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RECOMMENDED TECHNICAL SPECIFICATIONS FOR PROCUREMENT OF SYSTEMS FOR THE INSPECTION WORKSTATION

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I. INTRODUCTION

1. WHAT THIS MANUAL IS ABOUT

This manual furnishes technical specifications of the Inspection Workstation (IWS) in the Automated Manufacturing Research Facility (AMRF) at the National Bureau of Standards (NBS). These specifications should be useful when procuring inspection and computer equipment for an automated facility modeled after the IWS.

2. AUDIENCE

This manual is targeted for technical personnel who wish to procure inspection and computer equipment for an automated inspection facility.

3. OVERVIEW

Chapter II describes technical specifications of the main IWS inspection equipment—a coordinate measuring machine, a surface roughness instrument, and a part-handling robot.

Chapter III describes technical specifications of the computer equipment which controls the main IWS inspection equipment.

Next, Chapter V describes technical specifications of the miscellaneous IWS equipment—an automatic dial indicator and an electronic safety fence.

The appendices consist of useful information. Appendix A lists the entire IWS documentation set. References specific to the IWS are listed in Appendix B. Appendix C contains a glossary of terms used in this document.

Completing the document is a reader comment form. The reader is encouraged to write down comments and mail the attached form to the address specified.

II. MAIN INSPECTION WORKSTATION EQUIPMENT SPECIFICATIONS

The main IWS inspection equipment is made up of a coordinate measuring machine (CMM), a surface roughness instrument (SRI), and an inspection (part-handling) robot.

1. COORDINATE MEASURING MACHINE SPECIFICATIONS

The CMM is a modified four-axis moving-table horizontal arm type coordinate measuring machine. It is a displacement measuring device which provides digital readout for the distance travelled by a movable machine component. The travelling component, a gage head with the mounted sensing probe, is guided along three mutually perpendicular, straight-line paths contained in common planes representing the X, Y, and Z axes of a Cartesian system of coordinates.

1.1. Machine Description

The CMM has three components that move along mutually perpendicular guide ways. The measuring probe is mounted to a cantilevered beam (horizontal arm). The horizontal arm is supported at one end only by a vertical support column and has the capability to move up and down on its support column. The support column may move from side to side on the base of the machine. The support column and the horizontal arm provide positioning along the CMM's X and Y machine coordinate axes, respectively. The staging table is an airlifted rotary table that moves back and forth on the machine base to provide positioning along the CMM's machine coordinate Z-axis.

The machine column supporting the horizontal arm (ram) and probe move along the X-axis on roller bearings. The Y-axis is the vertical axis. The ram moves up and down the column on recirculating ball bearings and is counterbalanced by means of a dead weight supported by a steel cable. The Z-axis is the staging table, or horizontal axis, of the machine. The table may be moved to relocate the part instead of maneuvering the probe. Moreover, the staging table rotates to permit 360-degree exposure of workpiece (part) features to the measuring probe without repositioning the part.

1.2. Dimensional Measurement

The CMM provides dimensional measurement by touching a workpiece (part) at various points on the part with a measuring probe. Dimensional measurement may be performed by moving the part to be measured and/or the measuring probe along the three mutually perpendicular axes. The outcome of the inspection will typically be a comparison of the measured geometry with the nominal specified by the part design.

1.3. PH9 Measuring Probe

The principal measuring probe of the CMM is a motorized two-axis, three-dimensional probe (Renishaw PH9). This measuring probe is force sensitive and sends a latch signal to the CMM microprocessor upon touching a part. The adjustable touching force is maintained at approximately 5 grams for normal IWS operation. When the probe is displaced, the circuit is interrupted and at a set resistance value the signal is sent to the processor to read the scales. While the low force of 5 grams allows most parts to be measured without being secured to the table, small parts should be secured in a fixture or held in place with a magnetic or vacuum chuck.

The PH9 processor is programmable for sixty-four different tip positions. This processor has a battery supported memory unit that can retain the probe orientations for several hours in case the machine is turned off or its power supply is interrupted.

1.4. Machine Operation

The CMM is equipped with servos for remote control or direct computer control (DCC) of measuring probe positioning to meet application requirements for operating in either manual or automatic (computer-controlled) mode, respectively. The CMM functions in the automatic mode for all IWS operations except for the positioning of the probe to the 0,0,0 machine position and the initial calibration of the probes.

1.5. Built-in Microprocessor-based Control

Microprocessor-based firmware furnished by the CMM manufacturer provides fundamental machine operations—metric/inch conversion, linear data display, part reference implementation, part alignment, point handling, measuring probe positioning, coordinate measurement data processing and calculations, and error handling. Programmed servo positioning is not possible through the firmware, but initial part setup, limited measurement calculations, and manual servo positioning are available through the remote control unit (RCU) machine controls. The RCU is equipped with joysticks for operator control of machine movement.

1.6. Remote Microprocessor Machine Control

The CMM is controlled by an integrated, data-driven, hierarchical control software system called the Coordinate Measuring Machine Controller (CMMC). The CMMC program is written in Hewlett-Packard (HP) Pascal 3.0 Language System which provides a level of software control and flexibility necessary to implement essential IWS software applications. This controller is an NBS product and is, therefore, not commercially available.

Machine-related functions available in the CMMC function library help the CMMC software system control the CMM. The library includes software responsible for interfacing between the higher level commands executed by the CMMC program and the corresponding firmware level commands at the CMM's microprocessor level. The CMMC function library was translated into HP Pascal 3.0 from the Function Library BASIC (FLB) originally written in HP BASIC 2.0 and supplied by the CMM manufacturer.

1.7. General Coordinate Measuring Machine Specifications

The CMM should be equipped with an acceptable level of technical features, as outlined in Sections 1.1 through 1.6, to enable the inspection facility to measure dimensional tolerances of machine parts manufactured by the production facility. The CMM employed in an automated workstation fashioned after the IWS could be able to inspect a wide range of part sizes, shapes, and weights.

Next, the CMM should be designed with a standard communications interface suitable (i.e., Hewlett-Packard Interface Bus (HP-IB), General Purpose I/O (GPIO), RS-232 (Serial), etc.) for connecting to a host computer. The interface should permit both commands and data to be transmitted from the host computer to the machine as well as status information and data to be transmitted from the machine to the host computer.

Perhaps, a two-axis measuring probe could be installed to permit probe positioning in two axes and by that means minimize frequent part refixturing.

1.8. Machine Functionality

The CMM should implement commercial functions that are initiated remotely. These functions include:

(a) Initializing the CMM to a fixed position at system startup and/or automatic (computer-controlled) zero probe calibration;
(b) Moving the probe to a specified location in free space;
(c) Moving the probe and touching the part at a specified location on the part and saving the location data for the point touched;
(d) Setting the probe free space and touch speeds; and

(e) Selecting PH9 probe tip orientations (for CMM models equipped with a PH9 measuring probe).

The document Implementation of the CMM Controller [A.3] describes these functions in further detail.

2. SURFACE ROUGHNESS INSTRUMENT SPECIFICATIONS

The SRI is a photo-optical surface roughness instrument. This portable, hand-held commercial device provides non-contact, real-time surface roughness inspection.

2.1. Instrument Description

The principal components of the SRI consist of an optical scattering sensor and an electronic control unit. The sensor is mounted to an NBS-designed and manufactured holder. As a safety feature, the holder is seated directly on three ball bearings. This feature enables the sensor to pitch in order to tolerate inadvertent impacts sustained from the robot gripper or inspection parts inspected during normal inspection cycles.

The SRI sensor consists of a light emitting diode (LED) and twenty optical detectors (linear array of twenty photodiodes) mounted in a tube. The LED emits radiation at a near infrared wavelength frequency of 810 nanometers. This radiation is emitted first through a collimating lens, then through one side of a special measuring lens that focuses and redirects the radiation so that it illuminates the surface to be measured at a slight angle of incidence but very close to the optical axis. Typically, the radiation reflected, or scattered, by the measuring surface then passes through the other side of the measuring lens and is redirected to a linear photodiode array which measures a line sample of the scattered light beam to obtain an angular distribution of light intensity. A root mean square (rms) roughness value is estimated based on empirical analysis.

Inspection of the surface finish, or roughness, of parts manufactured by the AMRF has typically required a straight-design (type 40) measuring head having a measuring spot diameter of 1.8 millimeters. Special measuring spot diameters between 0.2 and 4.0 millimeters may be used for special applications.

2.2. Surface Roughness Measurement

The SRI provides surface roughness inspection by measuring the angular distribution of light scattered from the surface of the part. All measurements performed by the SRI are closely coordinated with the IWS robot and the automatic dial indicator (ADI). Valid optical scattering readings are obtained when the robot properly aligns the surface of the part in a direction essentially perpendicular to the plane of the SRI. The ADI is used to help the robot position the part in front of the SRI for its initial reading. Using the SRI optical signals as sensory input, the robot properly aligns the surface of the part in front of the SRI so that a valid optical scattering reading is obtained.

The SRI uniquely characterizes the surface roughness of machined parts. If the surface is smooth, the pattern of scattered light falling on the photodiode array is nearly the same as the circular pattern of the incident beam leaving the collimating lens. On the other hand, the scattered light pattern is broadened when the surface is rough. If the pattern of marks (lay) left on the surface by the finishing process is unidirectional, the scattered light pattern is elongated along the roughness direction. Various finishing processes, including milling, grinding, and turning, leave unidirectional machining patterns on the surface of a part and, therefore, yield elongated scattering patterns. Care must be taken to align the part so that the elongated scattering pattern is parallel to the long axis of the photodiode array.

Critical parameters of the optical system include the angle of incidence of the light (α), the angular resolution and angular range (β) of the detected scattering light pattern, the illuminated spot size (y'), and the axial distance of the surface from the measuring lens. The unitless light scattering parameter (S_N) output by the optical sensor serves as a measure of surface roughness. S_N is proportional to the variance of the intensity distribution about the mean (M) of the data. As a result of normalizing the integral of the intensity distribution, S_N is independent of the reflectivity of the inspection part test surface. The outcome of the inspection will typically be a comparison of the measured roughness with the nominal specified by the part design.

2.3. Part Fixturing and Alignment

The robot is exclusively accountable for part relocation and alignment. The alignment of the part must coincide with the axial orientation of the SRI sensor. Therefore, the approach for proper axial alignment of the part surface requires taking successive measurements of the part surface and subsequently aligning the part with respect to pitch, yaw, and roll.

2.4. Instrument Operation

The coupling of SRI and IWS robot operations during remote or automatic control of part positioning enables the IWS to meet application requirements for operating in either manual or automatic mode, respectively. The SRI functions in the automatic mode for all IWS operations except for the initial calibration of the SRI sensor.

2.5. Built-in Microprocessor Instrument Control

Microprocessor-based firmware furnished by the SRI manufacturer provides fundamental instrument operations—data display, automatic self-testing, single and continuous measurement, surface roughness data processing and calculations (statistics), and error handling. Complex surfaces and their microstructure may be described by means of stand-off distance, tilt, surface curvature, object movement, and/or contamination. Equipment functions can be controlled through a standard interface from a remote computer.

2.6. Remote Microprocessor Instrument Control

The SRI is controlled by an integrated, data-driven, hierarchical control software system called the Surface Roughness Instrument Controller (SRIC). The SRIC program is written in the HP Pascal 3.0 Language System which provides a level of software control and flexibility necessary to implement essential IWS software applications. This controller is an NBS product and is, therefore, not commercially available.

Machine-related functions available in the SRI function library help the SRIC software system control the SRI. The library includes software responsible for interfacing between the higher level commands executed by the SRIC program and the corresponding firmware level commands at the SRI (machine) microprocessor level.

2.7. General Surface Roughness Instrument Specifications

The SRI should be equipped with an acceptable level of technical features, as outlined in Sections 2.1 through 2.6, to enable the IWS to determine the surface roughness of machine parts manufactured by the production facility. The SRI employed in an automated workstation fashioned after the IWS should be able to inspect a wide range of surface textures. The technical features of the SRI should include rapid data collection, simple handling and ease of use, high reliability and ruggedness, correlation of measured values to standard values in specified production processes, and capability of integrating in automatic testing stations.

Next, the SRI should be designed with a standard communications interface suitable (i.e., Hewlett-Packard Interface Bus (HP-IB), General Purpose I/O (GPIO), RS-232 (Serial), etc.) for connecting to a host computer. The interface should permit both commands and data to be transmitted from the host computer to the machine as well as status information and data to be transmitted from the machine to the host computer.

2.8. Instrument Functionality

The SRI should implement commercial functions that are initiated remotely. These functions include initializing the SRI at system startup and retrieving and transmitting scattering (S_N), intensity (I), and individual detector reading (I_i) values. The document Implementation of the SRI Controller [A.4] describes these functions in further detail.

3. INSPECTION WORKSTATION ROBOT SPECIFICATIONS

The IWS robot is a standard six-axis robot. The principal applications of the robot consist of relocating inspection parts throughout the IWS and working in concert with the SRI to position a part in front of the SRI sensor as required.

3.1. Machine Description

The principal components of the robot consist of a six-axis attachment (robot arm), an NBS-designed and manufactured material handling gripper, a computer numerical control (CNC) controller, and a teach pendant. The robot arm is custom mounted upside down on an overhead gantry. The gantry enables the robot arm to reach essential areas in the IWS.

The robot has two asynchronous modes of movement—position and track. In position mode, the robot can be moved at six axes, or joints. The six axes of the robot arm are the waist axis, the shoulder axis, the elbow axis, the wrist rotate axis, the wrist flex axis, and the hand roll axis. In track mode, the robot can be moved along the gantry track.

The material handling gripper is mounted on the hand faceplate of the robot arm. The gripper is guided along three mutually perpendicular, straight-line paths contained in common planes representing the X, Y, and Z axes of a Cartesian system of coordinates.

3.2. Work Capacity

The defined work volume of the IWS robot is 72 inches by 40 inches by 40 inches approximately three feet from the floor. When the robot arm is fully extended, it has a maximum reach of 40 inches. The gantry axis travel is 72 inches. The maximum load, or lifting, capacity of the IWS robot arm is approximately 50 pounds.

3.3. Workpiece Handling Gripper

The robot is equipped with a prototype (NBS-designed and manufactured) robot gripper to meet the demands of the IWS for relocating inspection parts manufactured by the AMRF. The two-fingered gripper can secure a maximum part size of 5-3/4 inches. Its stroke distance (e.g., maximum distance - minimum distance) is 6 inches. Its fingers move in straight-line paths to maintain parallelism.

The gripper is actuated by compressed air adjustable up to a recommended maximum air pressure of 60 pounds per square inch. At the recommended maximum air pressure, a force of approximately 50 pounds is exerted by the fingers, which is adequate to handle the tasks of relocating inspection parts. The air pressure is not adjustable under automated control so fragile parts are likely to be damaged.

3.4. Machine Operation

The robot is equipped with servos for remote control or direct computer control (DCC) of robot and part handling gripper positioning to meet application requirements for operating in either manual or automatic (computer-controlled) mode, respectively. The robot functions in the automatic mode for all essential IWS operations except for teaching the robot and initial calibration of the robot.

3.5. Built-in Microprocessor-based Control

Microprocessor-based firmware furnished by the robot manufacturer provides fundamental machine operations—robot arm alignment, part handling gripper positioning, robot "teach" operations, robot program implementation, and error handling.

Seven independent 6809 microprocessors are dedicated to single tasks of controlling a single robot axis motor. All of the 6809 microprocessors are coordinated by a central Motorola 68000 microprocessor. This central microprocessor is responsible for performing major computing tasks while coordinating the activity of the 6809 systems.

The robot is equipped with a hand-held teach pendant/joystick for operator control of robot activity.

3.6. Manual Robot Control

The fundamental manual control of the robot is a teach pendant. The teach pendant includes a twenty key keypad with four different modes, furnishing eighty available commands. On the same pendant is a joystick control for the robot, with three degrees of freedom available at any one time. The joystick can regulate robot arm, elbow, or gripper movement in X, Y, and Z axes, or it can control pitch, yaw, and roll; the two modes "position" and "orientation" are selected by a switch. Additionally, there is a motor "ON/OFF" button and a program "RUN/STOP" rocker switch.

3.7. Remote Microprocessor Robot Control

The robot is controlled by an integrated, data-driven, hierarchical control software system called the Inspection Robot Controller (IRC). The IRC program is written in the HP Pascal 3.0 Language System which provides a level of software control and flexibility necessary to implement essential IWS software applications. This controller is an NBS product and is, therefore, not commercially available.

Machine-related functions available in the IRC function library help the IRC software system control the robot. The library includes software responsible for interfacing between the higher level commands executed by the IRC program and the corresponding firmware level commands at the robot (machine) microprocessor level.

3.8. General Robot Specifications

The standard robot should be equipped with an acceptable level of technical features, as outlined in Sections 3.1 through 3.7, to enable the IWS to automatically relocate inspection parts.

The robot should be capable of positioning an inspection workpiece to an accuracy of 0.25 inch within a defined working volume of approximately 70 cubic feet. This working volume, or region, includes three work areas—the delivery platform, the CMM table, and the SRI measurement region. The motion in the latter region requires a supplementary linear robot motion.

The robot should be equipped with a workpiece handling gripper capable of spanning a pick-up dimension of all machined parts as well as lifting and transporting these parts in a safe and proficient manner.

The robot should be designed with a suitable interface for connecting to a host computer permitting both commands and data to be transmitted from the host computer to the robot and status information to be transmitted from the robot to the host computer.

The control system of the robot should provide a teach mode, such as teach-pendant programming, whereby robot positions may be precisely measured and recorded. The resolution of this mode should be less than 0.005 inches.

The control system of the robot should include a programmable microprocessor with normal utility programs to simplify routine tasks such as writing robot programs, the storage and retrieval of these programs, file management, and communication between peripherals. This level of software sophistication allows the user to write programs which interface to the robot controller (IRC). The controller program will have to be modified at the machine module level to be interfaced to the robot.

3.9. Machine Functionality

The robot should implement commercial functions that are initiated remotely. These functions include:

(a) Initializing the robot to a fixed position at system startup;
(b) Automatic (computer-controlled) robot arm and material handling gripper calibration;
(c) Moving the robot arm and/or gripper to a specified location in free space;
(d) Moving the robot arm and/or gripper and retrieving a part from a specified location;
(e) Moving the robot arm and/or gripper and relocating a part from one specified location to another;
(f) Moving the robot arm and/or gripper and delivering a part to a specified location; and
(g) Setting the robot arm and/or gripper "move" speed and mode.

The document Implementation of the Robot Controller [A.5] describes these functions in further detail.

III. COMPUTER SYSTEMS EQUIPMENT SPECIFICATIONS

The IWS equipment and instruments are controlled by a integrated network of four Motorola 12.5 megahertz MC 68000 microprocessor-based microcomputers with 16-bit internal architecture. Each microcomputer is delegated specialized functions with respect to the inspection facility. Their respective tasks include main Inspection Workstation controller (WSC), coordinate measuring machine controller (CMMC), surface roughness instrument controller (SRIC), and inspection robot controller (IRC). These microcomputer systems allow the IWS to operate in stand-alone and integrated modes.

1. PRINCIPAL HARDWARE AND SOFTWARE COMPONENTS

Each of the four computer systems of the IWS consists of a selection of the following hardware and software components:

- (a) Hewlett-Packard (HP) 9000 Series 200 Microcomputer (Model No. 9920U or Model No. 9836U);
- (b) HP 12-inch Monochromatic Monitor (Model No. 82913A) (applicable for HP 9000 Series 200 Microcomputers (Model No. 9920U) only);
- (c) HP-HIL Nimitz Keyboard (Model No. 9820B) (applicable for HP 9000 Series 200 Microcomputers (Model No. 9920U) only);
- (d) HP 16.7-Megabyte (MByte) CS/80 Winchester Disc (Model No. 7908P) or 28.7 Mbyte CS/80 Winchester Disc (Model No. 7911P);
- (e) HP 286.72-Kilobyte (KByte) AMIGO Dual 3-1/2 Inch Flexible Disc (Model No. 9121D);
- (f) HP 1.0-MByte Random Access Memory (RAM) Card (Product No. 98257A);
- (g) HP 256-KByte RAM Card (Product No. 98256A);
- (h) HP Keyboard/HP-IB Interface Card (Product No. 9920A) (applicable for HP 9000 Series 200 Microcomputers (Model No. 9920U) only);
- (i) HP Composite Video Interface Card (Product No. 98626A);
- (j) HP Interface Bus (HP-IB) Interface Card (Product No. 98626A);
- (k) HP RS-232 Serial Interface Card (Product No. 98626A);
- (l) HP General Purpose Input/Output (GPIO) Interface Card (Product No. 98622A);
- (m) HP Programmable Data Communication Interface Card (Adds DCE (female, direct-connect) RS-232 cable) (Product No. 98628A/98691A Option 002); and
- (n) HP Pascal 3.0 Language System (Product No. 98615A Option 630).

1.1. Main Inspection Workstation Computer System

The principal hardware and software components of the main IWS computer system include an HP 9000 Series 200 Microcomputer (Model No. 9820U), several RAM boards, one HP-IB interface board, one RS-232 serial interface board, one GPIO interface board, three data communications interface boards, and the HP Pascal 3.0 Language System. The HP remote microcomputer contains an internal Random Access Memory capacity of approximately 786 kilobytes. The remote microcomputer has an HP AMIGO dual 3-1/2 inch flexible disc drive unit and an HP 16.7-Megabyte CS/80 Winchester disc.

1.2. Coordinate Measuring Machine Computer System

The principal hardware and software components of the CMM computer system include an HP 9000 Series 200 Microcomputer (Model No. 9836), several RAM boards, one built-in HP interface bus (HP-IB), one data communications interface board, and the HP Pascal 3.0 Language System. The HP remote microcomputer contains an internal Random Access Memory capacity of approximately 1,901 kilobytes. The HP-IB interface provides the communications link between the microcomputer and the CMM's built-in microprocessor. The remote microcomputer has two built-in 5-1/4 inch flexible disk drive units and an HP 65.6-Megabyte CS/80 Winchester disc.

1.3. Surface Roughness Instrument Computer System

The principal hardware and software components of the SRI computer system include an HP 9000 Series 200 Microcomputer (Model No. 9920U), several RAM boards, one GPIO interface board, one data communications interface board, and the HP Pascal 3.0 Language System. The HP remote microcomputer contains an internal Random Access Memory capacity of approximately 2,228 kilobytes. The RS-232 serial port provides the communications link between the microcomputer and the SRI's built-in microprocessor. The communications link between the microcomputer and the ADI is provided by the HP-IB interface port. The remote microcomputer has an HP AMIGO dual 3-1/2 inch flexible disk drive unit and an HP 16.7-Megabyte CS/80 Winchester disc.

1.4. Robot Computer System

The principal hardware and software components of the robot computer system include an HP 9000 Series 200 Microcomputer (Model No. 9920U), several RAM boards, one HP-IB interface board, one GPIO interface board, one data communications interface board, one RS-232 serial interface board, and the HP Pascal 3.0 Language System. The HP remote microcomputer contains an internal Random Access Memory capacity of approximately 1,048 kilobytes. The computer communication interfaces of the robot include sixteen bits of input and twelve bits of output controlled by the GPIO (parallel) port and the serial port which uses RS232 protocol. The remote microcomputer has an HP AMIGO dual 3-1/2 inch flexible disk drive unit and an HP 28.7-Megabyte CS/80 Winchester disc.

2. INTERNAL MEMORY (RAM) CAPACITY

The HP 9000 Series 200 Microcomputer models 9920U and 9836U base systems will support 3.07 and 2.05 MBytes internal RAM, respectively. The microcomputer systems currently possess an internal Random Access Memory capacity range between 750 KBytes and 2.0 MBytes each. Although present IWS software applications do not generally require greater internal memory capacities, capacities of 1,048 kilobytes (1.0 megabytes) or greater are recommended.

3. NETWORK COMMUNICATIONS

In keeping with the integrated, data-driven, hierarchical control strategy of the AMRF, programmable data communication interface (Product No. 98628A/98691A Option 002) cards were installed in each of the four microcomputers. These interface cards have erasable-programmable read-only memory (EPROM) integrated circuits to meet the specific AMRF-related data communication and serial interfacing needs. NBS personnel programmed the EPROM circuits in Z-80 assembly language and installed each circuit onto its respective data communications interface card. Information passed by these cards includes command and status information. The WSC has four of these communication interface cards and the other three controllers, the IRC, the CMMC, and the SRIC, each have one.

Integration of the IWS to the AMRF depends on a reliable and effective network communications system. In keeping with the strategy of the AMRF control system, inspection operations at the IWS must foster its important role as one of the controlled components of a fully integrated manufacturing cell. Other workstations of the AMRF include the Cleaning and Deburring Workstation (CWS), the Horizontal Workstation (HWS), the Material Handling System (MHS), the Turning Workstation (TWS), and the Vertical Workstation (VWS). Refer to the AMRF Network Communications document, written by S. F. Rybczynski, E. J. Bakmeyer, E. K. Wallace, M. L. Strawbridge, D. E. Libes, and C. V. Young, for specific characteristics of this network.

4. INSPECTION WORKSTATION SOFTWARE DEVELOPMENT

All IWS software applications approach specific goals in accordance with AMRF hierarchical control strategy. Nonetheless, local software development and implementation was influenced by the constraints imposed by each microcomputer system, its operating system, and the available HP Pascal 3.0 Language System. The high degree of software integration to the hardware may impede transfer of the IWS software to other computer systems.

IV. MISCELLANEOUS INSPECTION WORKSTATION EQUIPMENT SPECIFICATIONS

The miscellaneous Inspection Workstation equipment includes an automatic dial indicator (ADI) and a safety fence.

1. AUTOMATIC DIAL INDICATOR SPECIFICATIONS

The ADI is a digital dial gage. This instrument senses and measures axial distance variations and displays the amplified version of the sensed dimensional variation on a liquid crystal display (LCD) digital readout.

1.1. Instrument Description

The ADI employs a sensing (gage) spindle that moves back and forth in a supporting stem (measuring spindle guide) and a LCD digital readout indicator. The travelling component, or removable contact (gaging) point, attached to the anterior apex of the gage spindle, is guided along a linear path. Distance variation sensing and measuring is performed by the indicator. The mechanism of the indicator converts the axial displacement of the measuring spindle into rotational movement which is then amplified by mechanical means and displayed by a LCD digital readout.

1.2. Distance Measurement

The ADI measures axial displacement when a part touches the gaging point on the gage spindle. The distance between a reference plane at a fixed position relative to the instrument and a gaging point on the part is measured. This distance is then displayed on the liquid crystal display (LCD) digital readout.

1.3. Part Fixturing and Staging

Since the ADI by itself is not a complete measuring instrument, indicator measurements of length must be complemented with the inspection robot. The ADI is mounted to an NBS-designed and manufactured fixture mount.

The robot presents the part on a reference plane which is coincident with one end of the distance to be measured (the datum of the measurement). The permanent affixation of the ADI to a positive position from that reference plane allows the spindle to adjust to different distances to be measured.

Typically, the axial alignment procedure in the IWS is performed by way of the inspection robot moving the part to a position approximately one inch in front of the ADI and then moving the part toward the instrument in half inch steps until the part contacts the gaging point and a reading is made of the axial part position. In Chapter III, Section 2 of the document Implementation of the SRI Controller [A.4], this procedure is called the axial calibration.

1.4. Instrument Operation

The ADI is equipped with a battery-backed microprocessor for operating in either manual or automatic (computer-controlled) mode. Typically, the ADI functions in the automatic mode for all IWS operations except the initial zero adjustment of the instrument.

1.5. Built-in Microprocessor-based Control

The built-in microprocessor furnished by the ADI manufacturer provides fundamental instrument operations—metric/inch conversion, linear data display, axial displacement measurement, zero adjustment, and error handling.

1.6. Remote Microprocessor Instrument Control

The ADI is controlled by the SRIC software system, discussed in Chapter II, Section 2.6, through the machine-related functions available in the SRI function library. This library includes software responsible for interfacing between the higher level commands executed by the SRIC program and the corresponding firmware level commands at the ADI (machine) microprocessor level.

1.7. General Automatic Dial Indicator Specifications

The ADI should be equipped with an acceptable level of technical features, as outlined in Sections 1.1 through 1.6, to enable the inspection workstation to measure axial displacement. It should conform to basic American Gage Design (AGD) specifications for mounting in order to permit the same fixturing used for conventional AGD indicators. The ADI should be designed with a microprocessor-based electronic measuring system that allows the instrument to be integrated into automatic (computer-controlled) testing stations. Also, the ADI should be designed with a computer interface port for communication between the host computer and the instrument.

2. SAFETY FENCE SPECIFICATIONS

The safety fence is an electronically integrated system of two transmitter and receiver units. These electronic sensing devices promote safety in the IWS environment by protecting against bodily injury to personnel and damage to equipment and parts. These devices monitor the space occupied by the inspection robot to detect the infiltration thereof along electronically shielded regions, particularly during intervals of on-going inspection operations.

2.1. Device Description

The safety fence of the IWS integrates two sets of Dolan-Jenner Safescan IV 15 1/2 transmitter and receiver units, each separately supported by mounting stands. The transmitter and receiver units are housed in welded steel enclosures which meet the twelve NEMA requirements. The units were designed with vibration pads to help them withstand shock and vibration and thereby improve reliability of operation.

Each transmitter and receiver unit has eighteen sets of light emitting diode (LED) transmitters and receivers. The LED's can be pulsed or modulated (rapidly switched on and off to provide brief flashes of invisible light) to allow detectors or receivers to be tuned to the repetition rate and duration of the pulse. This LED pulse modulation technique of tuning out extraneous light makes the Safescan IV immune to light sources other than its own transmitter and allows the unit to extend its operating ranges to 45 feet. Sequential operation of the transmitters and receivers permits full beam intensity for each pair without interference from any other pair regardless of transmitter-receiver spacing.

2.2. Safety Fence Configuration

While the safety fence system is a part of the inspection robot system, its operation is not controlled by the IRC. However, when functioning in integrated mode, this system has the capability to stop the operation of the robot upon detection of any object coming across its electronic field. This inevitably halts IWS operations.

Safety in the inspection environment of the IWS is enhanced by the design and physical layout of this safety system. The transmitter and receiver units monitor two critical regions directly outside the space occupied by the inspection robot. These critical regions are deemed most accessible by personnel as well as automated equipment.

2.3. General Safety Fence Specifications

The safety considerations of an inspection workstation environment may prescribe integration of an electronic safety fence system. Therefore, general safety fence equipment should exhibit features such as highly-dependable operator protection, high stability and noise immunity, ease of installation and alignment, adequate range (distance) of operation, and high reliability in semi-clean inspection environments.

The safety fence equipment should be designed and constructed to meet Occupational Safety and Health Administration (OSHA) 1910.217 and the American Society of Mechanical Engineers (ANSI) B11.1-1982 requirements for point-of-presence sensing devices.

APPENDICES

A. IWS DOCUMENTATION LIST

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C. GLOSSARY (and abbreviations)

ADI Abbreviation for the Automatic Dial Indicator.

automatic dial indicator
Instrument used to measure the distance that a spring mounted stem is depressed.

CMM Abbreviation for the Coordinate Measuring Machine.

CMMC Abbreviation for the Coordinate Measuring Machine Controller.

controller
Supervises the operation of a mechanism and/or another controller.

coordinate measuring machine
Machine used to measure the dimensions of a part.

inspection robot
Robot used in the Inspection Workstation to retrieve and/or relocate a part.

inspection workstation
AMRF workstation that inspects parts for dimensional tolerance and surface finish.

IRC Abbreviation for the Inspection Robot Controller.

IWS Abbreviation for the Inspection Workstation.

Kbyte Abbreviation for kilobyte (1024 bytes).

Mbyte Abbreviation for megabyte (1,048,576 bytes).

RAM Abbreviation for Random Access Memory.

SRI Abbreviation for the Surface Roughness Instrument.

SRIC Abbreviation for the SRI Controller.

surface roughness instrument
Machine that measures the optical scattering from the surface of a part. The scattering can be correlated with its surface roughness.

WSC Abbreviation for the Workstation Controller.

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (*A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here*)

This document furnishes the technical specifications of the Inspection Workstation (IWS) in the Automated Manufacturing Research Facility (AMRF) at the National Bureau of Standards. The IWS is a prototype automated inspection facility. The principal commercial mechanical and electronic equipment and instruments of the IWS include the horizontal arm coordinate measuring machine (CMM), the inspection robot (IRC), and the optical surface roughness instrument (SRI). The computer systems of the IWS include the Main Workstation Controller (WSC), the Inspection Robot Controller (IRC), the Coordinate Measuring Machine Controller (CMMC), and the Surface Roughness Instrument Controller (SRIC). Other equipment and instruments include the automatic dial indicator (ADI) and the electronic safety fence.

12. KEY WORDS (*Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons*)

Automatic dial indicator; controller; coordinate measuring machine; Inspection Workstation; robot; surface roughness instrument; technical specifications

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