term basis, but the robot is approximately 25 percent more productive over the long term because of their consistency. Robots are taught to perform a job by using the teach control mode to move the arm through the desired sequence of operations. A recording of the program sequence is automatically stored in the control memory. Once recorded, the arm motions can be repeated precisely to a positioning accuracy of 0.040" (1.02 mm). (See figure A-31.)

A.9.1 Robot definition. The Robot Institute of America defines a robot as "a programmable, multifunction manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks."

A.9.2 Types of robots. In accordance with geometry of the manipulator.

A.9.2.1 Type I cartesian. Robots having three linear axes of motion. The first axis of motion is horizontal linear motion to orient the column (base). The second axis is vertical being perpendicular to the first axis and involves vertical motion of the manipulator. The third axis is horizontal movement of the manipulator that is at a right angle to the perpendicular axis. The work envelope is a cube or rectangular solid.

A.9.2.2 Type II cylindrical. Robots having one rotary and two linear axes of motion. The first axis of motion is rotary in a horizontal plane providing rotary motion to the column. The second axis is vertical motion of the manipulator within the column and is perpendicular to the first axis. The third axis is horizontal movement of the manipulator and is at a right angle to the vertical axis. The work envelope is a cylinder. An additional axis can be provided for horizontal movement of the column (base).

A.9.2.3 Type III spherical. Robots having two rotary and one linear axis of motion. The first axis of motion is rotary in a horizontal plane and provides rotary motion to the column. The second axis of motion is rotary movement of the manipulator at the top of the column. The third axis is linear motion of the manipulator so as to increase or decrease the distance of the end effecter from the pivot on the column. The work envelope is spherical. An additional axis can be provided for horizontal movement of the column (base).

A.9.2.4 Type IV articulated (revolute jointed). Robots having three or more axes of rotary or linear motion. The first axis is rotary motion of the base in a horizontal plane. The second axis is rotary motion of first segment of the manipulator at the top of the base. The third axis provides rotary motion of the manipulator at the end of the manipulator segment. The joints and motions afforded by this configuration allows positioning that simulates movement of a human arm. An additional axis can be provided for horizontal movement of the column (base).

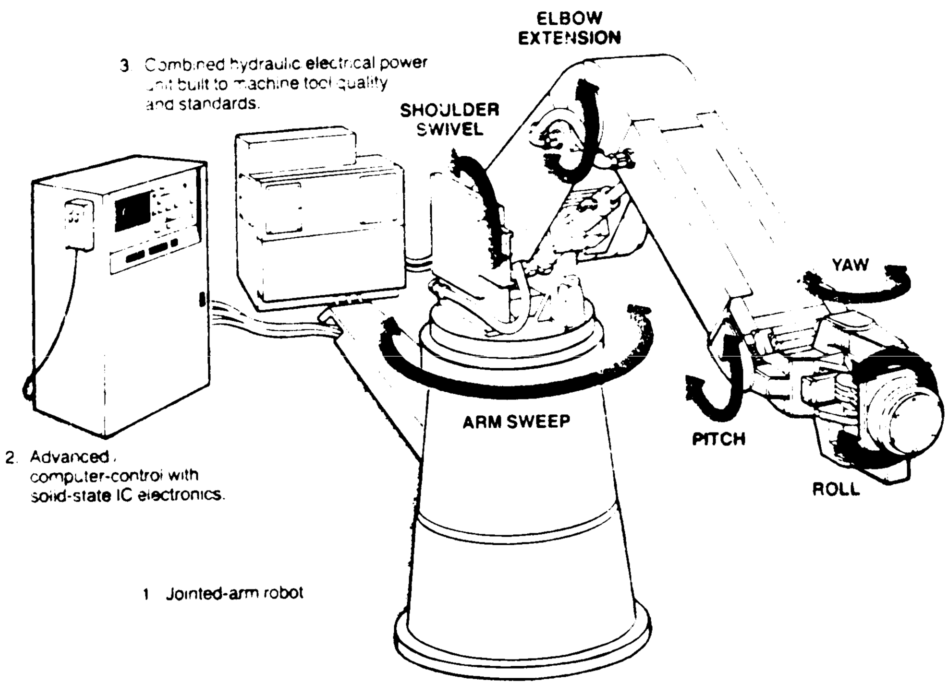


Figure A-31. Articulated Robot

A.9.2.5 Type V gantry. A robot provided within an elevated rectangular frame that provides a base for a cartesian, cylindrical, spherical or articulated robot and the necessary ways for longitudinal and transverse movement of the robot base. The base of the robot is oriented at the top of work envelope so that the robot mechanism is suspended down into the work envelope. Example of type: Type V (Gantry) with Type IV (Articulated).

A.9.2.6 Type VI panograph. A robot having three degrees of freedom. Standard axes include: the main arm axis (Theta 1) which rotates in the horizontal plane within a range of degrees; the forearm (Theta 2) which rotates horizontally, at the end of the main arm, through a range of degrees and a vertical (U) axis having specific linear motion capability. An additional axis can be provided for horizontal movement of the base.

ACKNOWLEDGEMENT: Photographs of machines in this appendix were used by permission of the manufacturers named in the caption accompanying the photographs. The Defense Industrial Plant Equipment Center gratefully appreciate the cooperation of the various manufacturers in making these photographs available.

DISCLAIMER: Products illustrated in this appendix may have important safety equipment removed or opened to clearly illustrate the product. Such safety equipment must be in place prior to operation. Reference herein to any specific commercial product, process or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement, recommendation or favoring by the United States Government or any agency thereof.

APPENDIX B

GROUP TECHNOLOGY
THE BASIS FOR HIGHER MANUFACTURING PRODUCTIVITY AND COMPUTER-AIDED MANUFACTURING

B.1 Scope. The industrial base activities within the DoD are challenged to improve the productivity of manufacturing in support of DoD maintenance or research and development. The most important challenge faced by the industrial base activities is to enhance the productivity of small lot manufacturing. Standardization was the enabling technique for mass production and standardization of a different nature is essential to improving productivity of batch production. Group technology standardizes produced parts on the basis of graphic classification which groups together parts of similar, shape, dimensions, technology and manufacturing process. Group technology thus establishes standardization which is one step towards reducing the time a workpiece spends in process. Mass production is not achieved by group technology but it enables the realization of mass production benefits in the batch production plant.

B.2 Referenced documents.

The Group Technology Concept Through Graphic Classification, Robert F. Guise, AMETA, Defense Computer-Aided Manufacturing Technique for Engineers

A Chain Structured Part Classification System (MICLASS) and Group Technology, Alexander Houtzeel, AMETA, Defense Computer-Aided Manufacturing Techniques for Engineers.

Group Technology Applications for Higher Manufacturing Productivity Professor Inyong Ham, November 1982 NC/CAM Workshop.

Group Technology, The Multi-Billion Dollar Revolution, Alexander Houtzell, October 1979 NC/CAM Workshop

Group Technology Characterization Code (GTCC), D. L. Norwood, T. H. Sparkman Vought Corporation, Integrated Computer-Aided Manufacturing (ICAM) Proceedings January 1982

GT Database - A Prerequisite For Flexible Manufacturing Systems Richard Fent and Michael J. Tracy, NC/CAD/CAM Numerical Control Society Proceedings 1981

GT Database - Prerequisite For Dynamic Standardization NC/CAD/CAM Numerical Control Society Proceedings 1981

B.3 Definition.

B.3.1 Group technology concept. Group technology is a manufacturing philosophy that exploits the premise that parts having the same shape or geometrical configuration are produced on the same machines in the same sequence of operations. The common approach to designatinq part families is to identify parts having the same shape; prismatic, cubic, rectangular or beam, flat, round cylinder, concave and convex cylinders and shafts. Each family when qualified by the range of size provides a basis for coding. Each family can be further divided as many times as necessary to reach subgroups that can be manufactured on the same machine using the same or similar tooling.

B.4 Background. In the attempt to solve industrial engineerinq problems and develop good engineering practices, manufacturing firms devised their own classification and coding systems, and have been using them in various areas such as design, materials, tools and manufacturing processes. In recent years the advancement of manufacturing technology has provided numerically controlled machines and computer aided systems for design and manufacturing that have the potential for improving the efficiency of all activities concerned with manufacturing. Coding of production parts systematically with one of the coding systems available provides a common basis for the interchange of part data between the dedicated computers in an integrated computer aided manufacturing system. The significance of shape coding on various organizations in an industrial base activity is shown in Figure B-1.

EFFECT OF SHAPE ON SEVERAL ORGANIZATIONS
OF AN INDUSTRIAL ACTIVITY

Function	Procure-ment	Engineering Design	Production Engineering	Manufac-turing	Equipment
Data	x	x	x	x	x
Main Shape	x	x	x	x	x
Type of Material	x	x	x	x	x
Rough Shape	x	-	x	x	x
Dimensions	x	x	x	x	x
Tolerance	x	-	x	x	x
Batch Size	x	-	x	x	x
Production Time	-	-	x	x	x

Table 1: Essentiality of part data to organizations for proper functioning

x = Information Required
\- = Information Not Required

Figure B-1

B.4.1 Classification and coding.

B.4.1.1 Formal parts coding. Formal parts coding in accordance with one of the commercially available systems or the system developed within the activity is absolutely essential to implementation of computer aided design (CAD)/computer aided manufacturing (CAM). Highly developed classification and coding systems, which are supported by computer software are commercially available. In may cases the standard commercial system requires modification to satisfy the user's requirements, in which case, the standard system serves as a guide for the generation of a detailed system to meet specific needs.

B.4.1.2 General purpose data base. The group technology part oriented data base serves to enable communication of part peculiar data in and between the functionally dedicated computer systems and the host or management control computer.

B.5 Benefits of Group Technology

B.5.1 Computer aided design. Design engineering benefits from the implementation of group technology when the opportunities afforded by the system are exploited. Advantages to the design engineer are:

a. Rapid design retreval
b. Avoidance of design redundancy
c. Better control of purchased items and materials

B.5.2 Numerically controlled manufacturing. Manufacturing accomplished on numerically controlled machines can be expected to benefit as follows:

a. Uniformity of process planning and execution.
b. Improved production scheduling and execution.
c. Reduced number of setups and setup time.
d. Reduced work-in-process inventory.
e. More manageable form of management information.
f. More predictable manufacturing cost.
g. Improvement ability to input and control rush orders.

B.6 DETAILED REQUIREMENTS

B.6.1 Coding process. Coding of the part, shown in Figure B-2, is accomplished in the following steps using a formal part coding system.

B.6.1.1 First digit. Form the major division code shown in Figure B-3 the first digit is determined to be "l" because the part is concentric, has no gear teeth or splinces and is not identifiable to another major division.

B.6.1.2 Second digit. The second digit designates the outside shape envelope of the part. The outside shape envelope for the part is multiple convex cylinder designated by "3".

B.6.1.3 Third digit. The third digit is determined by the center hole characteric. There is no center hole in the part being coded which is designated by l".

B.6.3.4 Forth digit. The presence or absence of holes other than the center hole is described by the fourth digit. From the chart bolt circle holes thereon are coded "8" as the fourth digit.

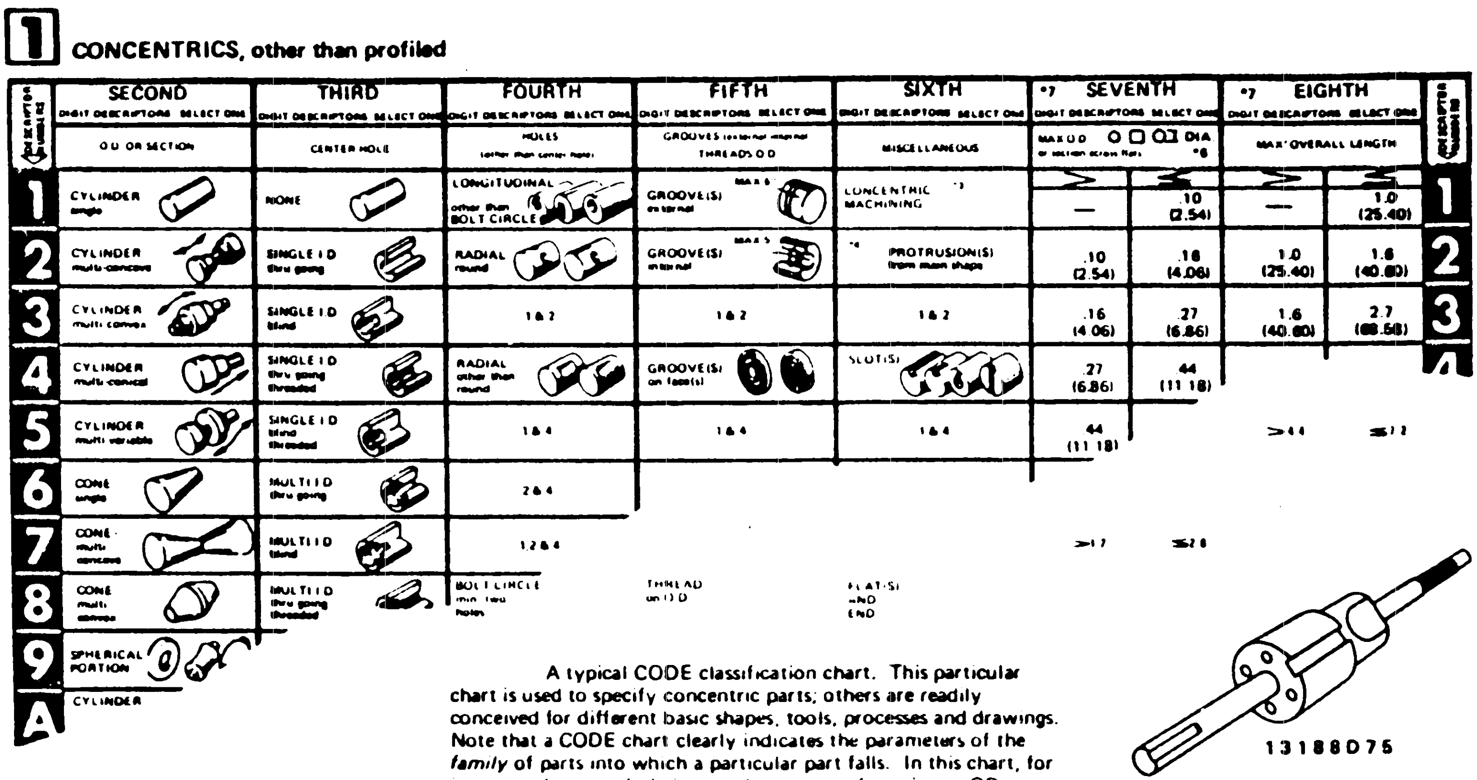
B.6.1.5 Fifth digit. Grooves external or internal and threads on the outside diameter determine the fifth digit. The threads on the outside diameter required an "8" as the fifth digit.

B.6.1.6 Sixth digit. The sixth digit covers miscellaneous physical charcteristics such as flats slots, protrusions from the main shape. The part has "1" concentric variations "4" slots and "8" flats. The alpha code "D" is descriptive of a part having these in combination.

B.6.1.7 Seventh digit. The maximum outside dimension determine the seventh digit. The part has a maximum outside dimension of 1.5 inches which falls between 1.2 and 2.0 inches and is described by "7".

B.6.1.8 Eight digit. Maximum length of the part is described by the eight digit. Lenght of the part is 5.7 inches which falls in the 4.4. to 7.0 inch range. The code that includes the actual length is "5".

B.6.1.9 Part code. The part coded in accordance with a formal coding system identifies as 13188D75.



A typical CODE classification chart. This particular chart is used to specify concentric parts; others are readily conceived for different basic shapes, tools, processes and drawings. Note that a CODE chart clearly indicates the parameters of the *family* of parts into which a particular part falls. In this chart, for instance, the seventh digit provides a range of maximum ODs, while the eighth gives a range of overall lengths.

Group Technology Concept

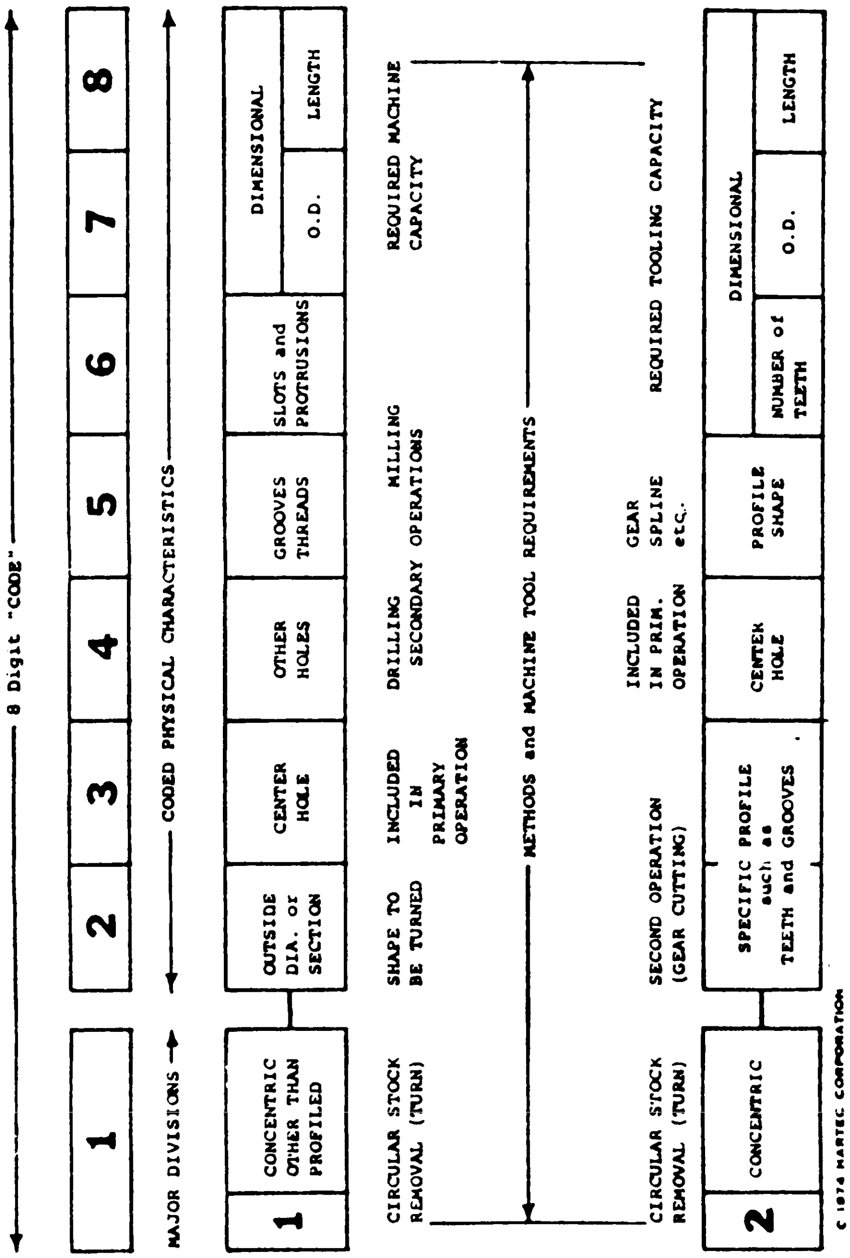


Figure B-3. Methods and Machine Tool Requirements CODE Categories 1 and 2.

APPENDIX C

JUSTIFICATION DOCUMENTS

C.1 Purpose. This Appendix provides guidance for seeking out and quantitativel-determining the direct and indirect labor costs identified to NC machines and relating these costs to line entries on the DD Form 1106. Computation procedures provided herein also apply to preparing the operating cost analysis in support of an economic analysis.

C.2 NC machine justification. The adequacy of the DD Form 1106 for justification of replacing conventional machines depends on the thorough analysis of the impact that the various sources of NC machine savings in paragraph 4.2, Chapter 4 have on cost values entered in the various lines on the DD Form 1106. The DD Form 1106 is supportable by a back-up document which organizes the rationale and computations supporting the entries for present and proposed equipment in lines 7 and 8.

C.2.1 Cycle-time comparison. Computation of the PIR in paragraph 3.3.3, Chapter 3 is based on production of identical size lots on conventional and NC equipment. The reduced set up and machine cycle times afforded by NC equipment make it feasible to produce small lots more frequently as a means of reducing the number of parts in inventory. This advantage is used by some production facilities to adopt the "produce just in time" concept and eliminate the inventory of back-up parts. Table C-1 recomputes the time value of NC production of smaller lots more frequently and provides a basis for recomputing the PIR.

Table C-1.

Cycle - Time Computation Conventional

Part No.	Cycle	Time Per Lot Size	Total Cycle	Total Lot	Lots Years	Total Year
VB-0670	1.80	3.5/20=0 1/5	1.975	39.500	12	474.00
HV-16198	3.60	4.7/10 = 0.470	4.070	40.700	6	244.20
PWP-01100	14.50	8.0/10 = 0.800	15.300	153.00	12	1836.00
GB-10221	17.50	5.5/5 = 1.100	18.600	93.00	12	1116.00
	37.4 hrs cycle time					
480 pieces	Total hours conventional machines					
		Numerically Controlled				
VB-0670	0.40	1.05/5 = 0.21	0.6100	3.050	48	146.40
HV-16198	1.20	1.25/5 = 0.25	1.4500	7.250	12	87.00
PWP-01100	2.50	2.00/5 = 0.40	2.9000	14.500	24	348.00
GB-10221	3.50	3.00/5 = 0.60	4.1000	20.500	12	246.00
	7.50hrs cycle time					827.40
480 pieces	Total hours numerically controlled					

The PIR is $\frac{3760.2}{827.40} = 4.54$

C.2.2 Direct labor. Data for Figures 3-6 and 3-7 is the basis for developing the computations for entry in block 7, DD Form 1106. The NC machine selected to replace the production of conventional machines is a horizontal spindle machining center having 26 inches of X-axis travel, 26 inches of Y-axis travel and 26 inches of Z-axis travel and a B-axis contouring table. It has a 45-position tool magazine, tool changer and a dual pallet work loading station. The acquisition cost of this machining center is $287,940.

C.2.3 Computation of direct labor savings. The Productivity Improvement Ratio for the machining center selected is 4.54 which was computed in paragraph C.2.l. This PIR computation takes into consideration the deteriorated condition of the conventional machines.

a. Conventional machine hours covered by the parts in in the total conventional machine workload.

3670 conventional hours ÷ 0.514 = 7140 Hours entry for line 7.a.a.

b. Required NC machine hours

$$\frac{7140 \text{ conve. mch hrs}}{4.54} = 1573 \text{ NC machine hours}$$

c. NC machine hours available, one shift 2000 hours
2000 hrs x production efficiency NC = 0.85 = 1700 hours available
1573 hrs entry for line 7.b.a. There are 127 excess hours available on the machine.

d. The direct labor rate is $13.50 per hour
Entry for block 7.a.b 7140 x $13.50 = $96390.00
Entry for block 7.b.b 1573 x $13.50 = $21235.50
Annual direct labor savings $75154.50

e. Conventional machines replaced by the NC machining center are sixteen years old. Deterioration of conventional machines requires that feeds and speeds be reduced and position readings be compensated to maintain required accuracy. The extent to which deterioration influences direct labor hours can be computed.

Replaced machines
2 Drilling machines, mfq G 1969
1 Boring machines, mfgA 1969
2 Milling machines, mfg P 1969
5 Conventional machines

These machines have deteriorated to a productivity of 80 percent. Equivalent hours on new conventional replacement machines.

7140 X 0.80 = 5712 hrs new conventional machines
7140 - 5712 = 1428 hours lost to deterioration
5712 - 1573 = 4139 hours due to productivity improvement
5567 hours total direct labor hour saving

The PIR for the NC machine compared to new conventional machines is

$$\frac{5712}{1573} = 3.63.$$

C.2.4 Indirect labor computation. Indirect labor is defined as the costs applicable to overhead expenses that include but need not be limited to administration, supervisor, inspection, janitorial services safety and training, shift premiums, bonuses, etc..

The ratio of indirect to direct labor is 1.06 to 1.
Indirect labor for present equipment line 7.c.a. is: $96390 x 1.06 = $102173

Indirect labor for proposed equipment, line 7.c.b. is:
$21235.50 X 1.06 = $22509.63

C.2.5 Fringe benefits computation. Expenses incurred by the employer to provide annual, sick holiday and military leave to employees, allowance for protective clothing, and contribution to medical and life insurance and retirement. This is expressed as a percentage of direct labor.

Fringe benefits percentage is 35.
Fringe benefits cost for present equipment line 7.d.a. is:
$96390 X 0.35 = $33376
Fringe benefits cost for proposed equipment line 7.d.b. is:
$21235.50 X 0.35 = $7432.43

C.2.6 Maintenance. Maintenance is defined as the estimated costs for maintenance and repair for the next 12 month period. It does not include costs for major overhaul or rebuilding. When major overhaul or rebuilding of present equipment is contemplated, it will be the subject of a complete analysis, comparing the present equipment, as is, against rebuilding it and further comparing the results of this analysis against procuring new equipment. Rebuild to like-new is considered to be a capital investment.

Labor, parts, services and material
Maintenance of present equipment shows that parts for the five machines cost $900
Labor factors Indirect labor (1) and fringe benefits (0.35) = 1.35.
Maintenance hours on five machines 780: Hourly rate $14.00
Labor 780 hr x $14 x 1.35 = $14742
Parts = $ 900
$15642 for line 7.e.a.
Maintenance for the new NC machine will average:
100 hours per year per shift
100 hr x $14 x 1.35 = $1890 for line 7.e.a.

C.2.7 Power. Power consumption is the product of horsepower of motors used on equipment x hours x conversion factor x cost per kilowatt hour.

Present

	Hours	Qnty Mach	Factor	HP	cost $lKWH	Total
Drill	1428 x	2 x	0.746 x	5 x	0.038	$404.81
Boring	1428 X	1 X	0.746 X	10 X	0.038	$404.81
Mill	1428 X	2 X	0.746 X	7.5 X	0.038	$607.21
	Entry for block 7.f.a					$14516.83

1416.83 ÷ 0.1984 = 0.1984 per hour

Proposed

	Hours	Motors	Factor	HP	cost $lKWH	Total
Spindle	1573	1 x	0.746 x	10 x	0.038	$445.91
Axis	1573	3 X	0.746 X	3.5 X	0.038	468.21
Table	1573	1 X	0.746 X	6.0 X	0.038	267.55
	Entry for line 7.f.b					$1181.67

$1181.67 ÷ 1573 = 0.7512 per hour

C.2.8 Scrap and rework. Scrap and rework chargeable to the present equipment due to human error is considered here. Computation requires use of the labor, machine time and material cost expended on:

a. Pieces produced 480 ÷ 0.514 work-mix portion = 934 pieces

b. Production cost at departmental rate conventional equipment

Direct Labor	$96390
Indirect Labor	102173
Fringe Benefits	33376
Labor Cost Manual	$231939

c. Machine Cost at Service life from Appendix 6A DLAM 4215.1.

	Qty	Cost New	Life	Life Hours	Dep Amt	Hourly	Weight
Drilling	2	$48,000	24yrs	48,000	43,200	0.90	0.40
Boring	1	$105,000	22 yrs	44,000	94,500	2.15	0.20
Milling	2	$85,000	19 yrs	38,000	76,500	2.01	0.40

Weighted Average Machine Cost
(0.40) X $0.90 + (0.10) X $2.15 + (0.40) X $2.01
$0.36+ $0.215 +0.804 = $1.379 hourly machine rate
Consumable tool cost from paragraph C.2.9.e: $1698 per hour
Hourly machine rate $3.077 per hour

d. Material Cost.

Part No.	Material	Weight	Dollar Value
VE-0670	$4.80	0.50	2.40
HV-16198	$11.20	0.125	1.40
PWP-01180	$4.00	0.250	1.00
GB-10221	$22.00	0.125	2.75

Weighed average material value: $7.55 per piece

e. $231939 ÷ 934 = $234.33 labor per piece

f. 7140 ÷ 934 = 7.64 machine hours per piece
Machine cost per piece $1.379 x 7.64 = $10.54

g. Scrap 2 percent at all material, one half labor and one half machine cost.

0.02 x 934 = 19 pieces scrap
19 [$7.55 +0.5 X $234.33 + 0.5 X $10.54] = $2470.00

h. Rework 1 percent of total piece
0.01 x 934 = 9 pieces
20 percent of labor cost = 0.2 x 234.33 = $46.87 per piece
9 x46.87 = $421.83 $421.83
Material welding rod, plugs fillers at 6.00 per piece is $54.00
Total $2945.83

i. Total scrap and rework for line 7.g.a. is $2904.
NC part program prove out and repeatability provides evidence that scrap and rework on NC produced parts will be eliminated.

C.2.9 Tooling. Tool and fixture savings identified to utilization of numerically controlled equipment are: (1) Avoidance of new conventional tooling procurement and (2) reduction in stocking, storing and issuing tooling. Numerically controlled machines under control of the part program influences a lower tool consumption cost in supporting the same production formally assigned to conventional machines. Numerically controlled machines require preset tooling which incurs a cost not elsewhere considered.

a. Fixture cost.

TABLE C-2

Tool and Fixture Costs

Part No.	NC Machine Fixture Cost	Conventional Fixture Cost
VB-0670	$1240	$1200
HV-16198	$2448	$9500
PWP-01100	$5880	$19000
GB-10221	$5295	$30150
Fixture Investment	$14855	$59850

b. Fixture maintenance cost. Data drawn from the experience of industrial facilities shows that tool maintenance cost is 24 percent of the total original cost of fixtures. Twenty percent of parts are replaced each year. New parts replace these and incur annual investment with is an operating cost.

		Conve.	NC
1.	Tooling Investment	$116439	$28900
2.	20% Replacement x Line 1	$23288	$5780
3.	80% Tool maintenance x 24 x Line 1	$22356	$5549
4.	Total Lines 2 + 3 Fixture replacement and maintenance	$45644	$11329

Savings on replacement and maintenance $34315 annually.

e. Consumable tool cost. A study of consumable tooling for conventional and numerically controlled equipment shows there is a close correlation between the dollar value of tools consumed the direct labor hours. Such a relationship yields a dollar value of tooling consumed per hour.

The dollar value for a conventional machine hour is less for an NC machine hours.

Table C-3
Dollar Cost Of Consumable Tooling

Machine	Conventional Dollars per Direct Hour	Numerically Controlled Dollars per Direct Hour
	$1.71	-
Horizontal Boring Mill	$1.23	$3.41
Drilling	$1.92	$4.08
Machining Center		$4.42

Conventional machine tooling cost:
Milling 0.40 x 1.71 = 0.684
Drilling 0.40 x 1.92 = 0.768
Boring 0.20 x 1.23 = 0.246
Weighted Average = $1.698 per direct hour
$1.698 X 7140 $12123.72
NC-Machining center: $4.42 x 1573 = 6952.66
Consumable tool savings $ 5171.06

d. Tool setting cost. Toolsetting cost actually exists on conventional machines and paid for at the machine rate when the operator sets depth stops and shims cutting tools. On NC machines this is done on a bench and could be considered set-up time.

Time for toolsetting was not including in the time value for NC machine set-up and is an offsetting cost against savings.

Toolsetting cost 0.25 hours per tool:

Part No.	Tools	Lots	Toolsetting Cycles	Time Cycle	Total
VB-0670	5	5	25	0.25	6.25
HV-16198	12	5	60	0.25	15.00
PWP-O11OO	6	5	30	0.25	25.00
GB-10221	20	5	100	0.25	25.00
Total Time Sample					53.75 hours

Total Time NC Workload: 53.7 ÷ 0.541 = 99.35 hours

Indirect Labor	= $1390.90
Fringe Benefits D.L. x 0.35	= $486.82
Total Toolsetting Cost	$1877.72

e. Part programming cost. Programming does exist for conventional machines which is in the Indirect labor seament of operating costs which includes planning, time standard estimating and fixture design. The standard time for machine cycle hour. The standard time for computer assisted programming is 7.5 hours per machine cycle hour. The standard time for manual NC part programming is 40 hours per machine cycle hour. NC programming is considered a tooling cost by most texts covering estimation for NC justification.

	Conv.	NC
Machine cycle time Table C-1	37.4	7.6
Total workload cycle time	72.8	14.8

37.4 ÷ 0.514 = 72.8 7.6 ÷ 0.514 = 14.8
7.5 X 72.8 = 546 hours conve. programming time
40 X 14.8 = 592 hours NC programming time

Only that part programming time for NC that exceeds conve. programming is a cost for entry on the DD Form 1106.

592
-546
46

46 x $15 hour labor x 1.35 (indirect labor = benefits) = $931.50

f. Entries for lines 7.h.a. and 7.h.b. for tooling.

	7.h.a.	7.h.b.
Fixture replacement and maintenance	$45644	$11329
Consumable tools	12124	6953
Tool setting cost	----	1878
Part programming exceeding indirect labor		932
Amount for entry DD Form 1106	$57768	$21092

C.2.10 Savings other operations, assembly.

a. Inspection cost. Parts produced on the conventional machines are high value parts that must fit other components upon final assembly. Due to the critical nature of these parts and the condition of the machines producing them they are inspected 100 percent.

Inspection time per piece average 0.10 hours each 934 pieces x 0.10 = 93.4 hours at $13.50 per hour 93.4 x $13.50 x 2.41 = $3039 inspection of conventional production.

Inspection of numerically controlled machine production is performed by the operator on one piece per lot. Workpieces are set on pallets. When machining is being accomplished on the operator inspects the piece just produced. Inspection is absorbed as part of the machine operation and eliminates inspection cost as such.

b. Secondary operations. Deburring, grinding, and reaming requires another 750 hours of set-up and machine operating time. NC production eliminates these operations.

Departmental Rate	$30.00	per hour
Material	2.00	per hour
Total	$32.00	

750 X 32.00 = $24,000 for secondary operations

c. Assembly. Line reaming and other manual work to fit pieces for assemblyes 100 hours on conventionally produced parts. Numerically controlled machining eliminates the necessity for these operations.

Department Rate = $28.00 per hour
100 X $28.00 = $2800 for assembly

Entry for line 7.i.a. $3039 + $24000 + 2800 = $29839

d. Other operations for NC. Parts are now being produced on two vertical spindle bed type millng machines and one turret head drilling machine. These three machines are productivity enhanced by having been fitted with digital readout systems. Utilization of digital readout system requires a minimum of jigs and fixtures and lots of the minimum quantity are produced. Converting this work now requiring 5100 hours on the conventional equipment would load a second shift of NC machining for the proposed equipment. The PIR of the proposed equipment is 3 in comparison to present equipment.

		Conve.		NC
Direct Labor	($13.50 x 5100)	$68850.00	($14.85 X 1700)	25245.00
Indirect Labor	D.L. X 1.06	$72981.00		26759.70
Fringe Benefit	D.L. X 0.35	$24097.50		8835.75
Total Labor		$165928.50		$60840.45

Maintenance	$5570.00		$1890.00
Power 10HP x 3 x 0.746 x 1700 x 0.038	$1445.75		$1277.02
Scrap and rework the same	None		None
I = $15000		I=4000	
Tooling Fixtures Repl I x 0.2	$3000		$800
Fixture holding cost 0.81 x 0.24	$2880		$768
Consumable Tooling	$8660		$7514
Tool Setting Cost			
142 Tools x 5 x 0.25 = 177.5 hours			
177.5 hours x $14 x 1.35			$3355
Part Programming Cost conv.			
128 hr x 7.5 = 960 hrs			
42.67 X 40 = 1706.8 1706.8 - 960 = 746.8			
746.8 X $15 X 1.35			$1522.70
Material handling 633.5 hr x $16	$10456	217.8 X $16	$3485
Inspection (reduced) 1307 pieces x $1.63	2130.41		
Secondary operations (reduced)			
$24000 x 1.4 piece ratio x 0.5 occurence	168000		
Assembly			
$2800 x 1.4 piece ratio 0.5 occurance	1960		
Total	$218930.66		$95052.17
Inventory savings 1.4 x $2267			(3174.00)
Total	$218930.66		$91878.17

Differential cost line 7.i.a $218930.66
-91878.17
7.i.a $127052.49

C.2.11 Other costs.

a. Inventory savings.

Part	Matl.	Set Up & cycle	Machine Rate Hour	Labor Rate Hour	Total cost Each	Lot	Total Inventory	Average Inventory
VB-0670	$4.80	1.975	$3077	$32.48	$75.03	20	$1500.60	$750.30
HV-16198	$11.20	4.070	$3.077	$32.48	$155.91	10	$1559.17	$779.58
PWP-01100	$4.00	15.300	$3.077	$32.48	$548.02	10	$5480.22	$2740.11
GB-10221	$22.00	18.600	$3.077	$32.48	$683.36	5	$3416.80	$1708.40
	Conventional Equipment Inventory						$11956.79	$5978.39

Machine rate from paragraph C.2.6.C

Part	Matl .	Set Up & Cycle Hours	Machine Rate Hour	Labor Rate Hour	Lot	Total Inventory	Average Inventory
VB-0670	$4.80	0.61	$12.44	$32.4 8	5	$161.01	$80.50
HV-16198	$11.20	1.45	$12.44	$32.48	5	$381.67	$190.84
PWP-01100	$4.00	2.90	$12.44	$32.48	5	$671.34	$335.67
GB-10221	$22.00	4.10	$12.44	$32.48	5	$1030.86	$514.43
	Numerical Control Equipment Inventory					$2242.88	$11232.44

Machine Rate NC Equipment

Basic machine	$241450
Accessories, hold down fixtures, tools	46490
Installation transportation & Misc.	21690
cost	$309630
Less disposal value of old equip.	37100
Net capital investment	$272530

Service life FSC 3408, Appendix 6B, Chapter 3, DLAM 4215.1: 10 years
1608 x 2 shifts = 3400 hours per year
$272530 ÷ 3400 X 10 = $8.02
Consumable tooling $4.42 per hour (see C.2.7.C)
Total machine rate $12.44 per hour

Workmix sample
Average inventory $5978.39 conven. - 1122.44 NC = $4855.95
$4855.95 ÷ 0.514 = $9447 Total workload inventory value reduction
Standard carrying expense for inventory 0.24
$9447 X 0.24 = $2267 Savings on inventory

b. Material handling.

Present equipment moves
1 move to machine material
2 moves between machines
1 move to secondary operations
1 move to inspection
1 move to inventory
6 moves x 934 pieces = 5604 moves ÷ 12 per hour = 467 hrs

NC equipment moves
1 move to NC machine (material from storage)
1 move to inventory
2 Moves x 934 = 1868 moves ÷ 12 per hour = 156 hrs
Departmental rate for trucking: $16 hour
467 - 156 = 311 hours saved x $16 = $4976
Entry for line 7.j.a. $2267 + 4976 = 7243

C.2.12 Capital cost analysis of proposed equipment.

Block 8.a. Acquisition cost $287940
Includes all attachments, accessories, universal tooling and hold down fixtures.

Block 8.b Installation, transportation and miscellaneous costs.

Transportation 1000 miles at $1.09 per mile	$1090.00
Installation-foundation, utilities, leveling	9000.00
Postprocessor	8000.00
NC program conversion	3600.00
	$2169000

Block 8.c. Total installed costs (8a plus 8b) $309636

Block 8.d. Present disposal value of present equipment

2 Milling machines new cost 85,000 x 0.10 x 2	$17000
1 Boring machine new cost 105,000 x 0.10	10500
2 Drilling machine new cost 48,000 x 0.10 x 2	9600
Total	$37100

Block 8.e. Net required investment 8.c. minus 8.d $272530

Block 8.f. Service life from Appendix 6B, Chapter 3, DLAM 4215.1

FSC 3408 Numerically Controlled, Traveling Table Shuttle pallets 10 years

Block 8.g. Chart percent from Appendix 6C, Chapter 3, DLAM 4215.1. 10 year percent is 20.

Block 8.h. Total capital cost 8.e x 8.h
$272530 X 0.20 $54506

Block 9. Next years savings from replacement (71 minus 8h) $343998

C.2.13 Amortization. block 8.e divided by block 7.1 provides the amortization period in years which is entered on the right side of DD Form 1106 in blank space below outline of the form.

$272530 ÷ $398504 = AMORTIZATION 0.7 Years

C.2.14 Sample DD Form 1106 used as justification for NC equipment.

INDUSTRIAL PLANT EQUIPMENT REPLACEMENT ANALYSIS WORKSHEET	ANALYSIS NUMBER 85-006 / DATE 1 June 1985	Form Approved Budgett Bureau No. 22-R179	
1. ACTIVITY: ABC Arsenal	2. LOCATION: Davenport, IA	3. SHOP: K	4. BUILDING NO.: 45

PRESENT EQUIPMENT	PROPOSED EQUIPMENT
a. DESCRIPTION: Milling Machine, Vert., Bed Type, Table 2; Boring Machine, Horiz., Table Type 1; Drilling Machine, Vert., Turret 2	b. DESCRIPTION: Machining Center, Horizontal Spindle, 10 HP pallet shuttle 2 positions, 45 tool magazine and tool changer, rotary milling table Travel X=26", Y=26", Z=26" B axis table
MANUFACTURER: See attached sheet; c. MODEL NO.: See attached sheet	b. MANUFTURER: XXXXXXXXXX; c. MODEL NO.: XXX
	D. PLANT EQUIPMENT CODE: XXXXXXXXXX
e. DEPARTMENTAL IDENTIFICATION NO.: See attached sheet; f. YEAR Built: ; g. TOTAL ACQuisition cost: 371,000; h. QUANTTITY: 5	e. QUANTITY: 1; F. PRODUCTITY INCREASE RATIO: 4.54:1

OPERATING COST ANALYSIS FOR EQUIVALENT OUTPUT (Next Year)

FACTOR		l. PRESENT EQUIPMENT	b. PROPOSED EQUIPMENT
a. MACHINE LOAD (Hours next year)		7140	1573
b. DIRECT LABOR	$13.50 Hr.	$ 96390	$ 21236
c. INDIRECT LABOR	106 percent DL	$ 102173	$ 22510
d. FRINGE BENEFITS	35 percent DL	$ 33376	$ 7432
e. MAINTENANCE		$ 15642	$ 1890
f. POWER		$ 1417	$ 1182
g. SCRAP/REWORK		$ 2946	$ ----
h. TOOLING		$ 57768	$ 21092
I.SAVING/OTHER OPERATIONS, ASSEMBLY	Other Oper. NC	$ 29839 127052	$
j. OTHER COSTS		$ 7243	$
k. TOTAL OPERATING COSTS		$ 473846	$ 75342
l. NET OPERATING COSTS FAVORING PROPOSED EQUIPMENT (k, col, minus k, col b) $		398504	

8. CAPITAL COST ANALYSIS OF PROPOSED EQUIPMENT (Next year)	
a. ACQUISITION COST	$ 287940
b. INSTALLATION, TRANSPORTATION AND MISCELLANEOUS COSTS	$ 21690
c. TOTAL INSTALLED COSTS (8a Plus 8b)	$ 309630
d. PRESENT DISPOSAL VALUE OF PRESENT EQUIPMENT	$ 37100
e. NET REQUIRED INVESTMENT (8c minus 8d)	$ 272530
f. SERVICE LIFE	10Years
g. CHART PERCENT	20%
h. TOTAL CAPITAL COST(8e x 8g)	$ 54506
9.NEXT YEARS SAVINGS FROM REPLACEMENT (7lminus 8h)	$ 343998

DD FORM 1 SEP 72 1106 REPLACES EDITION OF 1 JUN 70, WHICH MAY BE USED.

Amortization 0.7 years

C.3 Upgrading versus replacement.

C.3.1 Metalworking (MW) and selected IPE.

The comparison of three alternatives status quo (SQ) upgrade, and replacement) requires two DD Forms 1106. An example consisting of two DD Forms 1106 has been provided in this Appendix. Example 1 compares the present equipment versus rebuilding it. Example 2 compares present equipment with new replacement equipment. The analyst should submit only one DD Form 1106 (ordinarily the one showing the quicker amortization) and summarize (in the project justification) the analysis of the rejected alternative. This latter analysis should be filed in the project folder to be available at on-site reviews. Unlike the example, actual DD Forms 1106 should be supported with backup data.

b. In most situations, the status quo alternative is realistic since the machine could continue to do its job after the repair of a specific malfunction or other machines could be used as a backup but at the expense of cost or other penalties. However, in some cases the status quo alternative is not a viable option. Examples are fire damage, severe violation of OSHA/EPA rules, unavailability (due to downtime for repair) for production, etc. In these cases, use one DD Form 1106 to compare the alternatives of upgrade and replacement. The amortization period will shown the years required to amortize the incremental cost of a new machine over that of a rebuilt machine. An amortization period over 5 years (3.5 years for COCO) shows that rehab is preferred, since additional savings from a new machine would not amortize the incremental cost of a new machine. In the example provided, the amortization period is 12.17 years and rebuild would be the preferred course of action. Data supporting Example 3 is extracted from the back-up for Examples 1 and 2.

C.3.2 Non-metalworking IPE and non-IPE.

Essentially, this equipment consists of all the other equipment found in the Provision of Industrial Facilities and Depot Maintenance Plant Equipment projects. For them, the DD Form 1106 is not a practical or appropriate way of presenting cost-benefit considerations for decision-making. A proper comparison of the status, upgrade, and replacement alternatives rewires the thoughtful application of the entire spectrum of economic analysis (EA). The comprehensiveness of the analysis should be commensurate with the cost and complexity of the investment. Remember, formal EA’s are preferred for investments of over $200,000 and abbreviated forms of the EA’s for situations where the costs are less.

b. Typically, the project need only include the EAs or AEAs (i.e., summaries) that show the final outcome or comparison leading to the selection of the alternative of choice. The other analyses should be filed in the back-up folders by the installation and an explanation included in the justification as to why the other alternative(s) was rejected.

c. Usually, two abbreviated economic analyses (AEAs) or two EAs will provide the proper comparison when the status quo, upgrade, and replacement alternatives are being considered. One EA would compare the present equipment versus new equipment. A second EA would compare the present equipment to the upgrade option. The decision would be indicated by the comparison with the highest Savings/Investment Ratio.

d. When the status quo alternative is not applicable, two Format As should be prepared -- one for the upgrade option and one for the replacement or new equipment option. Each of the Format As will provide an indication of the life cycle cost (LCC) for the alternative. The alternative with the least Uniform Annual Cost (UAC) would be the preferred alternative.

C.3.3 Economic justification for the upgrading program. The following tabulation shows a breakout of the economic justificatlons that may be required when upgrading is among one of the alternatives. The following paragraph provides special instructions for adapting the DD Form 1106 to the Upgrade Program.

ECONOMIC JUSTIFICATION FOR THE UPGRADING PROGRAM

Equipment Category	SQ	Alternatives Upgrade	Replc	Economic Justification
1 MW and Selected IPE * * * * * * *	x	x	x	2 - DD Form 1106s
DD Form 1106 is required	--	x	x	1 - Special DD Form 1106
2 Non-MW and Non-IPE and Computer Aided Systems	x	x	x	2 - EAs * (S/I> 1) Format A1s or AEAs EAs or AEAs lowest UAC)
DD Form 1106 is not required or appropriate.	--	x	x	2 Format As
	(Special Situation)			None, if quick return on investment procedures apply or PECIP

C.3.4 Special instructions for the DD Form 1106.

C.3.4.1 Cases where the Status Quo (SQ) is an alternative.

Use two DD Form 1106s prepared in the usual way comparing each alternative to the status quo (see paragraphs C.3.5 and C.3.6).

b. For the upgrade alternative:

(1) Enter in line 6a. the level of upgrade. Example: Rehabilitate to 02 condition; rebuild to El; or remanufacture with retrofit.

(2) Enter in line 8.f. the increment in service life gained by upgrading. This increment varies depending on the level of effort. For example, about five year for rehabilitation, eight years for rebuild, and 10 years for remanufacture.

C.3.4.2 Cases where the Status Quo (SQ) is not an alternative.

Use one DD Form 1106 modified as indicated herein and referred to as a special DD Form 1106. The comparison being made is based upon the assumption that the on-hand equipment has been upgraded; it takes the place of the present equipment on the form. This allows the comparison of the upgraded item to a new item (see C.3.7).

b. Enter in line 5.a. the level or extent of upgrading.

c. Enter in line 6.a. the word "NEW".

d. In line 7.e., indicate the annual maintenance cost, including custom manufacture of replacement parts if necessary, of the present item after upgrading. Do not forget to include the maintenance cost for the new equipment.

e. Enter in line 8.a. the difference between the cost for the new item and the cost for upgrading the old one.

f. In line 8.b., show the cost difference for installation, transportation, etc., between the new and the upgraded equipment. It will be a negative figure if the costs are lower for the new item than for the upgraded one.

g. In line 8.d., show the current disposal value (prior to upgrade) of the item on-hand.

h. Do not complete lines 8.f., a, h, and 9, but be sure to include the amortization period for the incremental cost of the replacement item.

C.3.5 Example 1 - Status Quo vs. Upgrade

INDUSTRIAL PLANT EQUIPMENT REPLACEMENT ANALYSIS WORKSHEET	ANALYSIS NUMBER 85-012 DATE 1 July 1985	Form Approved Budget Bureau No. 22-R179	
ACTIVITY ABC Arsenal	Z. LOCATION ABC Arsenal Davenport, IA	3. SHOP M	4. BUILDING NO. 220

5. PRESENT EQUIPMENT				6. PROPOSED EQUIPMENT	
a. DESCRIPTION Machining Center, numerically controlled, 5 axis. 30 position tool magazine, 15 HP maximum spindle, horiz. spindle tilting rotary contouring table. X axis-44", Y axis-44", z axis-32", pallet shuttle				1. DESCRIPTION Same machine rebuilt to new machine tolerances and retrofitted with 20 HP DC spindle motor, DC servo motors, down sized hydraulic system. New machine capability and life expectancy.	
MANUFACTURER Kearney & Tracker Corporation		c. MODEL NO. Milwaukee-matic III		b. MANUFACTURER Kearney & Trecker Corporation	c. MODEL NO. Milwaukee-matic III
t. PLANT EQUIPMENT CODE				d. PLANT EQUIPMENT CODE	
DEPARTMENTAL IDENTIFICATION NO XXXX	f. YEAR BUILT XX	g. TOTAL ACQUISITION COST $XXXXX	h. QUANTITY 1	e. QUANTITY 1	f. PRODUCTIVITY INCREASE RATIO 1.155:1

OPERATING COST ANALYSIS FOR EQUIVALENT OUTPUT (Next Year)

FACTOR		a. PRESENT EQUIPMENT	b. PROPOSED EQUIPMENT
MACHINE LOAD *(Hours next year)*		3100	2686
b. DIRECT LABOR		$ 43942.50	$ 37574
c. INDIRECT LABOR	1.06 DL	$ 46579.05	$ 39828
d. FRINGE BENEFITS	0.35 DL	$ 15379.88	$ 13151
e. MAINTENANCE		$ 13434.20	$ 6049
f. POWER		$ 6151.51	$ 3845
g. SCRAP/REWORK		$	$
h. TOOLING		$ 25462	$ 25235
I. SAVINGS/OTHER OPERATIONS, ASSEMBLY		$ 32578	$
j. OTHER COSTS		$ 52255	$
k. TOTAL OPERATING COSTS		$ 235782	$ 125682

1. NET OPERATING COSTS FAVORING PROPOSED EQUIPMENT (k, col, minus k, COl *b)* 110100

8. CAPITAL COST ANALYSIS OF PROPOSED EQUIPMENT (Next Year)

a. ACQUISITION COST	Rebuild and retrofit	$ 372000
b. INSTALLATION, TRANSPORTATION AND Miscellaneous COSTS		$ 17600
C. TOTAL INSTALLED COSTS (8a Plus 8b)		$ 89600
d. PRESENT DISPOSAL VALUE OF PRESENT EQUIPMENT	Not applicable	$
e. NET REQUIRED INVESTMENT (8d minus *8d)*		$ 389600
f. SERVICE LIFE		10 Years
g. CHART PERCENT		20 %
h. TOTAL CAPITAL COST (8e x8g)		$ 77920
9. NEXT YEARS SAVINGS FROM REPLACEMENT *(71 minus 8h)*		$ 32180

DD FORM 1 SEP 72 1106 REPLACES EDITION OF 1 JUN 70, WHICH MAY BE USED.

Amortization 3.54 years

BACKUP FOR ANALYSIS NUMBER 85-012

1. Item 6.f.

a. Productivity Improvement Ratio of the upgraded machining center:

The rebuild and retrofit of this machine will include installation of a 20 HP DC spindle motor having a speed range of 20 to 2000 RPM. The spindle will provide 15 HP at 112 RPM and 20 HP at speeds above 154 RPM.

	Original Spindle		Retrofitted Spindle		Change
RPM		HP	HP	HP	%
50	6	0.1200	6.7	0.1340	+11.67
190	15	0.0780	20	0.1050	+34.62
200	10	0.0500	20	0.1000	+100.00
490	15	0.0306	20	0.0408	33.33
500	6	0.0120	20	0.0400	233.33
2000	15	0.0075	20	0.0100	33.33

b. The part programmer has determined that 80 percent of the feeds and speeds on representative parts can be increased at least 20-30 percent so as to reduce machine cycle time per part by 20 percent.

0.80 X 0.20 = 0.16 increase in metal removal rate

Each hour of machine cycle time is reduced to 0.84 hour.

Impact of increased metal removal rate:
83.8 percent of available machine time is machine cycle time on the present equipment.

0.838 X 0.84 = 0.704 hour of time on proposed equipment replaces 0.838 hour on present equipment. The set-up time averages 0.162 hours per piece.

The PIR for the rebuilt and retrofitted machine is 1 ÷ (0.162 +0.704) = 1 ÷ 0.866 = 1.155

2. Item 7.b. Direct Labor

a. Status Quo

First Shift $13.50 x 1550 hours	$20925
Second Shift $14.85 x 1550 hours	$23017.50
Total Direct Labor	$43942.50

b. Rebuilt Machine PIR 1.155

First Shift $13.50 x 1343	$18130.50
Second Shift $14.85 x 1343	$19943.55
Total Direct Labor	$37574.05

3. Item 7.c. Indirect Labor

a. Status Quo
$43942.50 X 1.06 — $46579.05

b. Rebuilt machine
$37574 X 1.06 — $39828.44

4. Item 7.d. Fringe Benefits

a. Status Quo
$43942.50 X 0.35 — $15379.88

b. Rebuilt Machine
$37574 x 0.35 — $13150.90

5. Item 7.e. Maintenance

a. Preventative Maintenance Scheduled Conve. or NC
15 hours per month x 12 = 180 hours per year per shift conve.
17 hours per month x 12 = 204 hours per year per shift NC
Labor rate $13.90 per hour overhead, Indirect

Cost for Status Quo or Rebuilt Machine

180 hours x $13.90 x 1.35 = $3377.70 for 1700 math hours
$1.986 hr.
204 hours x $13.90 x 1.35 = $3828.06 for 1700 math hours
$2.252 hr.
3100 math hours x $2.252 = $6981.20 Status quo.
2686 math hours x $2.252 = $6049 Rebuilt

b. Past year maintenance Status Quo Repair

Repair	200 hours
$13.90 X 200 X 1.35 =	$3753.00
Parts	$2700.00
Total Repair	$6453.00

6. Item 7.f Power

a. Status Quo
55 HP X 0.746 X 3100 X 0.038 = $4833.33
15 HP x 0.746 X 3100 x 0.038 = $1318.18
Total Power Status Quo $6151.51

b. Rebuilt Machine

20 HP X 0.746 x 2686 X 0.038 =	$1522.85
20 HP X 0.746 X 2686 X 0.038 =	$1522.85
10.5 HP X 0.746 X 2500 x 0.038 =	799.49
Total Power Rebuilt Machine	$3845.19

$3578.94 ÷ 2500 $1.4316 per hr.

7. Item 7.g. Scrap/Rework

a. Scrap and rework due to production on conventional machines during the past year resulted in scrapping 18 pieces.

Average labor on each scrapped piece was 0.926 hours
Factor Direct Labor (1) + Indirect Labor (1.06)
+ Fringe Benefits (0.35) = 2.41
cost = 18 piece x 0.926 hr x $12.50 hour x 2.41 = $502.12

The average machine time spent on each piece scrapped was 0.85 hour.
Hourly Department Rate $45.10
18 X 0.85 X $45.10 = $690.03
Total cost of Scrap $1192.15

b. Rework. Rework was required on 56 pieces. The following average cost per piece was incurred.

Transportation and handling	$0.25
Welding	$3.27
Remachining 0.131 hr x 45.10	$5.91
Total cost per piece	$9.43

Rework 56 x 9.43 = $528.08 used in item 7.i.

8. Item 7.h. Tooling

a. Consumable Tooling
1. Status Quo Consumable
3100 X $4.42 per hour $13702

2. Rebuilt Machine Consumable
2686 x $4.42 per hour $11872

b. Fixtures	Status Quo	Rebuilt
1. Investment	$30000	$34320
2. Tooling Replacement 20 percent annual	$6000	$6864
3. Tool Holding Cost Invest. x 0.8 x 0.24	$5760	$ 6589
Total Cost (2+3)	$11760	$13453
c. Entry for 7.h	$25462	$25235

9. Item 7.i. Savings/Other operations assembly.

a. The repair on the present equipment caused it to be out of production for 300 hours. Conventional machines were used to produce parts that had been assigned for NC production. Conventional machining required 1050 hours to replace the 300 hours of lost production time onn present equipment. The PIR of present equipment in relation to the conventional machines used to compensate capacity is 3.5 to 1. The rebuilt machine has a PIR of (3.5 x 1.155) = 4.04:1 in comparison to the utilized conventional machines.

b. The impact of utilizing conventional machines on cost. The differential cost between conventional and rebuilt machine production is an expense chargeable to Status Quo.

	Conven. 1050 hr ÷ 4.04		Rebuilt NC 260 hr
Direct Labor $13.50 hr.	$14175		$3510.00
Indirect Labor 1.06 D.L.	$15025.50		$3720.60
Fringe Benefits 0.35 D.L.	$4961.25		$1228.50
Total Labor	$34161.75		$8459.10
Maintenance 1050 x 1.987	$2086.35	260 hr x $2.252	$585.52
Power 20 x 0.746 x 1050 x $0.038	$595.31	260hr x $1.4315	$372.21
Scrap/Rework	$1720.23		
Tooling			
1. Fixture Investment (I)	$17280.00		$4320.00
2. Fixture replacement 0.20 x I	$3456.20		$864.00
3. Fixture holding cost 0.8 I x 0.24	$3317.76		$829.44
Fixture cost 2 + 3	$6773.96		$1693.44
Consumable tooling 1050 hr x $1.698	$1782.90	260 hr x $4.42	$1609.64
Toolsetting Cost NC			
30 Tools x 12 Lots x 0.25 - 90 hrs			
90 x $15 x 1.35			$1822.50
Part program cost	programmed		*
Total	$47120.50		$14542.41
	-14542.41		
Different Cost	$32578.09	Entry for Item 7.i.a.	

* Part programs converted - part of item 8.b.

10. Item 7.k. other operating costs.

For the purpose of estimating the savings from new work transferred from conventional to NC production a cost of $45.62 per hour for conventional machining and $47.79 per hour for NC machining is applied.

Analysis 85-006
$558402 ÷ 12240 = $45.62

From Status Quo Vs Ungrade 2500 NC hours cost $125682
$125682 ÷ 2686 = $47.79 per hour for NC

Savings from new NC work transferrable

Total capacity of replaced NC	3400 hrs
Machine load of productivity enhanced	
Machining center 2686 + 260	2946 hrs
Available for new NC work	454 hrs

454 x 4.043 = 1633 conventional hrs
Savings 1633 x 45.62 = $74497.46
454 x $46.79 -21242.66
Entry for 7.k. $522254.80 Different cost

11. Item 8.a. Acquisition cost of Rebuild and Retrofit $372000

12. Item 8.b. Installation, transportation Misc.

Transportation 2000 miles at $11.10 mile	$2200
Installation alignment and test	$2800
New postprocessor	$9000
Part program conversions	$3600
	$17600

13. Item 8.c. Total Installed Cost $389600

14. Item 8.d. Disposal Value (Reutilized) ______

15. Item 8.e. Net Required Investment $389600

16. Item 8.f. Service Life Appendix 6B, Chapter 3, DLAM 4215.1 FSC 3408 10 years

17. Item 8.g. Chart Percent Appendix 6c, Chapter 3, DLAM 4215.1 20%

18. Item 8.h. Total Capital Cost 8.e x 8.q $77920

19. Item 9 Next Years Savings From Replacement 7.1. minus 8.h $32180

20. Amortization $389600 ÷ $110100 3.54 years

C.3.6 Example 2 - Status Quo vs. Replacement

MACHINE TOOL REPLACEMENT ANALYSIS WORK SHEET	ANALYSIS NUMBER 85-013 DATE 1 July 1985	Form Approved Budget Bureau No. 22-R179

1. ACTIVITY	2. LOCATION	3. SHOP	4. BUILDING NO.
ABC Arsenal	ABC Arsenal Davenport, IA	M	220

5. PRESENT EQUIPMENT	6. PROPOSED EQUIPMENT
a. DESCRIPTION Machining Center, numerically controlled, 5 axis, 30 position tool magazine, 15 HP maximum spindle, horiz. spindle, tilting rotary contouring table. X axis 44", Y axis 44", Z axis 32", pallet shuttle A&B axis	a. DESCRIPTION Machining Center, numerically controlled, 5 axis, 49 position tool magazine, 25 HP spindle, horiz. spindle. Tilting rotary contouring table. X axis 72", Y axis 60" Z axis 30" & A&B rotary axes. Pallet shuttle new
b. MANUFACTURER: Kearney & Trecker c. MODEL NO.: Milwaukee-matic III	b. MANUFACTURER: Kearney & Trecker c. MODEL NO.: Moduline 7260
d. PRODUCTION EQUIPMENT CODE	d. PRODUCTION EQUIPMENT CODE
e. DEPARTMENTAL IDENTIFICATION NO. / f. YEAR BUILT / g. TOTAL ACQUISITION COST / h. QUANTITY	e. QUANTITY: 1 f. PRODUCTIVITY INCREASE RATIO: 1.37 : 1

7. OPERATING COST ANALYSIS FOR EQUIVALENT OUTPUT *(Next Year)*

FACTOR		a. PRESENT EQUIPMENT	b. PROPOSED EQUIPMENT
a. MACHINE LOAD *(Hours next year)*		3100	2262
b. DIRECT LABOR	$13.50 $14.85	$ 43942.50	$ 32063.85
c. INDIRECT LABOR	1.06 DL	$ 46579.05	$ 33987.68
d. FRINGE BENEFITS	0.35 DL	$ 15379.88	$ 11222.35
e. MAINTENANCE		$ 13434.20	$ 5094.02
f. POWER		$ 6151.51	$ 3971.70
g. SCRAP/REWORK		$	$
h. TOOLING		$ 25462	$ 25958
i. SAVINGS/OTHER OPERATIONS, ASSEMBLY	NC work on conv. mach.	$ 34642	$
j. OTHER COSTS	Conventional work transferrable to proposed equipment	$ 64746	$
k. TOTAL OPERATING COSTS		$ 250337	$ 112297.60
l. NET OPERATING COSTS FAVORING PROPOSED EQUIPMENT *(k, col a, minus k, col b)*		$ 138039	

8. CAPITAL COST ANALYSIS OF PROPOSED EQUIPMENT *(Next Year)*

a. ACQUISITION COST	$ 675000
b. INSTALLATION, TRANSPORTATION AND MISCELLANEOUS COSTS	$ 19930
c. TOTAL INSTALLED COSTS *(8a plus 8b)*	$ 694930
d. PRESENT DISPOSAL VALUE OF PRESENT EQUIPMENT	$ 90000
e. NET REQUIRED INVESTMENT *(8c minus 8d)*	$ 604930
f. SERVICE LIFE	10 Years
g. CHART PERCENT	20 %
h. TOTAL CAPITAL COST *(8e x 8g)*	$ 120986
9. NEXT YEARS SAVINGS FROM REPLACEMENT *(7l minus 8h)*	$ 17053

DD FORM 1 JUN 70 1106 REPLACES EDITION OF 1 AUG 57, WHICH MAY BE USED. S/N 0102-010-7601 B-1150 PLATE NO. 12133

Amortization 4.34 years

BACKUP DATA FOR DD FORM 1106

ANALYSIS NUMBER 85-013

1. The proposed equipment is a new MilwaukeeMatic Moduline Model 7260 5-axis machining center with a 25 HP spindle motor, X-axis travel 72", Y-axis travel 60", Z-axis travel 30", and a rotary contouring table, A-axis rotation around X-axis; and B-axis rotation around Y axis. Equipped with 49 tool capacity storage and automatic tool changer. The acquisition cost of the basic machine is $675,000. Tool welders used on the existing MilwaukeeMatic III can be used on the proposed equipment.

2. Item 6.f. Productivity Increase Ratio (PIR).

The proposed equipment has a 25 HP spindle and a 49-position tool magazine. More spindle horsepower faster traverse rates and the availability of l9 more tools in the tool changer make the proposed equipment 1.37 times more productive than the existing machining center on the work presently assigned thereto and considered for transfer to the proposed equipment. Entry for item 6.f. is 1.37.

3. Item 7a. Machine Load.

a. In the past 12 months 120 jobs were performed on the existing machining center in 3100 hours. The performance of maintenance and time the machine was down for repairs reduced available machine time by 300 hours. Downtime made it necessary for the shop to use 1050 hours of conventional machine time to produce parts programmed for NC production.

b. The machine load for the proposed equipment is for performance of the actual work now being served by the existing machining center.

1300 hours ÷ 1.37 = 2263 hours

4. Item 7.b. Direct Labor.

a. Status Quo.

First Shift $13.50 x 1550 hours	$20925.00
Second Shift $14.85 x 1550 hours	$23017.50
Total Direct Labor	$43942.50

b. Replacement machine PIR 1.37.

First Shift $13.50 x 1131	$15268.50
Second Shift $14.85 x 1131	$16795.35
Total Direct Labor	$32063.85

5. Item 7.c. Indirect Labor

a. Status Quo
$43942.50 X 1.06 — $46579.05

b. Replacement Machine
$32063.85 X 1.06 — $33987.68

6. Item 7.d. Fringe Benefits

a. Status Quo
$43942.50 x 0.35 — $15379.88

b. Replacement Machine
$32063.85 X 0.35 — $11222.35

7. Item 7.e. Maintenance

a. Preventative Maintenance Scheduled Conv./or NC
15 hours per month x 12 = 180 hours per year per shift conve.
17 hours per month x 12 = 204 hours per year per shift NC
Labor rate $13.90 per hour Overhead, Indirect

Cost for Status Quo or Replacement Machine

180 hours x $13.90 x 1.35 = $3377.70 ÷ 1700 = $1.987 per mch hour
(204 x 2) x $13.90 x 1.35 = $7656.12 ÷ 3400 = $2.252 per mch hour

b. Past years maintenance Status Quo Repair
Repair 200 Hours
$13.90 X 200 X 1.35 = $3753.00
Parts = $2700.00
Total Repair $6453.00
Used in Item 7.i.

8. Item 7.f. Power

a. Status Quo
55 HP X 0.746 X 3100 X $0.038 = $4833.33
15 HP X 0.746 X 3100 X $0.038 = $1318.18
Total Power Status Quo $6453.00

b. Replacement Machine
25 HP X 0.746 X 2314 X $0.038 = $1639.93
20 HP X 0.746 X 2314 X $0.038 = $1544.60
12 HP X 0.746 X 2314 X $0.038 = $787.17
Total Power Replacement Machine $3971.70
3971.70 ÷ 2314 = $1.7164 per hour

9. Item 7.g. Scrap/Rework

a. Scrap and rework due to production on conventional machines during the past year resulted is scrapping 18 pieces.

Average labor on each scrapped piece 0.926 hours
Factor Direct Labor (1) + Indirect Labor (1.06)
+ Fringe Benefits (0.35) = 2.41
cost = 18 piece x 0.926 hr x $12.50 hour x 2.41 = $502.12

The average machine time spent on each piece scrapped was 0.85 hour.
Hourly Department Rate $45.10
18 x 0.85 x $45.10 = $690.03
Total cost of Scrap and Rework $1192.15

b. Rework. Rework was required on 56 pieces. The following average cost per piece was incurred.

Transportation and handling	$0.25
Welding	$3.27
Remachining 0.131 hr x 45.10	$5.91
Total Cost per piece	$9.43

Rework 56 x 9.43 = $528.08 used in item 7.i.

10. Item 7.h. Tooling.

a. Consumable tooling

1. Status Quo Consumable
3100 x $4.42 per hour $13702.00

2. Replacement Machine
2314 x 4.42 per hour $10277.88

b. Fixtures.	Status Quo	Replacement
1. Investment	$30000	$40000
20 percent		
2. Tooling Replacement Annual	$6000	$8000
3. Tool Holding Cost Investment x 0.80 retained x 0.42	$5760	$ 7680
Total Cost (2 + c)	$11760	$15680
c. Entry for 7.h.	$25462	$25958

11. Item 7.i Savings/Other Operations Assembly

a. The repair on the present machine caused it to be out of production for 300 hours. Conventional machines were used to produce parts that had been produced on the machining center. Conventional machining required 1050 hours to replace NC production time.

b. The impact of using conventional machines on parts programed for NC production:

	Conventional	Replacement
	1050 Hr ÷ 4.795	219 Hr
Direct Labor $13.50	$1475.00	$2956.50
Indirect Labor DL x 1.06	$15025.50	$3133.89
Fringe Benefits 0.35 x DL	$4961.25	$1034.78
Total Labor	$34161.75	$7125.17
By the hour		
Maintenance Preventative	$2086.35	$ 493.18
1050 X $1.98 219 X $2.252		
Power		
20 HP X 0.746 X 1050 X $0.038	(219 x $1.7164)	$ 375.89
Conv. Machines	$ 595.31	
Scrap/Rework	$1720.23	
Tooling Consumable (1050 x $1.698	$1782.90 219 x $4.42	$ 967.98
Investment (conv $17280) (NC $4320)		
Fixture Replacement Cost 20%	$3456.20	$864.00
Fixture Holding Cost Invest x 80% x 0.24	$3317.76	$829.44
Toolsetting cost		
30 Tools x 12 Lots x 0.25=90 hours		
90 x $15 x 1.35		$1822.50
Part programming cost		Converted Part of Item 8.b.
Total Cost	$47120.50	$12478.16

The differential cost, $47120.50 minus $12478.16 = $34642.34 is the entry for Item 7.i Present Equipment.

12. Item 7.j. Other Operating Costs

For the purpose of estimating the savings from new work transferrable to the proposed equipment due to available hours, conventional machining is priced at $45.62 per hour and NC machining is changed at $49.64 per hour.

From Analysis 85-006

12240 hours conventional machine cost $558482

$558482 ÷ 12240= $45.62 per hour conv.

From Status Quo Vs Replacement

2262 NC hours cost $112297.60

$112297.60 ÷ 2262 = $49.64 per hour NC

Proposed Equipment

Hours present NC production	2262 hours
Hours for parts on conv. machine	219 hours
455 ÷ 1.186 Conventional Machine work	383 hours
	2974 hours

NC Work

383 x 3.5 (PIR existing equip.) x 1.37 PIR proposed equipment = 1836 hours of conventional machine time

Differential Cost

1836 X $45.62 = $83758.32
595 X $49.64 = -19012.12
Differential Cost $64746.20 Entry for 7.j.a.

13. Item 8a. Acquisition Cost. $675000

14. Item 8.b Installation Transportation and Miscellaneous Costs.

Transportation 300 miles at $1.10 mile	$ 330.00
Foundation	$4000.00
Installation Alignment and Test	$3000.00
New postprocessor	$9000.00
Part program conversions	$3600.00
Total 8.b. costs	$19930.00

15. Item 8.c. Total Installed Costs. $694930

16. Item 8.d. Present Disposal Value. $90000

17. Item 8.e. Net Required Investment $604930

17. Item 8.f. Service Life Appendix 6B, Chapter 3 DLAM 4215.1 FSC 3408. 10 years

18. Item 8.g. Chart percent Appendix 6C, Chapter 3 DLAM 4215.1. 20%

19. Item 8.h. Total Capital Cost 8.e x 8.q. $120986

20• Item 9 Next Years Savings From Replacement (7.1 minus 8.h). $17053

22. Amortization $604930 ÷ 138039 4.38 years

C.3.7 Example 3 - Upgrade vs. Replacement

INDUSTRIAL PLANT EQUIPMENT REPLACEMENT ANALYSIS WORKSHEET	ANALYSIS NUMBER 85-014 DATE 1 July 1985	Form Approved Budget Bureau No. 22-R179

1. ACTIVITY	2. LOCATION	3. SHOP	4. BUILDING NO.
ABC Arsenal	ABC Arsenal Davenport, IA	M	202

5. PRESENT EQUIPMENT	6. PROPOSED EQUIPMENT
a. DESCRIPTION Machining Center, numerically controlled, 5 axis, 30 position tool magazine, 20 HP spindle, horiz. spindle, tilting rotary contouring table, X axis 44", Y axis 44", Z axis 32" with A&B axes, pallet shuttle	a. DESCRIPTION Machining Center, numerically controlled, 5 axis, 49 position tool magazine, 25 HP spindle, horiz. spindle, tilting rotary contouring table. X axis 72", Y axis 60", Z axis 30" with rotary A&B axes & pallet shuttle - NEW
b. MANUFACTURER Kearney & Trecker Corporation Rebuilt & retrofitted-new cond. — c. MODEL NO. Milwaukee-matic III	b. MANUFACTURER Kearney & Trecker Corporation — c. MODEL NO. Moduline 7260
d. PLANT EQUIPMENT CODE	d. PLANT EQUIPMENT CODE
e. DEPARTMENTAL IDENTIFICATION NO. — f. YEAR BUILT — g. TOTAL ACQUISITION COST — h. QUANTITY	e. QUANTITY — f. PRODUCTIVITY INCREASE RATIO 1.186:1

7. OPERATING COST ANALYSIS FOR EQUIVALENT OUTPUT *(Next Year)*

FACTOR	a. PRESENT EQUIPMENT	b. PROPOSED EQUIPMENT
a. MACHINE LOAD *(Hours next year)*	2686	2262
b. DIRECT LABOR	$ 37574	$ 32064
c. INDIRECT LABOR	$ 39828	$ 33988
d. FRINGE BENEFITS	$ 13151	$ 11222
e. MAINTENANCE	$ 6049	$ 5094
f. POWER	$ 3845	$ 3972
g. SCRAP/REWORK	$	$
h. TOOLING	$ 25235	$ 25958
i. SAVINGS/OTHER OPERATIONS, ASSEMBLY NC work on conv. mach.	$ 14542	$ 12478
j. OTHER COSTS	$ 21243	$ 19012
k. *TOTAL OPERATING COSTS*	$ 161467	$ 143788
l. NET OPERATING COSTS FAVORING PROPOSED EQUIPMENT *(k, col a, minus k, col b)*	$ 17679	

8. CAPITAL COST ANALYSIS OF PROPOSED EQUIPMENT *(Next Year)*

a. ACQUISITION COST $675000 - 372000	$	303000
b. INSTALLATION, TRANSPORTATION AND MISCELLANEOUS COSTS 19930-17600	$	2330
c. TOTAL INSTALLED COSTS *(8a plus 8b)*	$	305330
d. PRESENT DISPOSAL VALUE OF PRESENT EQUIPMENT	$	90000
e. NET REQUIRED INVESTMENT *(8c minus 8d)*	$	215330
f. SERVICE LIFE		NA Years
g. CHART PERCENT		NA %
h. *TOTAL CAPITAL COST (8e x 8g)*	$	NA
9. NEXT YEARS SAVINGS FROM REPLACEMENT *(7l minus 8h)*	$	NA

DD FORM 1 SEP 72 1106 — REPLACES EDITION OF 1 JUN 70, WHICH MAY BE USED.

Amortization 12.17 years

C.4 Economic analysis formats. Computer aided design or manufacturing and other productivity enhancling projects may require any or all of several forms of economic analysis for support. The following discussion will include nomenclature from DoDI 7041.3. Figures C-1, C-2, and C-3 correspond to Formats B, A, and A-1, respectively, in the DoDI.

C.4.1 Format B. Format B is used to summarize quantifiable and non-quantifiable outputs, benefits, effectiveness, and performance. The main purpose of this summary is to identify and describe the benefit, output, or effectiveness implications of resource allocation decisions which must be provided in sufficient detail to permit a comparison of alternatives. It can be used as justification for alternatives costing above or below the $200,000 threshold. The value of the Format B rest with how strong and complete a case it presents in support of the alternative.

C.4.1.1 Format B as supplemental justification. In some cases, projects are proposed that are highly justificable except that the cost considerations show it to be uneconomical, or only marginally economical. The project, under these circumstances, can be better supported by the addition of a Format B which emphasizes the important quantifiable and non-quantifiable benefits associated with the proposal (see Figure C-1, Blank Format B).

C.4.2 Format A. Format A is used when several alternatives are being considered. It consists of the life-cycle costs of the alternatives and answers the implied question - which of the proposed alternatives will cost the least. Using the Uniform Annual Cost (UAC) is computed for each alternative. The decision of choice is therefore based on the alternative with the lowest UAC. This, of course, assumes that other benefits of the alternatives are equal (see Figure C-2, Blank Format A).

C.4.3 Format A-1. Format A-1 typically is used to compare an alternative to the present operation or status quo. In some instances, this is considered as a case where the capital investment is discretionary. The objective of this analysis is to determine whether or not sufficient savings are generated over the economic life of the investment to warrant the abandonment of the present operation. It answers the question-- are the gains worth the investments? Just as in the Format A, the technique of discounting is used to determine the Present Worth and account for the time value of money. The result is basically the computation of the savings to investment ratio (S/1) which provides a measure of the economic acceptability of the proposal.

C.4.3.1 Several viable alternatives, When there are several viable alternatives at the start of project formulation and one is chosen as the best alternative to compare against the status quo, the project justification should include, as a minimum, a statement of why the other alternatives were eliminated from consideration.

C.4.3.2 Return on investment. Some project may be better justified by computation of the Internal Rate of Return on Investment (ROI), (see Appendix B). It is the interest rate the equates the present value of the savings to the present value of the costs of the investment outlay. This percentage is another measure of the economic worthiness of the proposal (see Figure C-3).

C.4.4 Abbreviated Economic Analysis (AEA).

C.4.4.1 Purposes of AEA. An abbreviated EA may be used in lieu of a "formal" EA whenever the investment cost is less than $200,000. Again, as stated before, the objective of the AEA is to serve as a useful management tool, and reduce the administrative workload to a minimum.

C.4.4.2 Proposed alternative analysis with AEA. With respect to the project submission, the most frequently used EA is the one that compares the proposed alternative to the status quo. In this case, the AEA follows the techniques and precepts of the Format A-1 but in a condensed form. Figure C-4 provides a suggested format and an example of using this analysis to determine the best alternative.

C.4.4.3 Format A and B AEA. Abbreviated forms of Format A and B were not included in this handbook because they can be done by simply following the basic ideas already presented. Generally, they should be easy to formulate if one remembers that the scope and depth of an EA should be commensurate with the complexity, cost, and magnitude of the investment being considered.

FORMAT B

SUMMARY OF BENEFITS/OUTPUTS FOR ECONOMICS ANALYSIS

1. Submitting Organization: ____________________

2. Date of Submission: ____________________

3. Project Title: ____________________

4. Description of Project Objective: ____________________

5. Alternative: __________ 6. Economic Life: __________

7. Outputs:

   a. Dollar Quantifiable Outputs: (describe and justify)

   b. Other Quantifiable Outputs: (describe and justify)

   c. Non-quantifiable Outputs: (describe and justify)

8. Source/Derivation of Outputs: (use as much space as required)

   a. Dollar Quantifiable Outputs:

   b. Other Quantifiable Outputs:

   c. Non-quantifiable Outputs:

9. Name & Title of Principal Action Officer Telephone Number:	Date
10. Name & Title of Approving Authority	Date

Figure C-1.

FORMAT A

SUMMARY OF COSTS FOR ECONOMIC ANALYSIS

1. **Submitting Organization:** ____________________
2. **Date of Submission:** ____________________
3. Project Title: ____________________
4. Description of Project Objective: ____________________
5. Alternative: __________ 6. Economic Life: __________

7. Fiscal Year	8. Appropriation Identification	9. Program (if OMA)	10. Program/Project Costs					
			a. R&D	b. Investment	c. Operations	d. Annual Cost (a+b+c)	e. Discount Factor	f. Present Value Annual Cost (d x e)
19__								
19__								
↓								
11. TOTALS								

12a. Total Project Cost, Discounted (11f) __________
12b. Uniform Annual Cost (Before Allowance for Terminal Value) __________

13. **Less Terminal Value**, Discounted __________
14a. **Net Total** Project Cost, Discounted (12a-13) __________
14b. Uniform Annual Cost (After Allowance for Terminal Value) __________

Figure C-2.

FORMAT A

SUMMARY OF COSTS FOR ECONOMIC ANALYSIS

15. Source/Derivation of Cost Estimates: (use as much space as required)

a. Research and Development:

b. Investment:

c. Operations:

d. Net Terminal Value:

e. Other Considerations:

16. Name & Title of Principal Action Officer Telephone Number:	Date
17. Name & Title of Approving Authority	Date

Figure C-2.

PROJECT: 5855XXX SUBPROJECT: 1 ITEM: 6 PS-174
9-1-81

EXAMPLE

FORMAT A-1

SUMMARY OF COSTS FOR ECONOMIC ANALYSIS

1. Submitting Organization: Dyer Armament Company, Inc., Contractor for the Kansas City Plant, Kansas City, Missouri

2. Date of Submission: 9-1-81

3. Project Title: High Speed Priming Machines, Caliber .50 Manufacturing, Building #3

4. Description of Project Objective: This project will provide high speed priming machines which are available on the commercial market and, with state of the art detect/reject capability, will eliminate the present Pierce and Prime Operator Inspector and provide an appreciable cost reduction.

5a. Present Alternative: Continue with the present machines.

5b. Proposed Alternative: It is proposed to acquire three high speed priming machines with detect/reject capability which will, in turn, eliminate the present Pierce and Prime Operator Inspector.

6a. Economic Life of Present Alternative: None. The present machines were installed in 1941, accumulating approximately 75 years service from multi-shift operation.

6b. Economic Life of Proposed Alternative: Ten years (per ARRCOM Supplement 1 to AR 11-28, 17 December 1976)

Figure C-3.

PROJECT: 5855XXX SUBPROJECT: 1 ITEM: 6 PS-174
9-1-81

SUMMARY OF COSTS FOR ECONOMIC ANALYSIS (CONTINUED)

(Item 8 and 9: N/A)

7. Fiscal Year	10. Operations a. Present Alternative	10. Operations b. Proposed Alternative	11. Differential Cost	12. Discount Factor	13. Present Value Differential Cost
1985	$ 680,033	$ 680,033	$ 0	.954	$ 0
1986	675,633	262,026	413,607	.867	358,597
1987	673,591	261,234	412,357	.788	324,937
1988	673,591	261,234	412,357	.717	295,660
1989	673,591	261,234	412,357	.652	268.857
1990	673,591	261,234	412,357	.592	244,115
1991	673,591	261,234	412,357	.538	221,848
1992	673,591	261,234	412,357	.489	201,643
1993	673,591	261,234	412;357	.445	183,499
1994	673,591	261,234	412,357	.405	167,005
1995	673,591	261,234	412,357	.368	151,747
14. Totals	$7,417,985	$3,293,165	$4,124,820		$2,417,908

15. Present Value of New Investment:

a.	Land and Buildings	N/A
b.	Equipment	$792,400
c.	Other (Equipment Installation)	12,000
d.	Working Capital	N/A

16. Total Present Value of New Investment: $804,400

Figure C-3

PROJECT: 5855XXX SUBPROJECT: 1 ITEM: 6 PS-174
9-1-81

SUMMARY OF COSTS FOR ECONOMIC ANALYSIS (CONTINUED)

17.	N/A		
18.	Less: Value of existing assets replaced, $18,000 x .954 =		-17,172
19.	Less: Discounted terminal value of new investment—$80,440 x .368 =		-29,602
20.	Total New Present Value of Investment:		$761,626
21.	Present Value of Cost Savings from Operations (Col. 13)	$2,417,908	
22.	N/A		
23.	Total Present Value of Savings	$2,417,908	
24.	Savings/Investment Ratio (Line 23 divided by Line 20)	3.17	

25. Source/Derivation of Cost Estimates:

Historically, PSR funding is not received until late in the fiscal year; therefore, this project is initiated in FY 85.

Figure C-3

PROJECT: 5855XXX SUBPROJECT: 1 ITEM: 6 PS-174
9-1-81

SUMMARY OF COSTS FOR ECONOMIC ANALYSIS (CONTINUED)

a. Investment:

(1) Costs:

Three High Speed Priming Machines:

Labor	$172,045
Overhead	619,355
Material	1,000
Installation	12,000
Total *	$804,400

* Submitted by Process and Equipment Records.

(2) Net Terminal Value:

Estimated at salvage value of 10% of acquisition cost or $80,440.

b. Operations: Derivation of operation costs will be made on a cost per ammunition primer production basis. The projected production numbers were obtained from the Five Year Defense Plan (FYDP). The Present vs. Proposed Costs/Thous. units of production will result in the savings shown in Column 13. The projected ARRCOM production schedule indicates levels of 79,591,000 units - FY 85, 79,076,000 - FY 86, and a level off quantity of 78,837,000 for FY 87 through 95.

Figure C-3

SUMMARY OF COSTS FOR ECONOMIC ANALYSIS (CONTINUED)

(1) Personnel:

Present Method: (Present Priming Crew)

Classification	Hrs./Thous.	x	Hrly. Rate	=	Cost/Thous.	x	Wage Escalation	=	Total Cost/Thous.
T/S, Pierce & Prime *	.0964	x	$9.56	=	$ .9216	x	1.095	=	$1.0092
Primed Inspector	.3856	x	8.15	=	3.1426	x	1.095	=	3.4411
Primer Carrier	.0454	x	8.15	=	.3700	x	1.095	=	.4052
Hand Trucker	.0429	x	7.98	=	.3423	x	1.095	=	.3748
Salvage Inspectors	.0429	x	8.32	=	.3569	x	1.095	=	.3908
									$5.6211
					Industrial Relations at 52%				2.9230
					Total Cost/Thous.				$8.5441

* T/S = Tool Setter

Proposed Method: (Present Crew-Less Primed Inspector)

$8.5441 - $3.4411 + 52% or $1,7894 or $5.2305 = $3.3136 Cost/Thous.

c. Other Considerations: The crew reduction of the Primed Inspector is the only consideration at this time. Based on our experience with similar high speed machines now in use on smaller calibers, we anticiplate possible further crew reduction and increased machine efficiency in the future.

Figure C-3

AEA EXAMPLE

ABBREVIATED ECONOMIC ANALYSIS FORMAT A-1

PROJECT: Produce parts in-house that are none produced by contractor.

Title: Produce Depot Maintenance Support Parts In-House

Purpose: Produce depot maintenance parts on the horizontal spindle machining center proposed in Analysis 85-006, DD Form 1106, by utilizing a second shift to provide the required machine time. Parts required are now produced by an outside contractor because workload now exceeds capacity of the shop. Production of parts herein considered would be in lieu of other operations for NC used in the DD Form 1106 analysis.

Analysis:

A. Investment Costs:

FY 85 Constant Dollar Cost: $272530.00

Work on machining center, replaced machines Analysis 85-006	1573 Hours
Work on machining center, contractor produced parts	1704 Hours
Total	3277 Hours

Portion of investment identified to production of parts in-house $\frac{1704}{3277} = 0.52 \times 100 = 52$ percent

Net Investment DD Form 1106 $272530

$272530 X 0.52 = $141715.60 Allocated Net Investment Contact Parts

$272530 X 0.48 = $130814.40 Allocated Net Investment Converted to NC

Since delivery and installation are expected to take one year
$141715.60 X 0.954 = $136613.84 Contract $130814.40 x 0.954 =
$130814.40 X 0.954 = $124796.94 Converted to NC
0.954 project year one (1) Appendix C, Table A, DLAM 7041.1

B. Economic Life: 10 years.

C. Savings Over Life:

Savings per year: $146947.78
Discount Factor: 6.815 (Project year 11 Table B Appendix C DLAM 7041.1) - 0.954 (Project year 1) = 5.861
Total Discounted Savings = $146947.78 x 5.861 = $861280.93 on contracted parts.

Total discounted savings $127052 x 5.861 = $744651.77
In-house transfer of work to NC (line 7.i. DD Form 1106)
Analysis No. 85-006

Figure C-4.

D. Explanation of Savings: The proposed machine is intended for production of parts involving complex machining operations that can not be produced by the existing machines in-house. The alternative to produce the eight parts in-house on proposed machine provides an opportunity to save per year $146947.78 based on the FY 86 schedule. Castings and material for these parts are furnished to the contractor by the Government. The proposed equipment at two shifts will have an available capacity of 3277 productive hours per year.

CONTRACT Part	FY'86 Schedule	PROPOSED Classification	Hourly Rate	Cost Schedule	Hrs/ Thousand	Cost Schedule Direct Labor
A	800	Machinist	14.85	$26396.99	250	2970.00
B	150	Machinist	14.85	6929.21	350	779.63
C	1200	Machinist	14.85	23757.29	150	2673.00
D	600	Machinist	14.85	31676.38	400	3564.00
E	60	Machinist	14.85	4751.46	600	534.62
F	900	Machinist	14.85	59393.22	500	6682.50
G	600	Machinist	14.85	55433.67	700	6237.00
H	480	Machinist	14.85	16661.78	263	1874.66
	4790 pieces			$225,00000		$25315.39 DL

PROPOSED	COST
Direct labor 1704.74 hours x $14.85 second shift	$25315.39
Indirect labor 1.06 x D.L.	$26834.31
Fringe Benefits 0.35 x D.L.	$8860.39
Maintenance	$ 1890.00
Power $1704 x 1.202	$ 2048.21
Annual Fixtures 20% replacement	$ 6000.24
Tool Maintenance $3000 x 0.80 x 0.24	$ 5760.00
Consumable Tooling 1704 x $4.42	$ 7532.68
Tool Setting 80 tools x 6 lots x 0.25 hr x $14 x 1.35	$ 2268.00
Part programming 3.213 x 40 x $15 hr x 1.35	$ 2602.53
Material handling 4790 x 2 = 9580/12 = 798 hours	
798 hours x $16	$12768.00
Total	$101879./5
Less	
Inventory savings (225,000 - 101879.75)/2 x 0.24 =	$14774.43
Inspection savings - 100 percent Inspection 4790 pieces x 0.10 hour x $14 x 1.35	9053.10
Net Cost	$78052.22

Est. proposed savings/year	Contracted Parts		Other NC Work
Contract Cost	$225000.00		$127052 line 7.i.a
	78052.22	87100.32	
	$146947.78		$127052

DD Form 1106
Analysis No. 85-006

E. Saving/Investment Ratio

1. $861260.98 ÷ $141715.60 = 6.08 contracted parts
2. $744651.77 ÷ $130814.40 = 5.69 work converted to NC

Conclusion: Utilization of available capacity to produce parts now on contract yields the highest S/1 Ratio.

APPENDIX D

RANKING OF CAPITAL INVESTMENTS BY RETURN ON INVESTMENT FOR CAPITAL EQUIPMENT

D.1 Evaluating equipment or systems by return on investment (ROI). The return on investment (ROI), the short name for rate of return on investment, has been and still is being used bv both the private and public sectors of industry as a method of rating alternative equipment investments. The ROI method affords DoD activities a means to perform rapid equipment evaluation during the selection phase of productivity enhancement or modernization projects. This appendix presents the development of the ROI method, how the method is used, and a chart for use in determining the ROI utilizing the equipment payback period and useful economic life as coordinates.

D.2 References.

(a) Economic Analysis, DLAM 7041.1, March 1978 authored by Defense Logistics Agency
(b) Service Life Tables, Appendix 6B, Chapter3, DLAM 4215.1 authored by Defense Logistics Agency

D.3 Purpose. To provide a rapid economic evaluation of capital equipment through the use of a return on investment technique. This evaluation will assist the manager in determining equipment acquisition and disposal actions.

D.4 Scope and limitations. This procedure may be applied to all capital equipment with an initial investment of $25,000 or more. The type of actions using this procedure include capital equipment budgeting, establishing priority, acquisition, retention, and disposal. The use of the return on investment technique is limited by the given assumptions. Additionally, the return on investment is not always the only and most important criteria in making capital equipment decisions, other factors, such as safety and fire regulations and mandatory requirements for war mobilization and accommodation of a new type of work should be considered in the decision making process.

D.5 Background. Decisions on replacing and retaining equipment have been made without the benefit of a readily available return on investment discipline. Due to limited funds, this can lead to acquiring or retaining equipment with lower rates of return than other equipment alternatives not considered or inadvertently discarded.

D.6 Definitions. The following are the definitions of the terms used in this procedure.

D.6.l Return on investment. Return on investment (ROI) is short for rate of return on investment and is that interest rate at which the present worth of investment is equal to the present worth of the savings. This definition considered the time value of money.

0.6.2 Cost. A resource input to a project expressed in dollar terms. There are two types of costs - nonrecurring and recurring.

D.6.2.1 Nonrecurring. Costs which occur on a one-time basis. These costs include initial equipment procurement, installation fees, start up training, initial tooling and accessories package, and spare parts.

D.6.2.2 Recurring. Expenses for personnel, material consumed, operating overhead and support services, and other items which occur on a regular annual basis. These costs include direct labor support (i.e. equipment operator), utilities, rental and service contracts.

D.6.3 Economic life. The period of time over which the benefits to be gained from a proposal may be reasonably expected to accumulate. The economic lift of an equipment project starts the year the investment starts producing benefits and is limited by its mission life, physical life, or technical life, whichever the shortest.

D.6.4 Payback period. The time period for which accumulated present value savings are sufficient to offset the total present value investment costs of a proposed alternative.

D.6.5 Present value. The estimated current worth of future benefits or costs derived by discounting the future values, using an appropriate discount rate (usually 10 percent).

D.7 Assumptions. To apply ROI the following assumptions are made:

a. Initial capital investment results in constant income and cost reductions/avoidances. This has been true in most cases.

b. The present and future savings result from equipment with a basis acquisition cost of $25,000 or more.

c. Service life in reference D.2.(c) for NC machines is based on two-shift operation and exceeds or is equal to economical and physical life.

d. Cost savings data for equipment is readily available and can be accurately estimated. This is extremely difficult when predicting a constant workload level for a future of 5, 10, or 20 years.

e. Equipment already procured has reutilization value which is equal to the present terminal value determined from the 10 percent discount factor in reference D.2.(c) for the terminal year of the project.

D.8 Procedure for commutation of ROI.

a. From Payback Calculation, Example D1 the payback period is 3.5 years. The problem is to find the percent where the cumulative present worth factor is equal to 3.5 for the life of the project. The service life from reference D.2.(b) is 10 years and is also the economic life of the project.

b. The cumulative value for 10 years at 20 percent (see Table D-1) is 4.1910 and 30 percent is 3.0915. The cumulative value required lies between these values.

TABLE D-1

PERIOD AND CUMULATIVE DISCOUNT FACTORS

	20%	Cumulative	30%	Cumulative
1	0.8333	0.8333	0.7692	0.7692
2	0.6944	1.5277	0.5917	1.3609
3	0.5786	2.1063	0.4552	1.8161
4	0.4822	2.5885	0.3501	2.1662
5	0.4018	2.9903	0.2693	2.4355
6	0.3348	3.3251	0.2072	2.6427
7	0.2790	3.6034	0.1594	2.8021
8	0.2325	3.8359	0.1226	2.9247
9	0.1937	4.0296	0.0943	3.0190
10	0.1614	4.1910	0.0725	3.0915

4.1910 - 3.0915 = 1.0995 PWF Difference
-3.5000 Required PWF
0.6910
0.6910 ÷ 1.0995 = 0.628
0.628 X 10% = 6.28
+ 20%
26.3 is the ROI for the Investment covered in Example D1.

c. Most calculators can compute the present value of the individual future years by first solving for $\frac{1}{(1 + r)}$ which yields the first period value. To obtain subsequent value press the [Xl key to get the individual period values.

D.9 Procedure for use of Chart D-1. The following is the three-step procedure for determining equipment ROI

a. Determine the remaining economic life of the equipment. The economic life is limited by three factors - mission life, physical life, and technological lives can be determined using reference D.2.(b).

b. Determine the payback period for the equipment. This is done by dividing the present value of the total investment by the uniform annual savings or cost reduction. The following formula illustrates this procedural step:

$$PB = \frac{PV(I)}{A(S)}$$

Where: PB = Payback period in years
PB(I) = Present Value of Investment in dollars
A(S) = Annual uniform savings in dollars per year

See examples D1 through D3, payback calculations

Determine the return on investment (ROI) using the equipment economic life, its payback period, and the chart from payback calculation example Dl:

Payback period 3.5 years = PB
Project life is 10 years = N
$\frac{N}{PB} = \frac{10}{3.5} = 2.9$ Payback ratio

c. Enter chart D-1 at 3.5 years payback period look across to find $\frac{N}{PB}$ value of 3 by visual interpolation the ROI (vertical line) is 25 which is the precent return.

D.10 Evaluation of ROIs. Application of ROI to equipment will result in the following two general situations:

a. The payback period is greater than the economic life of the equipment. This makes the investment uneconomically sound. Frequently, this occurs when a piece of equipment is idle for a long period of time. Since savings on idle equipment are zero, the equipment causing the highest cost to retain should be excessed first.

b. The rate of return is greater than zero. New or rebuilt equipment with the highest rate is the preferred investment. Additionally, existing equipment with the highest rate of return should be retained first.

D.11 Evaluation of ROI examples. Table D-1 shows the organization of data that adequately support the analysis of investment and cost avoidance opportunities.

TABLE D-2

EVALUATION OF ROI EXAMPLE

The following equipment is being considered for retention and acquisition based on costs and ROIs. If $1 million is funded for new equipment acquisition, what equipment should be procured? What costs can be avoided by excessing idle equipment?

EQUIPMENT	RANKING OF AMORTIZATION LIFE (IN YEARS)	CALCULATED PRESENT VALUE OF INVESTMENT	CALCULATED ANNUAL SAVINGS	CALCULATED PAYBACK IN YEARS	CALCULATED LIFE TO PAYBACK RATIO	RATE OF RETURN	COMMENT
A	4	$700,000	$300,000	2.3	4.3	44%	Proposed new machine
B	6	100,000	30,000	3.3	3.0	27%	Proposed new machine
C	3	400,000	200,000	2.0	9.0	50%	Proposed new machine
D	10	200,000	10,000	20.0	0.8	-	Uneconomical
E	7	100,000	20,000	5.0	4.0	19%	Proposed new machine
F	11	70,000	0	Infinite	0	-	Idle machine
G	9	300,000	40,000	7.5	1.7	9%	Proposed new machine
H	5	30,000	10,000	3.0	3.3	31%	Proposed new machine
I	8	470,000	90,000	5.2	3.3	18%	Proposed new machine
J	2	330,000	250,000	1.3	12.3	80%	Proposed new machine
K	1	210,000	190,000	1.1	4.5	90%	Proposed new machine
L	12	100,000	0	Infinite	0	-	Idle machine

Page 1 of 2

TABLE D-2 (Continued)
EVALUATION OF ROI EXAMPLE

New equipment priority using ROI:

EQUIPMENT	RANK (ROI)	INVESTMENT COST
K	1 (90%)	$210,000
J	2 (80%)	330,000
C	3 (50%)	400,000
A	4 (44%)	700,000
H	5 (31%)	30,000
B	6 (27%)	100,000
E	7 (19%)	100,000
I	8 (18%)	470,000
G	9 (9%)	300,000
		$2,640,000

Retention priority using investment cost:

EQUIPMENT	RANK	INVESTMENT COST
F	1	70,000
L	2	100,000
		$170,000

ANSWER: Fund equipment K, J, C, and H for $970,000. By excessing equipment F and L, $170,000 in costs will be avoided and the value of such equipment for reutilization will be realized.

PAYBACK CALCULATION EXAMPLE D1

EXAMPLE NO. 1

Cost Center 25 has proposed the purchase of a numerically controlled, 5-axis machining center. Calculate the payback period.

Step 1. Determine present value of investment PV(I)

$621,000	Basic 5-axis machining center cost
75,000	Equipment installation
31,000	Initial start-up tooling package
12,000	Spare parts start-up kit
2,000	Training
$741,000	Total initial investment

$166,000	Terminal value at end of 10 years
X 0.405	10% discount factor (Table A, Appendix C, reference (b))
$ 67,000	Present terminal value

PV(I) = Initial investment - present terminal value

= $741,000 - $67,000 = $674,000

Step 2 Determine uniform annual savings, A(S)

$237,000*	Annual operating costs of present equipment
44,000*	Annual operating cost of 5-axis machine
$193,000	Uniform annal savings, A(S)

Step 3. Determine payback, PB

$$PB = \frac{PV(I)}{A(S)}$$

$$= \frac{\$674{,}000}{\$193{,}000} \text{ yrs}$$

= 3.5 yrs

*Calculated using DD Form 1106

PAYBACK CALCULATION EXAMPLE D2

EXAMPLE NO. D2

Calculate the payback period of a numerically controlled, 5-axis machining center which has only 5 years remaining on its 10 year life. Assume only two alternatives exist. One is to retain the equipment and the other is to return to using the same type of equipment as used in justifying the 5-axis machine when it was new.

Step 1. Determine present value of investment PV(I)

$342,000	Current value of 5-axis machining center (basic acquisition cost minus 5 years depreciation)
0	Equipment installation (sunk cost)
0	Tooling (sunk cost)
12,000	Spare parts replacement
$354,000	

$166,000	Terminal value at end of 5 years
X 0.652	10% discount factor (Table A, Appendix C, reference (b))
$108,000	

PV(I) = Initial investment - present terminal value

= $354,000 - $108,000 = $246,000

Step 2. Determine uniform annual savings, A(S)

$119,000*	Annual operating cost of replaced equipment
27 000*	Annual operating cost of 5-axis machine
$ 92,000	

Step 3. Determine payback, PB

$$PB = \frac{PVI}{A(S)}$$

$$= \frac{\$246,000}{\$92,000} \text{ yrs}$$

$$= 2.7 \text{ years}$$

*Calculated using DD Form 1106 with workload dropping to half of what was predicted for machine when it was new.

PAYBACK CALCULATION EXAMPLE D3

EXAMPLE NO.D3

Calculate the payback period for a year old numerically controlled lathe. In 1 more year the machine will be at the end of its service life. It is estimated that the machine's service life will be extended for 5 more years if a major overhaul is performed 1 year from now. The overhaul will cost $60,000.

Step 1. Determine present value of investment PV(I)

$17,000 Current depreciated value of lathe
57.000 Present value added of overhaul ($60.000 X 0.954)
$74,000

$30,000 Terminal value at end of 6 years
X 0.592 10% discount factor (Table A, Appendix C, reference (b))
$18,000

PV(I) = Initial investment - present terminal value

= $74,000 - $18,000 = $56,000

Step 2. Determine uniform annual savings, A(S)

$194,000* Annual operating cost of non-overhauled equipment
136 000* Annual operating cost of overhauled equipment
$ 58,000

Step 3. Determine payback, PB

$$PB = \frac{PV(I)}{A(S)}$$

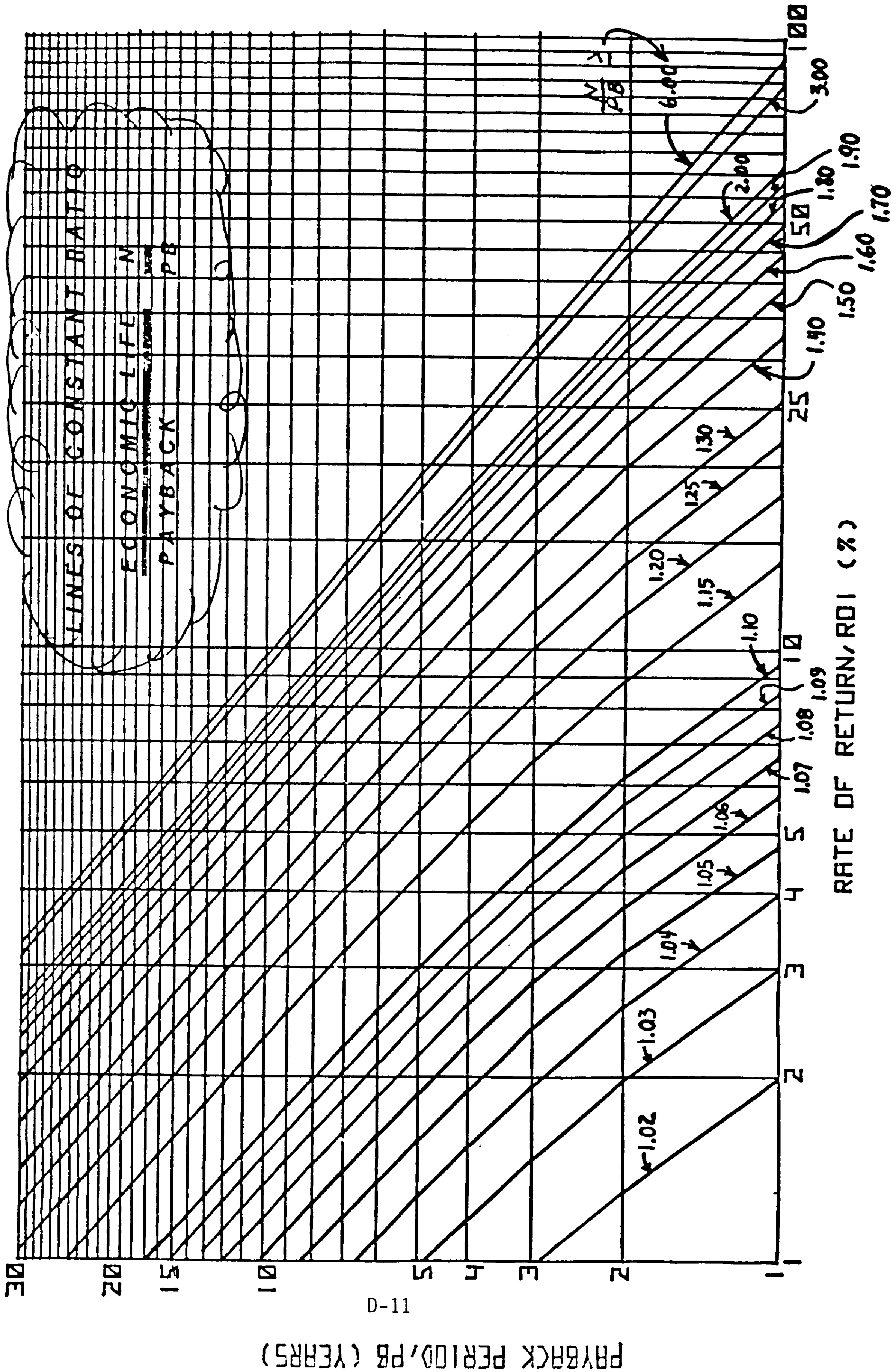
$$= \frac{\$56,000 \text{ yrs}}{\$58,000}$$

$$= 1.0 \text{ yrs}$$

*Calculated using DD Form 1106.

Chart D-1

ROI CHART



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