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RECOMMENDED TECHNICAL SPECIFICATIONS FOR PROCUREMENT OF EQUIPMENT FOR A TURNING WORKSTATION

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RECOMMENDED TECHNICAL SPECIFICATIONS
FOR PROCUREMENT OF EQUIPMENT FOR A TURNING WORKSTATION

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TABLE OF CONTENTS

	<u>Page</u>
I. INTRODUCTION	1
II. MAJOR COMPONENTS	2
II.1. CNC Turning Machine	2
II.1.1 Functional Requirements	2
II.1.2 Performance Characteristics	3
II.1.3 Applicable Specifications, Codes, and Standards	16
II.1.4 Performance Acceptance Testing	19
II.1.5 Evaluation Criteria	21
II.2. Robot System	25
II.2.1 System Elements	25
II.2.2 Performance Characteristics	25
II.2.3 Applicable Specifications, Codes, and Standards	30
II.2.4 General Features	30
II.2.5 Safety	34
II.2.6 Final Inspection	35
II.2.7 Documentation and Support	35
II.2.8 Performance Testing	37
II.2.9 Evaluation Criteria	38
III. SUMMARY	40

TABLES

		<u>Page</u>
TABLE I.	Specific Machine Tool Requirements	8
TABLE II.	Specific Requirements for Machine Control Unit, CNC Control	10
TABLE III.	Tool Setting and Part Gaging	16
TABLE IV.	Machine Accuracies	23
TABLE V.	Performance Test	25

FIGURES

	<u>Page</u>
Figure 1. The Tool Coordinate System	41
Figure 2. Space Accessible by Robot	42

I. INTRODUCTION TO THIS MANUAL

This manual serves as a technical guide to the specifications required to procure commercially available, major components important in a Turning Workstation. The specifications are written specifically for the procurement of an industrial robot and a turning center (a computerized numerical control (CNC) turning machine) for use in a technology transfer program. This program is developing a small-batch flexible manufacturing workstation for the Mare Island Naval Shipyard. Some of the specifications included herein are developed to meet the technical requirements for the machining of families of nuclear submarine RISIC parts. This manual is intended to be used as an aid for those in government, industry and academia who are engaged in automated manufacturing research.

II. MAJOR COMPONENTS

1. CNC TURNING MACHINE

This turning center will be used in an extended series of experiments to evaluate the effectiveness and limitations of on-line computer correction of machine-tool performance and completely automated operation in a small batch manufacturing environment. The turning center will become a research element of a microprocessor-based, network controlled turning workstation and will be automatically tended by an industrial robot(s) and controlled by a host computer, a workstation controller. This machine tool will run untended by a human operator.

1.1. Functional Requirements

The turning center shall be designed and engineered to meet the purchaser's requirements as follows:

- a) The turning center shall be delivered and installed as a self-contained unit capable of performing CNC machining operations on parts held in a 3-jaw power chuck or mounting between centers.
- b) The turning center shall be controlled by a microprocessor-based machine control unit (MCU) interfaced to the machine tool. The MCU shall receive commands from a program stored in a self-contained memory unit or from a program manually entered from a keyboard on the machine controller as manual data input (MDI). The memory shall accept programs from memory storage, magnetic tape, and MDI inputs. It shall be possible to save programs for future use by writing the memory to external storage such as a magnetic tape cassette recorder, paper tape punch, and bubble memory cartridge reader through appropriate interfaces.
- c) The turning center machine-tool-controller software shall be programmed in a high-level structured language such as ADA or Pascal so that it can be modified by the purchaser. The contractor shall furnish a listing of the controller source code and an editor to modify the software.
- d) The turning center shall provide a machining capability "C" axis, that is, the spindle position can be programmed via the CNC controller.

- e) The turning center shall have a quick change tool head at the tool turret that can be actuated remotely for quick change of tooling.
- f) The turning center shall have turret-mounted live tooling for all secondary machining operations. Secondary machining operation shall include, but not be limited to, face milling, slotting, and off-axis drilling and tapping.
- g) The turning center shall have an automatic gaging system, furnished with a tool and a workpiece gaging probe, and necessary software integrated into CNC control.
- h) The turning center shall be equipped with automatic lathe door open and door close functions.

1.2. Performance Characteristics

1.2.1. General Description

The machine tool shall be new and essentially one of the manufacturer's current models. The machine tool shall be a 2-axis, continuous path positioning/contouring machine with a rotary turret for tool positioning. In addition, the machine tool shall be capable of holding the spindle in position in order to allow the use of live tooling. The design of the machine shall include features and components necessary for maintaining alignment and accomplishing turning, boring, threading, drilling, and shaft turning operations as well as off-axis boring, threading, drilling and milling. The machine shall have a horizontal axis spindle. Motion in the X and Z axes, spindle operation, and turret indexing shall be directed by a computer numerical control (CNC) type MCU. The machine shall have full-axis servo drives on the linear axes with precision positioning feedback devices and turret indexing with at least 12 indexing positions to allow the specified machine capacity to be exercised.

The machine functions shall be controllable directly by manually-operated control devices, semi-automatically by manual data input devices, and automatically from parts programs in data memory, and remotely from a computer.

All parts of the machine or system that are subject to wear, breakage, or distortion shall be accessible for adjustment, replacement, and repair.

1.2.2. Detailed Requirements

Construction Features: The machine shall be so constructed that when installed, filled with operating fluids, and connected to power, it will be ready for operation. The machine shall be constructed of parts which are without defects and free of repair. The structure shall be capable of withstanding all forces encountered during operation of the machine to its maximum rating and capacity without permanent distortion.

Castings and Forgings: All castings and forgings shall be free of defects, scale, and mismatching. No process such as welding, peening, plugging, or filling with solder or paste shall be used for reclaiming any defective part.

Welding, Brazing, or Soldering: Welding, brazing or soldering shall be employed only where specified in the original design. None of these operations shall be employed as a repair measure for any defective part.

Fastening Devices: All screws, pins, bolts, and similar parts shall be installed in such a manner as to prevent change of tightness. Those subject to removal or adjustment shall not be swaged, peened, staked, or otherwise permanently deformed.

Surfaces: All surfaces of castings, forgings, molded parts, stampings, and welded parts shall be cleaned and free from sand, dirt, fins, sprues, flash, scale, flux, and other harmful or extraneous materials. All edges shall be either rounded or beveled unless sharpness is required to perform a necessary function. Except as otherwise specified herein, the condition and finish of all surfaces shall be in accordance with the manufacturer's standard commercial practice. The manufacturer's standard-color paint shall be used where applicable.

Threads: All threading of parts shall be done in the SI (metric) unit system, or inch system conforming to Federal Screw Thread Standard H28, excluding hydraulic components and manufacturer's standard electronic connectors.

Plates: All words on speed-and-feed indicating plates and/or instruction plates shall be in the English language and engraved, etched, embossed, or stamped in boldface characters on a contrasting background.

Gears: The gears used in the machine shall be machined in either the SI (metric) unit system or in inches. In either case, the gears shall be suitable for the intended purpose, and shall be heat-treated by a process that will impart the necessary toughness and hardness that will enable the gear train to transmit full-rated torque without failure or premature wear.

Lubrication: All bearings (except sealed-for-life type), matting gears, and sliding parts shall be provided with means for automatic lubrication with a system of capacity for at least 100 hours. Oil reservoirs shall be fitted with oil-level sight gages. Manually operated systems for ways and remote areas shall have control handles mounted in accessible locations. All oil holes, grease fittings, and filter caps shall be easily accessible.

Interchangeability: To provide for replacement of work parts, all parts bearing the same part number shall be functionally interchangeable without modification of part or machine, and shall be dimensionally identical within the manufacturing tolerance limits in use by their manufacturer.

Reclaimed Materials: The machine shall contain reclaimed materials to the maximum extent possible without jeopardizing its intended use or its performance. The reclaimed materials shall have been reprocessed, remanufactured or recycled in a manner which restores them to the same chemical composition and physical properties as the materials originally selected for use on the machine. Reclaimed materials shall include iron, steel, copper, brass, aluminum, glass, fiber products, plastics, and elastomers that have been collected from discarded solid, liquid, semisolid, or gaseous waste such as garbage, refuse, or sludge.

1.2.2.1. Component Specification

The principal components of the turning center shall include, but shall not be limited to: bed base, turret, carriage, 3-jaw chuck, spindle, head stock, numerically controllable axes, precision feedback devices, coolant system, electrical system, hydraulic system, numerical control system, machine/control system interfaces, and appropriate safety devices. These components shall provide a machine tool that conforms as described in Table I Specific Machine Tool Requirements and Table II Specific Requirements for Machine Control Unit, CNC Control.

Numerical Control System: The turning center shall have a fully automatic numerical control system with a machine control unit (MCU), axis servo drives, and position feedback devices. This control system shall be configured in a manner consistent with the functional requirements stated in Section I.3 above to allow the purchaser to accomplish the operations outlined in Sections I.1 and II.3. The MCU shall have the features listed and described in Table II, and shall operate as follows: The system shall control the machine to accomplish axis movement, spindle operation, turret indexing, and all other part-program-directed functions. Spindle operations include spindle locking

in order to machine with the rotary tooling. The MCU shall be a continuous-path contouring unit.

System Software: Part programs, the operating program, tool data, materials data, time cycles, and resident diagnostics shall be stored and processed by the MCU utilizing semiconductor memory. The MCU memory capacity shall be sufficient to store the equivalent or at least 1000 feet (394 m) of multiple part-program tape data in addition to the storage of all other software of the system. Programs stored in memory from tape input shall be accessible for repetitive execution without the use of the tape reader.

The MCU shall translate the program data into machine control language and shall store this in the memory.

The MCU shall also be capable of accepting binary code perforated paper tape input and magnetic tape input.

The system shall control the axis servo drives to move the controlled elements to the program-commanded positions with the MCU regulating speed, direction, sequence, and dwell. The system shall position the controlled slides in rapid traverse, feed in any controlled axis at the program feed rate, elect spindle speed and direction of rotation, initiate tool index, and control the flow of coolant fluid.

Movement of the X and Z turret axes shall be actuated through closed-loop electric or hydraulic servo mechanisms. The speed shall be variable on X and Z movements. The feed drives of the linear axes shall be accomplished using antibacklash ball lead screws with preloaded recirculating ball nuts. Positioning feedback devices on the axes shall provide the MCU with position data in order that it may be compared with the control output and the machine slides moved in the direction that will tend to reduce the difference to zero.

The contractor shall furnish source code such that the system software can be modified.

Numerically Controlled Axes: With machine axis and motion nomenclature assigned in accordance with EIA RS-267, the MCU shall control the axes of the machine to perform turning, boring, drilling, continuous-path contouring, and threading through simultaneous movements of the X and Z axes utilizing linear interpolation and circular interpolation. Positioning axes shall execute program movement at fixed or programmed velocities independent of the movements of any other axis. Contouring axes shall have simultaneous start and completion of defined moves with vector and velocity control.

The MCU shall provide interface circuitry and plug receptacles to output stored programs from the memory to external storage.

The MCU shall provide interface circuitry and plug receptacles to output stored programs from the memory to external storage. Memory space formerly occupied by deleted programs shall be accessible for reutilization. The methods used shall be those stated in Section II.1.1 (b).

MCU's utilizing volatile-type memory shall have a self-contained emergency power source that will maintain program and data storage for a period of not less than 24 hours.

Auxiliary Functions: The MCU shall respond to all program command auxiliary functions. System preparatory and miscellaneous functions shall be coded in accordance with EIA RA-274, Appendix B. Preparatory functions shall include interpolation, fixed cycles, and dwell. Miscellaneous functions shall include program stop, optional program stop, end of program, spindle CW, spindle CCW, spindle off, coolant on, coolant off, turret index, end of program (rewind) and program restart.

TABLE I. Specific Machine Tool Requirements

Characteristics must not be less than the requirements shown, except when a range is specified; acceptable performance for a range is from the smaller figure, or less, to the larger figure, or more.

X Axis Travel: 6-inch working travel

Z Axis Travel: 8.5-inch working travel

Resolution, Both Axes: 0.00001 inch

Maximum Turning Diameter, w/3-jaw chuck: 12 inches

Maximum Turning Length, distance between centers: 15 inches

3-Jaw Chuck Size, Powered: 12-inch (include at least one set of soft jaws and one set of hard jaws)

Collet Chuck Size, Powered: N/A

Hole Through Spindle: 2.5 inches

Spindle Speed Range: 45-3000 rpm

Main (Spindle) Drive Motor: 30 hp

Spindle Indexing: 1800 positions per revolution (0.2 degree)

Minimum Tool Positions: 12

Minimum Turret Indexing Positions: 12

Rapid Traverse Rate (All Axes): 300 ipm

Rotary Tool Spindle Speed: 0-3000 rpm

Rotary Tool Spindle Motor: 7 hp

Procurement Specifications

Machine Ways (hardened)

Chip Conveyer: NC controlled on/off.

Axis-Drive Motors: DC servo

Coolant System: Flood type, NC controlled on/off

Electrical System: 460 Volt, 3 Phase, 60 Hertz; shall conform to NFPOA 378; shall meet or exceed electromagnetic interference characteristics of MIL-STD-461.

Hydraulic System: Shall be complete and adequate to perform all specified functions.

Motors: Shall be specifically designed for the purpose to be used and shall conform to NEMA std. MG1.

TABLE II. Specific Requirements for Machine Control
Unit, CNC Control

Characteristics must not be less than the requirements shown, except when a range is specified; acceptable performance for a range is from the smaller figure, or less, to the larger figure, or more.

Controlled Axes: 2 Axes (X and Z), simultaneously

Decimal-Point Programming

Increment System:

Least Input Increment: 0.00001 inch

Maximum Programmable Dimension: 99.9999 inches

Program Input/Output: RS-232 interface, paper-tape reader, MDI

Rapid Traverse Override: 100%, 50%, 25%, 0%, or 0-100% or greater.

Feed rate Override: 0-110%

Automatic Acceleration/Deceleration

Absolute/Incremental Programming

Absolute-Zero-Point Programming

Linear/Circular Interpolation

Tool Offset: 32 pairs in memory

Dry Run Capability

Part Program Storage Capacity (equivalent): 1000 feet of tape program

Backlash Compensation: 0-0.255 mm (0-0.010 inch)

Single Block Operation

Interlock

Machine Lock

Stored Stroke Limit

Feed Hold

Tape Reader: The MCU shall have a photoelectric-type tape reader for holding, feeding, and reading one inch, eight channel perforated tape as required herein. The tape reader shall be located on the exterior of the MCU, in a position that is readily accessible, visible, and protected from environmental contaminants. The reading speed of the tape reader shall be not less than the capability of the MCU to receive and process such input data and, in any event, not less than 150 characters per second. The MCU shall have controls for feeding, rewinding, and stopping the tape for single and multiple block operation to include stored program and sequence number search.

Parity Check: The MCU shall have a parity check system which stops the tape reader and illuminates an error indicating light on the control panel or produces an error message on the CRT or readout when the number of holes read in a traverse row of tape data does not comply with the program character code (EIA RS-244 or EIA RS-358). The system shall include controls for overriding parity error.

Tape Hold Verification: The reader shall be stopped and a read error signal given if parity check indicates that the number of holes read does not conform to the established tape format, if sprocket hold verification detects the absence of a hole, or if there is tape misalignment. It shall be possible to feed tape data which is not required for control operation through the reader without registering a parity error, such as leader information containing program identification data, operator messages, and other functions as appropriate.

Block Delete: The MCU shall have a block delete system which can be controlled by the operator for reading through or ignoring blocks of tape data.

Buffer Storage: The MCU shall have buffer storage for transferring blocks of program data from the tape reader to internal storage without delaying the next incoming block or interrupting the active command functions. The buffer shall delay or store input data

until allocated by the controlling devices. The buffer shall store one or more blocks of program data.

MCU Console: The MCU console shall be constructed in accordance with the applicable requirements of EIA RS-281. The MCU shall be a solid-state, modular-type unit. The console shall have a control panel for displaying the visual signals and operating controls of the system and machine. The console shall have removable panels or other means that provide access to all circuit boards, wiring, and other components contained within. Circuits shall include tagged or color-coded wiring, terminal board markings, and branch circuit fusing. The MCU shall include electrical and safety interlocks as required for the protection of the system, machine, and the operator. The console shall be sealed to protect the contained components from dust or other environmental matter that could adversely affect performance of the MCU. The system shall function effectively and accurately within any ambient temperature ranging between 10° C and 48° C and in a relative humidity of up to 95 percent.

Control Panel: The control panel of the MCU shall include an alphanumeric keyboard and other switches and push buttons necessary to control the unit. A cathode ray tube (CRT) display shall be provided.

Program Edit: The MCU shall be configured with an edit mode that is operational through the control panel keyboard and other controls as necessary for the display and modification of program data of tape being input and programs stored in memory. The mode shall include controls for searching the selected data input source (tape or data memory) both forward and reverse and block-by-block for a designated sequence number of block of program data. When located, the designated block shall be displayed for review and editing. The mode shall permit data to be deleted or altered and shall permit additional blocks to be inserted between blocks of program data. It shall also permit the edited data of tape programs to be input to data memory and merged with the programs for tape execution.

Tape Punch Interface: The MCU shall include a tape punch output interface with necessary hardware and software for allowing the coded data of stored programs to be produced by a tape punch unit. In order to facilitate punch unit connection, the interface shall include necessary circuitry and a plug receptacle in accordance with EIA RS-232.

Direct Machine Control: The MCU console shall be configured to provide direct override control over feed rates and spindle speed and to provide jogging capability on

all axes. Feed rate override shall allow manual adjustment of the tape or stored program commanded feed rate for each axis controlled by the numerical control system. The override shall be as specified in Table II, and have a continuous low- and high-speed bidirectional jog movements of the slides for each controlled axis.

Program Adjustment: The MCU shall have controls for locating the zero reference (set) point at any position throughout the range of departure for each controlled axis.

The MCU shall have linear and circular interpolation capability for directing contouring cuts by simultaneous incremental or absolute movements of any or all axes controlled. Circular interpolation shall provide a means within the system for generating an arc in any one quadrant using one block of program data. Direction of the tool center arc shall be clockwise or counterclockwise.

The MCU shall be configured to allow tool length offsets up to at least 999.999 mm or 99.9999 in, as applicable, and gauge lengths ranging from not more than 0.003 mm (0.0001 in) to at least 999.999 mm or 99.9999 in, as applicable, for at least 12 tools. Tool length offsets and gauge lengths shall be set through the control panel and shall be displayed on the control panel.

Direct Numerical Control Interface (DNC): A DNC interface to the MCU shall be provided that permits DNC operation of the machine tool and bidirectional communications with a host computer. The protocols utilized to implement communications and error checking on the computer link shall be described. The hardware to implement the DNC interface at the MCU, and a 300-foot cable and connector for the computer link shall conform to RS-232C or EIA-422. The minimum data transmission rate shall be 9600 baud. The DNC interface and computer link shall permit the following operations: a) transmit machine control data from the host computer to the MCU for storage in program memory, b) transmit edited machine control data from MCU memory to the host computer.

Safety Devices: Covers, guards, or other safety devices shall be provided for all parts of the machine that present safety hazards. The safety devices shall not interfere with the operation of the machine. The safety devices shall prevent unintentional contact with the guarded part, and shall be removable to facilitate inspection, maintenance, and repair of the parts. All machine parts, components, mechanisms, and assemblies furnished on the machine, whether or not specifically required herein, shall comply with all of the Standards promulgated under OSHA that are applicable to the machine itself.

Maintenance tools: One set of wrenches and operating and repair tools shall be furnished according to the normal practice of the manufacturer.

Documentation: At least three copies of documentation for the complete turning center shall be supplied. This shall include operating, service, and programming manuals as well as mechanical drawings, and complete electronic and electrical schematics. In addition, source code for the operating system shall be supplied.

Training: Reasonable technical training in the operation, maintenance, programming, and routine use of the turning center shall be provided at the buyers site. For this purpose, the manufacturer's standard courses in the machine operation, maintenance, programming, and routine use will suffice.

Plates: A corrosion-resistant metal nameplate shall be securely attached to the machine. The nameplate shall contain the information listed below. If the machine is a special model, the model designation shall include the model of the basic standard machine and a suffix identified in the manufacturer's permanent records. The captions listed may be shortened or abbreviated, provided the entry for each such caption is clear as to its identity:

Nomenclature

Manufacturer's Name

Manufacturer's Serial Number

Manufacturer's Model Designation

Class, Axes Pos., Axes Cont.

Size, HP Spindle Motor

Power Input (Volts, Total Amps, Phases, Frequency)

Contract Number/P.O. Number

Date of Manufacture

Also, a lubrication chart or plate shall be permanently and securely attached to the machine. It shall be placed in a transparent plastic folder or permanently sealed

between clear plastic sheets with suitable means for mounting. The following information shall be furnished on the chart or plate:

Points of Application

Service Interval

Type of Lubricant

Viscosity

Chip and Coolant Shielding: The machine shall be provided with shielding for the reasonable containment of coolant and chips. The containment device must be transparent or contain a transparent window to provide work area visibility.

Power Operated Chuck: The chuck shall be a heavy-duty, three-jaw self-centering chuck not less than the size required in Table I. The chuck shall be operated by pneumatic or hydraulic power as normally supplied. Chuck grip pressure and manual operating controls shall be provided.

In-Process Part Gaging: The machine tool shall be equipped with a turret-mounted touch probe and necessary control software to provide automatic in-process part gaging operation on the machine. The required repeatability of the probe is given in Table III.

TABLE III. Tool Setting and Part Gaging

Tool Setting Station:

Repeatability of the touch probe .000020 inch, one standard deviation

Positioning repeatability of the arm +/- .0002"

In-process Gaging Probe:

Repeatability .000020 inch, one standard deviation

Tool Setting Station: The machine tool shall be equipped with a tool setting station and necessary control software to provide automatic measurement of tool offsets on the machine and update the tool offset registers automatically. The required repeatability of the tool setting station is given in Table III.

Tooling: The machine turrets shall be equipped with tapered shank tooling that can readily be changed by a robot. Live tooling is not required to have tapered shank.

Automatic Lathe door: The lathe door opening and closing shall be remotely under CNC control. When the door is fully open, it shall have a minimum of 21-inch wide clearance for robot access into the lathe work volume.

1.3. Applicable Specifications, Codes, and Standards

The following documents of the issue in effect on date of request for proposals form a part of this specification to the extent specified herein.

UNITED STATES MILITARY STANDARDS

MIL-STD-1815 ADA Programming Language

MIL-STD-461 Electromagnetic Interference Characteristics Requirements for Equipment

(Copies of military specifications, standards, drawings, and publications required by contractors in connection with specific procurement should be obtained from the procuring activity or as directed by the Contracting Officer.)

OCCUPATIONAL SAFETY AND HEALTH ACT (OSHA) OF 1970

Title 29, Code of Federal Regulations, Chapter XVII, Part 1910, and amendments. Occupational Safety and Health Administration Standards

FED-STD-H28 SCREW THREADS FOR FEDERAL SERVICES

ANSI B1 - ISO Metric Screw Threads

(Application for copies should be addressed to the Superintendent of Documents, Government Printing Office, Washington, CS 20402.)

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI X3.9-FORTRAN

ANSI X3.37-Programming Language APT

(Application for copies should be addressed to the American National Standards Institute, Dept. 969, 1430 Broadway, New York, NY 10018.)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) STANDARDS

NFPA No. 79-Electrical Standard for Metalworking Machine Tools.

(Application for copies should be addressed to the National Fire Protection Association, 470 Atlantic Avenue, Boston, MA 02110.)

ELECTRONIC INDUSTRIES ASSOCIATION (EIA) STANDARDS

RS-227 One-Inch Perforated Paper Tape

RS-232 Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange

RS-267 Axis and Motion Nomenclature for Numerically Controlled Machine Tools

RS-274 Interchangeable Perforated Tape Variable Block Format for Positioning, Contouring, and Contouring/Positioning Numerically Controlled Machines

RS-281 Electrical and Construction Standards for Numerical Machine Control

RS-350 Subset of USA Standard Code for Information Interchange for Numerical Machine Control Perforated Tape

(Application for copies should be addressed to Electronic Industries Association, Engineering Dept., 200 Eye St., N.W., Washington, DC 20006.)

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)
STANDARDS

IEEE-488 Digital Interface for Programmable Instrumentation

IEEE-770-1982 Pascal Computer Programming Language

(Application for copies should be addressed to the Institute of Electrical and Electronics Engineers, 345 E. 47th St., New York, NY 10017.)

NATIONAL ELECTRICAL MANUFACTURER'S ASSOCIATION (NEMA)
STANDARDS

MG1 Motors and Generators

(Application for copies should be addressed to the National Electrical Manufacturer's Association, 155 East 44th St., New York, NY 10017.)

NATIONAL MACHINE TOOL BUILDERS' ASSOCIATION (NMTBA)

Definition and Evaluation of Accuracy and Repeatability for Numerically Controlled Machine Tools

(Application for copies should be addressed to the National Machine Tool Builders' Association, 7901 Westpark Drive, McLean, VA 22101.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and among Federal agencies.)

1.4. Performance Acceptance Testing

Contractor Responsibility: The contractor shall provide and maintain an effective inspection system which will assure that all articles submitted to the purchaser for acceptance conform to contract requirements whether manufactured or processed by the contractor, or procured from subcontractors or suppliers. Quality assurance personnel shall perform or verify all inspections or tests. The purchaser reserves the right to perform any inspections or tests necessary to assure articles conform to prescribed requirements.

The contractor shall perform sufficient inspections of parts, components, and assemblies to assure that articles conform to the latest applicable drawings and specifications with respect to workmanship, configuration, finish, performance, and identification. These inspections shall include receiving, fabrication, assembly, end-item, and shipping phases. The contractor shall maintain calibrated suitable inspection equipment of range, accuracy, and type necessary to ensure conformance; maintain control over processes which are not readily detectable or measurable by inspection of finished articles; and maintain effective and positive control of nonconforming articles.

It is intended that documentation will be minimal; however, the contractor shall provide objective evidence of quality in the form of records of inspections. The contractor's existing documentation shall be utilized whenever possible, subject to review by the purchaser.

The supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection specified herein, unless disapproved by the purchaser. The purchaser reserves the right to perform any of the inspections set forth in the specification when such action is

deemed necessary to ensure that supplies and services conform to prescribed requirements.

1.4.1. Preshipment Examination

The purchaser reserves the right to examine the completed machine tool before it is packaged for shipment to confirm that it meets the specified requirements in Sections II.1.1 and II.1.2 above (including Table I and Table II).

The purchaser reserves the right to examine source code for the controller software to confirm that it is suitable for the requirement in Sections II.1.1 and II.1.2.

All tapes, materials, and tools required to perform and evaluate these tests shall be furnished by the supplier. The numerical control test tapes and computer printouts used shall become the property of the purchaser.

1.4.2. Operational Test

The machine and its numerical control system shall be operated in accordance with the manufacturer's standard operating test procedure for warm-up and run-off checks. During the warm-up period, proper operation of all manual controls, motors, adjustment mechanisms and accessories shall be verified. After warm-up, the machine shall be cycled continuously under numerical tape control for a period of not less than 4 hours. This operation shall include turret indexing, spindle speed, and feed rate changes that include the highest, intermediate, and lowest settings of each range, rapid traverse of all slides, simultaneous movement of slides and automatic feed cycles as applicable. The numerical control system shall be further tested to verify proper operation of MDI, program edit, and system diagnostics. Should a malfunction occur, it shall be corrected and the operational test repeated until a full 4 hours of running time is completed without failure.

1.4.3. Alignment and Accuracy Test

The machine and its numerical control system shall be tested for conformance with the alignment and accuracy requirements listed in Table IV. The evaluation of accuracy shall follow NMTBA guidelines unless otherwise specified.

To assess axis positioning accuracy and overshoot values, the following tests shall be used. Starting at positions other than the extremes of axis travel, two identical movements of each controllable linear axis shall be programmed and executed in each direction. Programmed span shall not be less than 200 mm and each digit of starting and end point shall be other than zero with respect to reference zero. Feed rate axis shall be 50mm per minute. Absolute positioning and positioning repeatability errors shall not exceed the permissible tolerances of Table IV. Similar movements of each linear axis shall be programmed at varied feed rates to test for slide overshoot at accelerated feed rate without programmed deceleration. One pass shall be programmed at feed rates nearest to 10, 20, and 100 percent of maximum linear feed rate. Automatic stops shall be programmed appropriately for inspection of control positioning accuracy.

1.4.4. Performance Accuracy Test

The machine shall be used to produce two test parts in accordance with the manufacturer's standard test methods. The supplier shall provide a test part configuration that will most effectively utilize all the capabilities of the turning center and control. The test shall include at least one cut in each mode of departure, including operations that demonstrate straight turning, taper, shoulder, facing, boring, threading, and contouring. The material used may be the supplier's choice, and the cutting speeds shall be based on the recommended SFPM for the material and tooling used for the test. The test part accuracies shall meet the requirements of Table V.

1.4.5. Maximum Horsepower Test

The machine shall be subject to a cutting test which applies not less than the full rated input power to the spindle motor for at least one minute. Spindle speed shall be chosen by the supplier as low as practical for this test without applying torque in excess of the design maximum value to any machine component. Material and dimensions of the workpiece, tooling, depth of cut, and feed rate shall be at the option of the supplier to achieve the required loading. There shall be no evidence of chatter, stalling or permanent distortion during or after the test.

1.5. Evaluation Criteria

Criteria should be evaluated roughly as follows:

- a) Mechanical specifications: 35%
- b) Control system specifications : 35%
- c) General requirements (documentation, training, etc.): 15%
- d) Price and delivery: 15%

Past performance, as it pertains to prior relevant contracts, should be considered in the evaluation of each criterion.

TABLE IV. Machine Accuracies.

The machine accuracies shall be within the given tolerances when checked in accordance with II.1.4.3.

Bedway Level

Head end: .0005"/12"

Tail end: .0005"/12"

Spindle Nose

Center runout: .0005"

Nose runout: .0003"

Face runout: .0005"

Runout of Axis of Spindle Through Hole (T.I.R.)

At nose: .0003"

At end of 12" test bar: .0006"

Parallelism of Spindle Axis With Carriage Path

Vert. plane low at end of 12" test bar: .0005"

Horz. plane low at end of 12" test bar: .0004"

Cross Slide Alignment

Concave on 12" diameter: .001"

Reversal Lost Motion (Uncompensated Rotary Feedback)

Z axis: .001"

X axis: .001"

Motion Repeatability (Unidirectional)

Z Axis: .00005"

X Axis: .00005"

Parallelism of Axis of Centers With Carriage Path in 12" Length

Vert. plane up at tail: .0008"

Horz. plane forward at tail: .002"

Repeatability of Index of Turret

End: .0003"

Face: .0003"

Parallelism of Turret Boring Bar with Carriage Path in 6"

Each position top of bar: $\pm.002$ "

Each position side of bar: $\pm.002$ "

Coincidence of Bar Holder Vertical
Centerline with Spindle Centerline

Each position: $\pm.002$ "

Parallelism of Tool Locating Surfaces
with Turret Slide Path in 4"

Each tool pocket face: $\pm.002$ "

TABLE V. Performance Test.

The machine shall perform within the given tolerances when checked in accordance with II.1.4.4.

Straight turning test, outside diameters:

Turning diameter cylindrical to within 0.001" in 12"

Turned diameter round to within 0.0003"

Facing cut, flatness, concave only 0.0007" in 10" diameter

Turned diameter to within 0.001" in 12"

Boring cut, 5" depth of bore, cylindrical to within 0.0005" and round to within 0.0005"

Thread lead error 0.001/inch

Comparison of dimensions of two test parts 0.0005" max. deviation

Test part must demonstrate surface finish not rougher than 60 microinches.

2. ROBOT SYSTEM

2.1. System Elements

The principle system elements consist of the mechanical system, which includes the arm, joints, power source and power transmissions, and the control system, which includes the means for translation of programmed instructions into position and sequence commands, and the means for measuring and regulating the configurations of the mechanical system resulting from those commands. The control system also includes a pendant for teach programming, a means to save and later access programs which reside external to the systems, and a means to program robot motions via an off-line programming language.

2.2. Performance Characteristics

2.2.1. Mechanical Requirements

Degrees of Freedom: The robot system shall be constructed of gantry design with three orthogonal positioning axes (X, Y, Z) and tool orientation axes (wrist). A total of at least 5 electric servo-driven axes.

Load Capacity: Without rotation loading, the robot manipulator shall have a minimum load capacity of 150 lbs, including end-effector, when loaded 10 inches from the end-effector mounting plate. With rotation loading, the robot shall have a minimum moment capacity of 750 in-lb.

Positioning Repeatability: +/- 0.005 inches, at full-rated load at the center of the end-effector mounting plate. The positioning repeatability requirement shall be met under all load conditions not exceeding full-rated load and at all points within the specified working volume. The system warmup time necessary to meet this specification shall be provided. If repeatability is subject to change due to load, velocity, oil and/or ambient temperatures or other factors, then data relating repeatability changes to these factors shall be provided.

Speed: A maximum translational speed, at full-rated load, of at least 16 inches per second measured at the center of the end-effector mounting plate.

Motion Specifications: Note: In defining the motions required of this robot system, reference will be made to a coordinate system attached to the tool or end effector. Specifically, imagine a simple screwdriver attached to, and orthogonal to, the end effector mounting plate as shown in Figure 1. The tip of the screwdriver blade, 10 inches from the mounting plate, is defined as the tool point and is the origin of the tool coordinate system.

The tool coordinate system consists of at least two mutually perpendicular rotation axes. The tool roll axis is the axis about which the screwdriver would rotate when advancing or retracting a screw. The tool pitch axis lies in the plane perpendicular to the roll axis which passes through the tool point. The functions of the robot manipulator are 1) to position the tool point within a defined working volume, and 2) to orient the tool coordinate system.

- a) Tool Point Positioning: The regions of space which must be accessible to the tool point are defined in Figure 2.

Region A is a rectangular prismatic volume of base 48 inches x 42 inches and a height of 36 inches. The base is 33 inches above, and parallel to, the floor. The robot must be able to position the tool point at any point within this volume as an option.

Region B is a 4 foot x 10 foot x 3 foot volume 33 inches above the floor that the robot must be able to access. Floor space occupied by the robot and its mounting structure, the robot controller, and any auxiliary equipment associated with the robot system may not be included in the regions A, B, and C.

Region C is a 4 foot x 10 foot x 3 foot volume 33 inches above the floor that the robot must be able to access as an option.

b) Tool Orientation: With the tool point held fixed at some point within the working volume defined in (a), the robot must be capable, via some combination of joint movements, of providing pure roll and either pitch or yaw motions of the tool coordinate system. The required ranges of these motions are as follows:

- 1) Tool Roll: The robot must be capable of continuous, bi-directional rotation of at least ± 160 degrees of the tool coordinate system about the tool roll axis.
- 2) Tool Pitch: With the tool point and the tool roll axis held fixed, if the robot is moved so as to cause the tool coordinate system to rotate about the tool pitch axis, then the point where the tool roll axis intersects the end effector mounting plate will move along an arc of a circle of 10 inch radius lying in the plane containing the tool roll axis and the tool yaw axis. The angle subtended by this circular arc at the tool point measures the range of tool pitch motion. The robot must be capable of providing a range of pitch motion of at least ± 105 degrees.
- 3) Tool Yaw: With the tool point and the tool roll axis held fixed, if the robot is moved so as to cause the tool coordinate system to rotate about the tool yaw axis, then the point where the tool roll axis intersects the end-effector mounting plate will move along an arc of a circle of 10 inch radius lying in the plane containing the tool roll axis and the tool pitch axis. The angle subtended by this circular arc at the tool point measures the range of tool yaw motion. The robot must be capable of giving a range of yaw motion of at least ± 105 degrees if provided.

It is to be stressed that the robot must be able to provide the full range of tool coordinate system orientations with the tool point fixed at any point within the prismatic volume of Region B, and Region A and C as option (see Figure 2).

The width of the robot wrist along the pitch axis shall not be wider than 18 inches.

2.2.2. Control System Requirements

The vendor shall furnish system level source code for the robot controller and an editor to modify the control software.

The control system shall provide for simultaneous control of all supplied electric servo-driven axes.

Motions shall be programmable relative to a point on the tool roll axis (see Figure 1) whose position is a selectable distance from the end-effector mounting plate.

The control system shall store programmed position and command sequence data, accept interfaced input and programmed data, and output command and control data to the servo systems of the robot and interlocked equipment.

The control system must have the capability for interfacing to an external device for real-time control of robot actions. This, for instance, could consist of a means to input joint coordinates to obtain the desired motions via an RS-232 link. Changes in the target point values (coordinate data) shall be possible during program execution via this communication link.

In particular, the control system shall provide the following interfacing capabilities:

- a) Position and/or velocity information sent to the robot may be updated through a communication interface at least 30 times per second, so that the trajectory of the robot may be altered in real time. The robot shall begin execution of a point within 30 milliseconds of receiving updated command information. It shall not be required that the robot come to a stop or reach the last commanded position.
- b) Through a communication interface, the robot shall return the current position of each axis and/or joint at a rate of at least 30 times per second. The resolution of this position information must allow resolving a change in position of the tool point of 0.001 inch, regardless of where the robot may be positioned within its working volume. The robot must return sufficient information to define the complete geometric configuration of the robot system. It is not sufficient to return only the position of the tool point and the orientation of the tool coordinate system.

- c) Execution of command data as specified in (a) and the return of position information as specified in (b) shall be accomplished simultaneously and independently. It will not be required that command execution be completed before returning position data, or vice versa.
- d) Through a communication interface, the robot shall return one bit of status information to signal that it has reached its commanded position within normal servo error.
- e) If the robot control system employs proportional-integral-differential (PID) servo loops, it is desirable to be able to adjust, via an interface, the gain coefficients of the integral and differential terms and, in particular, to be able to reduce them to zero.

Memory capacity resident in the control system shall be a minimum of 128 Kbytes, with 256 Kbytes desirable. The control system shall be capable of storing a minimum of 5000 programmed endpoints.

A minimum of 72 binary inputs and 48 binary outputs shall be provided, with wiring cabled to an industrial enclosure with terminals.

A user-programmable time-delay capability is desirable.

The control system shall be capable of testing inputs at programmed points and branching to different parts of its program as a result of the input state.

In addition to teach-pendant programming, the control system shall provide a high-level off-line programming language. Such high-level constructs as IF-THEN-ELSE, GOTO subroutines, subprograms, and pass-parameters are highly desirable. The vendor shall explicitly define the capabilities of this language, together with editing, error diagnostics, and tutorial capabilities. Instructions for the use of this language shall be provided.

The control system shall be capable of storing and executing programs down-loaded from an external computer or mass storage device. Program resident in control system memory shall be capable of being off-loaded onto an external mass storage device. These program transfers shall be accomplished via an RS-232 interface at a communication rate up to 9600 baud.

Program memory shall be protected from loss due to failure of AC power by a battery back up power supply. This battery back up shall provide a minimum of 72 hours of memory protection.

The control system display shall be a CRT or similar device and have the capability of displaying the coordinates of all axes and/or joints simultaneously while in the teach mode.

It is highly desirable that the control system contain high-level diagnostic capabilities with respect to the robot mechanical system and the control system electrical systems and software.

A demonstration program shall be furnished. This program should, as a minimum, manipulate each motion through its entire range and generally demonstrate the flexibility available. The program shall also, by means of the diagnostic/tutorial display system, if provided, or by a printed manual, indicate each programmed instruction used when the program is stepped, instruction by instruction, in manual mode.

2.3. Applicable Specifications, Codes, and Standards

The following specifications, codes, and standards shall be required where applicable to the robot and controller system. Detailed requirements listed in this specification shall override any contradictory portions of the following specifications, codes, and standards:

National Electrical Code, NFPA 70-1978.

Joint Industrial Conference Hydraulic Standard for Industrial Equipment and General Purpose Machine Tools H-1-1973.

Joint Industrial Conference Pneumatic Standard for Industrial Equipment 1957.

Occupational Safety and Health Standards, Title 29, Chapter XVII, Part 1910.

American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII.

2.4. General Features

2.4.1. Construction

The design and manufacture of the specified equipment shall comply with high standards, material and workmanship associated with heavy duty, precision, industrial machinery. All components shall be constructed for long life under continuous service. The robot system, including the controller, is expected to perform as specified under a reasonable range of relative humidities and ambient temperatures. The manufacturer shall specify the appropriate limits.

- a) The machine shall be so constructed that when installed and connected to power, it will be ready for operation upon filling with operating fluids. The machine shall be constructed of parts which are without defects and free of repair. The structure shall be capable of withstanding all forces encountered during operation of the machine to its maximum rating and capacity without permanent distortion.
- b) All castings and forgings shall be free of defects, scale and mismatching. No process such as welding, peening, plugging, or filling with solder or paste shall be used for reclaiming any defective part.
- c) All surfaces of castings, forgings, molded parts, stampings and welded parts shall be cleaned and free from sand, dirt, fins, sprues, flash, scale, flux, and other harmful or extraneous materials. All edges shall be rounded or beveled unless sharpness is required to perform a necessary function. Except as otherwise specified herein, the condition and finish of all surfaces shall be in accordance with the manufacturer's standard commercial practice.
- d) All words on instruction plates shall be in the English language, engraved, etched, embossed or stamped in boldface characters on a contrasting background.
- e) The overall design of the machine shall place emphasis on the accessibility, maintainability and reliability of components. Replacement and/or adjustment of components shall be possible without major machine disassembly.
- f) All primary operator controls (buttons, switches, levers, gauges, meters, regulating devices, etc.) shall be functionally grouped and permanently identified.
- g) Protective covers shall be provided to eliminate the entry of foreign matter into the moving parts of the machine.

- h) Adjustable leveling devices and anchor bolts shall either be supplied with the machine or the requirements for them shall be specified as part of the bid proposal.
- i) The equipment shall be delivered complete and ready to operate after being installed and connected to shop utilities. The manufacturer shall state estimated or design figures for required utilities.

2.4.2. Electrical Equipment

- a) Electrical equipment and its installation shall comply with the intent of the NFPA standards.
- b) The machine and all its sub-systems shall operate from one basic terminal utilizing 460V plus or minus ten percent, 60 Hz, 3 phase or 115 V, single phase, 60 hertz power. The main power disconnecting device (fuse disconnect or breaker) NEMA 12 enclosure, shall be supplied and mounted by the Manufacturer. All other power supplies shall be derived from this basic power source. Disconnecting device shall be lockable in OFF position.
- c) An identified terminal shall be provided, suitable for connection of a grounding conductor. The electrical system shall meet or exceed the electromagnetic interference characteristics of MIG welding power supply equipment.
- d) Control circuits shall be 115V AC or lower. Control circuits of 24V DC are preferred.
- e) All interconnecting wires and cables between stationary terminal points of the machine systems and the machine control cabinets shall be enclosed in oiltight sheet metal, with hinged or detachable covers, wire troughs, or conduit. All wire terminations shall be identified as shown on wiring diagrams. All interconnecting wiring, conduits, gutters, etc., shall be furnished by the manufacturer.
- f) All control and power cables connecting stationary and moving members of the machine shall be protected from damage by abrasion and shall be supported by power track or otherwise include strain relief devices to prevent conduits from pulling out of their fittings.

2.4.3. Lubrication

- a) All sliding and rotating parts, except sealed-for-life type bearings, shall be provided with means for lubrication.
- b) The points of adjustment shall have provisions for periodic lubrication as required.
- c) All filter and/or lubrication points shall be properly identified with type of lubricant and lubricating instructions.
- d) All systems shall be capable of operating a minimum of 40 hours without replenishment of the lubricant supply.

2.4.4. Noise

Noise generated by machines shall not exceed a level of 85 DBa at the operator's station. When feasible, noise levels shall not exceed 80 DBa. Manufacturer will state the guaranteed maximum noise level.

Particularly noisy components shall be suitably soundproofed. An enclosure may be used for this purpose.

2.4.5. Interchangeability

All replaceable parts shall be manufactured to definite standards or tolerance, clearance and finish in order that any such part may be field-installed without further machining. All parts shall be permanently marked with the original manufacturer's part number, where practical.

2.4.6. Color

- a) All exterior surfaces of the machine and control cabinets, except wear surfaces, shall be painted. The manufacturer will quote standard colors available.
- b) All interior surfaces of the machine and control cabinets, except wear surfaces, shall be painted an oil resistant light color per industry accepted standard.
- c) The manufacturer is responsible for the selection of a paint composition impervious to the lubrication used on the machine.

2.5. Safety

- a) The manufacturer is requested to make recommendations for safe manual or mechanical handling systems for moving parts into or out of the equipment and for holding of parts where applicable.
- b) Mechanisms, devices, machine structure, motors, gear-boxes, etc., which will be handled during erection and removed occasionally for maintenance or replacement shall be equipped with safe lifting attach points (i.e., lift lugs, lift rings).
- c) Essential safety operating instructions shall identify safety and health hazards associated with the equipment and the procedures and practices necessary for safe operations. These instructions shall be permanently placarded on the equipment.
- d) Weight in pounds of machine assembly or machine components in excess of 1000 pounds shall be marked in visible location for assembly maintenance handling.
- e) Placards shall be provided to warn operator or maintenance personnel of injury hazards, such as intermittent motion, stored energy systems, or restricted clearances.
- f) Covers, guards, or other safety devices shall be provided for all parts of the machine that present safety hazards. The safety devices shall prevent unintentional contact with the guarded part, and shall be removable to facilitate inspection, maintenance and repair of the parts. All machine parts, components, mechanisms, and assemblies furnished on the machine, whether or not specifically required herein, shall comply with all of the standards promulgated under OSHA that are applicable to the machine itself.
- g) If the robot is stopped at a command position and loses electrical power, the tool point shall move no more than three inches, for any load not exceeding the rated load.
- h) The vendor will furnish the time (seconds), the amount of travel and overshoot (degrees at the gripper) for the extended arm to stop from maximum swing speed under emergency shutdown.
- i) All electrical units shall include electrical and safety interlocks as required for the protection of the system, machine, and the operator.

2.6. Final Inspection

- a) The manufacturer shall inspect and test the machine at his facility to ensure that the equipment conforms to the specification. At the option of the buyer, a representative of the buyer may be in attendance during the final tests.
- b) The manufacturer shall supply the detailed testing procedure by which he intends to test the finished machine.
- c) Certified inspection sheets, signed by an official of the manufacturer, listing all inspection and test results shall be forwarded to the buyer prior to authorization for shipment of the machine.

2.7. Documentation and Support

2.7.1. Manuals

The manufacturer shall furnish five copies each of the following manuals or equivalent documentation prior to machine installation.

- a) Operator's Manual - shall provide a complete description of the function, operating range and capacity of the machine, including drawings, diagrams, etc., of the location and operation of all indicating, operating, and control devices and instructions on use of all control devices. This manual shall keynote safety hazards and cautions.
- b) Programming Manual - shall provide a complete description of how to program the system. It shall fully cover the teach method including appropriate examples. The off-line programming system shall also be fully described. The use of an external program storage device shall be described. Full explanation of any diagnostics shall be provided.
- c) Maintenance Manual - shall be complete to the extent of providing detailed instructions to service every component and assembly of the equipment and shall include:

The exploded view or cross-sectional type drawings showing all mechanical components in their relative positions and identified by part number referenced to the applicable section of the parts book.

The recommended preventive maintenance schedule, including frequency, normal time to accomplish, detailed step-by-step procedure, parametric data to establish component replacement control, and lubrication schedule.

A chart or separate section shall provide troubleshooting aids for both the control system and the robot.

2.7.2. Additional Documentation

In addition to the manuals described above, the manufacturer shall provide complete specification of the control system communication interfaces, including control information, data representation, logic levels, communication protocols, and hardware and electrical connection requirements.

If the control system communication interfaces are not standard options on the robot system, then they, and the documentation supporting them, should be provided by the manufacturer through a non-disclosure agreement, in order to protect any proprietary aspects of the control system.

2.7.3. Parts and Service

A listing of all components by part number, description and manufacturer shall be furnished.

A complete recommended spare parts package and list which includes modular components of the control system as well as robot parts subject to failure shall be provided.

The location of the nearest source of parts and service support shall be furnished.

2.7.4. Installation and Drawings

Manufacturer's drawings showing layout, design, and specification of foundation (including anchor bolt dimensions with concentric leveling devices) and the location and size of all required utilities shall be provided.

The following shall be supplied at least 30 days prior to shipment of the machine:

- a) The installation and handling instructions, including net and shipping weights.

- b) Three copies of electrical and electronic schematics, pneumatic schematics.
- c) An outline sketch showing outside dimensions, support bearing area, general arrangement and weight of the proposed equipment.
- d) A dimensional sketch of the work volume available to the center of the gripper mounting plate.

The manufacturer shall provide the services of a trained field engineer for supervision of erection and alignment.

2.7.5. Training

One week of training in programming shall be provided for two persons at the Manufacturer's facility.

One week of training in maintenance shall be provided for two persons.

Documentation and support require the manufacturer to supply manuals of at least three types. These are an operator's manual, a programming manual, and a maintenance manual.

2.8. Performance Testing

Final acceptance shall be contingent upon the robot system meeting the specifications and requirements set forth in this document, after final installation.

Load Capacity Test: a steel weldment in the form of a cube, weighing 150 pounds, will be bolted to the end-effector mounting plate. The robot will be expected to manipulate this load within the specified work volume.

Positioning Repeatability Test: The weldment used in the load capacity test will be fitted with gage blocks on each of the three orthogonal faces near one corner, in order to provide reliable gaging surfaces. The robot will repeatedly move this weldment to a gaging station consisting of three mutually perpendicular dial indicators, each of which will contact one of the gage blocks. The positioning repeatability will be measured with at least two directions of approach to the gaging station, and with at least two orientations of the tool coordinate system.

The repeatability test will be performed with the gaging station at three different points selected by the buyer. These points will be located within Region B (see Figure 2). None of these points will be located within six inches of any limit of travel of the robot manipulator.

Pitch and/or Yaw Tests: A steel shaft, 10 inches long and 1/4 inch in diameter will be attached to the center of the end-effector mounting plate, with one end of the shaft at the tool point. With the tool point fixed, the robot will be programmed to provide pure pitch and yaw motions of the tool coordinate system. The ranges of these pitch and yaw motions will be measured with a transparent protractor and mirror, arranged so as to eliminate parallax errors.

Region B Tests: Using a diagram supplied by the manufacturer, posts will be placed within Region B in order to delineate the 40 square feet of floor space, at heights between 33 inches and 69 inches above the floor, accessible to the robot tool point. Within this accessible volume, three posts will be placed at positions selected by the buyer, and it will be verified that the robot can position the tool point at all of them.

Control System Tests: The robot control system will be exercised in order to implement mechanical testing of the robot system. In the process of these exercises, the buyer will verify conformance of the control system with the specifications set forth in this document.

Power Failure Tests: With a test program loaded into the control system memory and the one foot cubic weldment attached to the end effector mounting plate, the following tests will be performed.

- a) With the robot stopped at a commanded position, AC power will be removed from the robot system. Any subsequent motion of the tool point will be measured.
- b) With the robot in process of executing a programmed move, AC power will be removed from the robot system. Any subsequent motion of the tool point will be noted, and to the extent possible, measured.
- c) After a period of not less than 24 hours, following power loss, AC power will be restored to the robot system. It will be verified that the test program is still resident in the control system memory.

2.9. Evaluation Criteria

Procurement Specifications

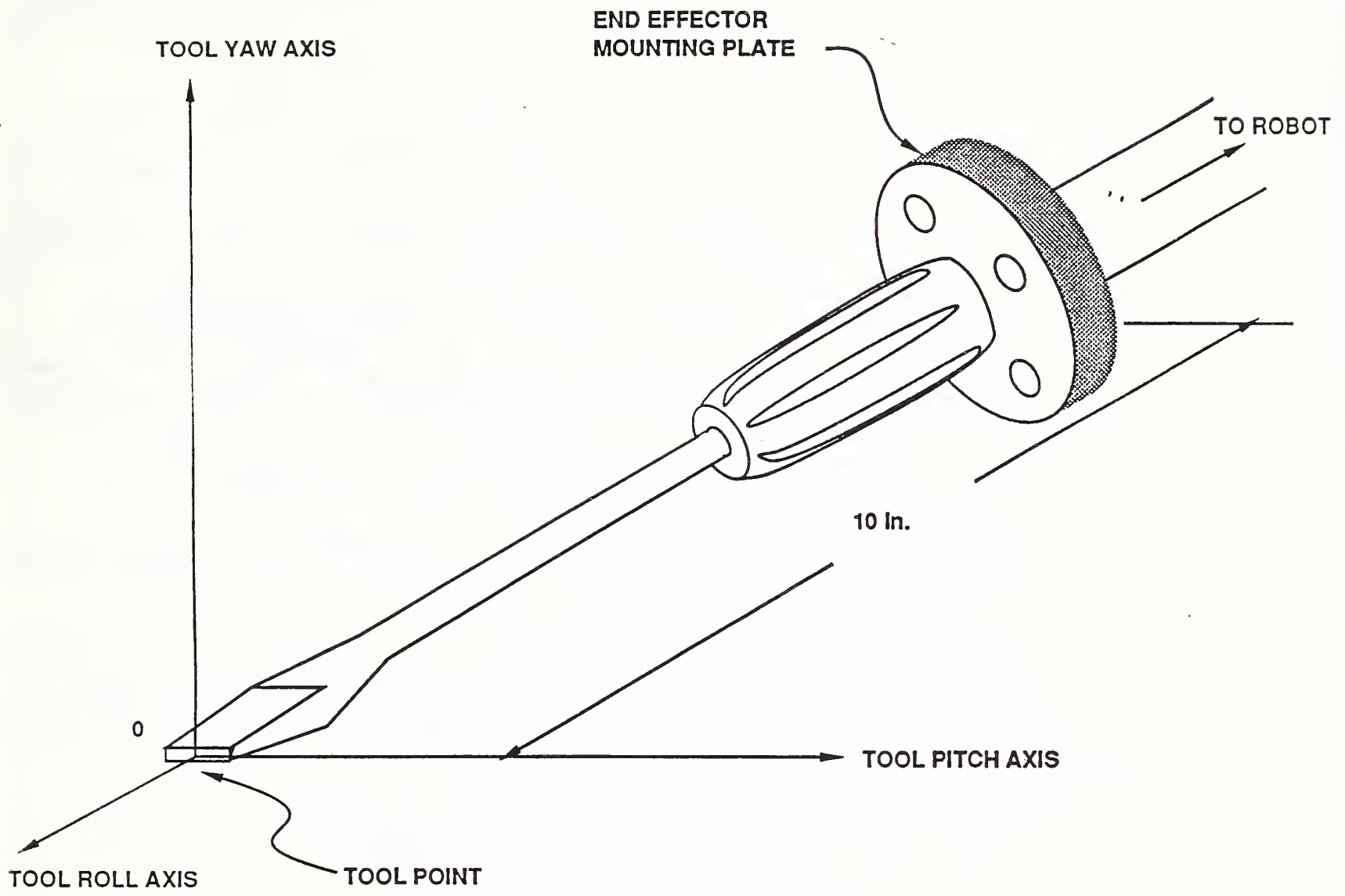
Evaluation criteria concerns the weight given to specific components when evaluating proposals. An example of both criteria and possible weight assigned is as follows:

- a) Mechanical specifications: 35%
- b) Control system specifications : 35%
- c) General requirements (documentation, training, etc.): 15%
- d) Price and delivery: 15%

Past performance, as it pertains to prior relevant contracts, should be considered in the evaluation of each criterion.

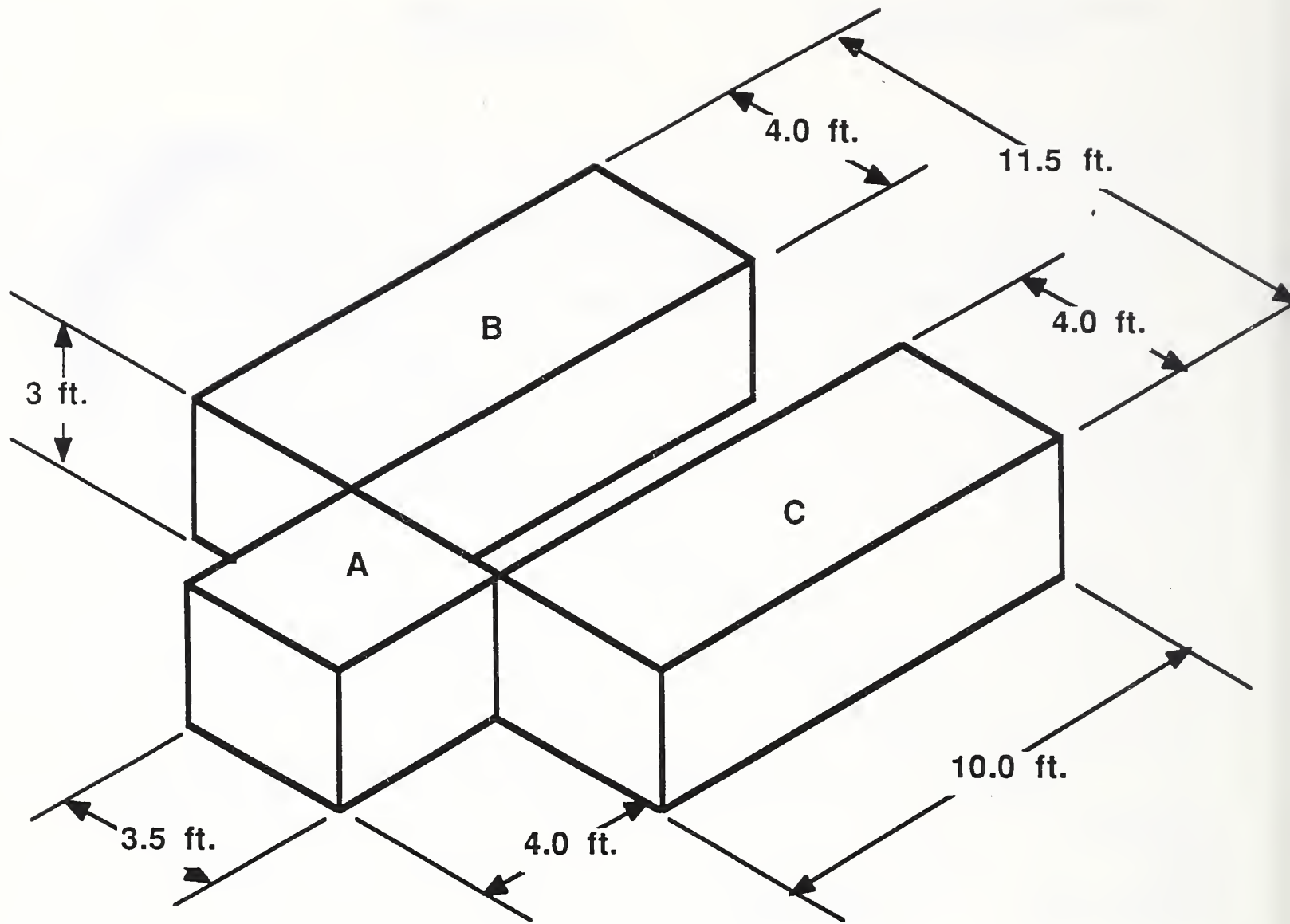
III. SUMMARY

The aforementioned recommended technical specifications for the procurement of commercially available systems are intended to be used as a general guide only. The specifications need to be modified so as to tailor them to the user's specific needs.



The Tool Coordinate System

Figure 1.



Robot must be able to access volumes A, B, and C.

A - 4.0 ft. x 3.5 ft. x 3.0 ft. prismatic volume with base located 33 inches above the floor.

B and C - 10.0 ft. x 4.0 ft. x 3.9 ft. prismatic volume with beside located 33 inches above the floor.

Space Accessible by Robot

Figure 2.

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET <i>(See instructions)</i>	1. PUBLICATION OR REPORT NO. NISTIR 88-3811	2. Performing Organ. Report No.	3. Publication Date JUNE 1989
4. TITLE AND SUBTITLE Recommended Technical Specifications for Procurement of a Turning Workstation.			
5. AUTHOR(S) Kang B. Lee			
6. PERFORMING ORGANIZATION <i>(If joint or other than NBS, see instructions)</i> NATIONAL BUREAU OF STANDARDS U.S. DEPARTMENT OF COMMERCE GAITHERSBURG, MD 20899		7. Contract/Grant No.	8. Type of Report & Period Covered
9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS <i>(Street, City, State, ZIP)</i> U. S. Navy Manufacturing Technology Program			
10. SUPPLEMENTARY NOTES <input type="checkbox"/> Document describes a computer program; SF-185, FIPS Software Summary, is attached.			
11. ABSTRACT <i>(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)</i> This manual serves as a technical guide to the specifications required to procure commercially available, major components such as a turning center and a robot system for an automated turning workstation.			
12. KEY WORDS <i>(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)</i> Turning center specification, robot specification, performance test, procurement.			
13. AVAILABILITY <input checked="" type="checkbox"/> Unlimited <input type="checkbox"/> For Official Distribution. Do Not Release to NTIS <input type="checkbox"/> Order From Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. <input checked="" type="checkbox"/> Order From National Technical Information Service (NTIS), Springfield, VA 22161		14. NO. OF PRINTED PAGES 48	15. Price \$12.95

