INVENTORY OF EQUIPMENT IN THE CLEANING AND DEBURRING WORKSTATION

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I. INTRODUCTION

This manual provides a complete inventory of equipment in the Cleaning and Deburring Workstation (CDWS). This inventory lists equipment in the Workstation Controller system, th Deburring System, and the Part Handling and Cleaning System. A list of suppliers whose equipment is used in the CDWS is located at the end of this document in Appendix A. Pertinent references for the Cleaning and Deburring Workstation are found in Appendix B.

1. SYSTEM DESCRIPTION

The CDWS is one of six workstations at the Automated Manufacturing Research Facility (AMRF) of the National Institute of Standards and Technology (NIST). The CDWS cleans and deburrs the metal parts produced by the machining workstations of the AMRF. Equipment at the workstation includes a six-axis electric robot for deburring, a five-axis hydraulic robot for part handling and buffing, a washer/dryer and buffing system for cleaning and polishing, a rotary vise for clamping parts, and two roller tray stations for transferring parts.

The machined parts enter and exit the workstation on part trays placed at the roller tray stations. The part handling robot, under command of the workstation controller (WSC), grasps and carries a part either to the rotary vise or to the washer/dryer system. Normally, parts first undergo deburring, so the part handling robot puts the part in the vise where it is clamped. The deburring robot moves to the vise and begins to deburr the edges on the top side of the part, changing its deburring tool as required. If necessary, the part handling robot reorients the part, and the deburring robot deburrs the edges of the newly exposed face. If a part is to be cleaned, the part handling robot places it on the washer/dryer index table. From here, the part cycles through the washer, where a hot spray removes cutting fluid, deburring dust, and buffing compound. Once washed, the part is indexed into the dryer, where hot air dries the residual water. When all cleaning and deburring processes are completed, the part handling robot transfers the part back to the tray station.

Process planning and task scheduling are undertaken by the WSC. The WSC is a set of software routines running on a SUN computer. The WSC provides a graphic interface for user selection of finishing processes and parameters, a scheduler which allocates tasks at runtime, interfaces to the equipment level, and an interface to the AMRF cell and database.

2. PURPOSE OF THIS MANUAL

The purpose of this manual is to provide an equipment inventory for the Cleaning and Deburring Workstation in the AMRF. This inventory includes a list of the names and addresses of manufacturers whose products are used. This document is intended to serve as a guide to implementing a research facility modeled after the CDWS. It is not to be construed as a recommendation of commercial equipment.

3. HOW THIS MANUAL IS ORGANIZED

This manual is divided into five parts. The Introduction gives a brief overview of the CDWS and explains the purpose and organization of the manual. Section II provides an inventory for the Workstation Controller, the highest level of the hierarchy. Section III provides an inventory for the Deburring System. Section IV provides an inventory for the Part Handling and Cleaning System. At the end of the document are the Appendices. Appendix A provides a list of

commercial suppliers whose equipment is used in the CDWS. Appendix B lists pertinent references.

4. WHO SHOULD USE THIS MANUAL

This manual is intended as a guide for researchers who need to specify and procure automated manufacturing equipment computer hardware and software for a cleaning and deburring research facility.

II. WORKSTATION CONTROLLER

The Workstation Controller is a set of software modules that comprise a graphics interface for process plan generation, a robot pose generator, and a task scheduler. The Workstation Controller communicates via an ethernet network to the higher levels of the AMRF, and to the workstation equipment levels via serial RS-232 connections.

1. COMPUTER HARDWARE

The workstation controller runs on a SUN computer, which supports multitasking and graphics in a windowing environment. The computer has 4 megabytes of main memory, and 142 megabytes of disk memory. The monitor is a high-resolution monochrome display. Auxiliary storage is provided with a 9-inch tape drive. The computer system provides standard ethernet network support, and has been augmented with hardware for serial communication. The equipment is as follows:

(a) SUN Microsystems 4-megabyte computer with monochrome display (model 3/160)
(b) SUN Microsystems 142-megabyte hard disk and controller
(c) Cipher Data Products 1/2-inch magnetic tape drive, 1600 bpi data density (Microstreamer F880640-90-1025U)
(d) SUN Microsystems 16-channel asynchronous multiplexer (model 481)

2. SOFTWARE

The software used to implement the workstation controller consists of the operating system, Unix, and the programming languages, C and LISP. The software is as follows:

(a) Franz Inc. LISP Programming Language (Franz LISP Opus 43.1)
(b) SUN Operating System, Version 3.0 (bundled with C and Unix)

III. DEBURRING SYSTEM

Deburring is performed by a six-axis electric robot, which applies tools to the edges of machined parts. The robot is fitted with a quick change wrist to allow for the selection of various pneumatic tools or a gripper. A wrist force sensor provides force feedback, which is used to compensate for inaccuracies. The robot is controlled using the NIST-developed Real-Time Control System (RCS), interfaced to the vendor-supplied controller according to a slave protocol.

1. ROBOTIC EQUIPMENT

Deburring is accomplished with a six-axis robot. The robot is fitted with a quick-change wrist to allow for the selection of several pneumatic deburring tools. The robot controller has been modified to allow slave control of the robot via an external computer system. The equipment is as follows:

(a) Unimation PUMA 760 six-axis electric robot and controller with slave software
(b) EOA Systems end-effector quick change (model 50)
(c) 5 EOA Systems quick-change mounting plates with tool ID and electrical connections (model 50 compatible)
(d) ARO pneumatic rotary tools (Models DL021A-50, 7236-C)
(e) Assorted Osborn Manufacturing abrasive-loaded nylon brushes
(f) NIST-designed tool rack

2. COMPUTER HARDWARE

The robot is controlled using the NIST-developed Real-Time Control System (RCS). This system implements functions normally performed by the vendor-supplied robot controller, which have been bypassed with the slave protocol. This protocol requires that the user compute and serially download robot joint angles every 28 milliseconds. The slave protocol allows the user a much greater control over the actions of the robot, but at the price of additional user computation. The computer hardware used to control the robot in slave mode is as follows:

(a) ETI Micro 23-slot ventilated PC board chassis, Multibus backplane, configured for parallel priority (8323 backplane, 8209 P2 backplane)
(b) 6 Intel single-board computers with floating-point processor (iSBC model 86/30 with 8087 processor)
(c) 4 Intel parallel communication interface modules (iSBC model 350)
(d) 2 Intel serial communication interface modules (iSBC model 351)
(e) Intel analog-to-digital conversion module (iSBC model 311)
(f) Intel 4-channel serial communication expansion board (iSBC model 534)
(g) Ciprico disk/tape controller board (Rimfire 45)
(h) 3 Plessey Microsystems 512Kbyte CMOS memory boards (model 512A)
(i) Lord Factory Automation force/torque sensing system (F/T Series model 75/250)
(j) Priam 14" Winchester disk (model 6650)
(k) Cipher Data Products 1/2-inch magnetic tape drive, 1600 bpi data density (Microstreamer F880640-90-1025U)
(l) TeleVideo Systems computer terminal (model 950)
(m) NIST-designed robot joystick controller
(n) NIST-designed RCS equipment interface

3. SOFTWARE

The vendor-supplied robot control software, VAL, is normally bypassed when running the robot in slave mode. This software is executed at boot-up, however, to invoke the execution of the slave interface software in the robot controller. This software accepts robot joint angles which have been calculated by RCS, and sends them to the robot servo boards.

The software used to implement RCS consists of an integrated software development and programming environment, polyFORTH. This software provides the operating system and FORTH programming language. In addition, the language has been extended by NIST with a set of macros which provide increased functionality. This extension, SMACRO, is written in FORTH and FORTH assembly language. The software is as follows:

(a) VAL Verion 1.0
(b) FORTH Inc. FORTH Programming Language (polyFORTH 1.4)
(c) RCS 2.2 (NIST-developed software)

IV. PART HANDLING AND CLEANING SYSTEM

The part handling and cleaning system is responsible for bringing incoming parts into the workstation, performing part fixturing for deburring, cleaning processed parts, and placing outgoing parts in the tray stations for delivery. The equipment and software are as follows:

1. ROBOTIC EQUIPMENT

(a) Unimation Unimate 2000 5-axis hydraulic robot and VAL-II controller (model 2750)
(b) NIST-designed pneumatic gripper
(c) NIST-designed rotary vise

2. BUFFING AND CLEANING EQUIPMENT

The buffing and cleaning equipment is used for polishing and cleaning the parts after deburring. Robot trajectories for buffing are currently programmed by teaching, but research is being conducted on methods to automate robot programming. Cleaning is scheduled as a pick-and-place task. Care must be taken to insure that the part is restrained during the cleaning cycle so that its position is known when it emerges. The buffing and cleaning equipment is as follows:

(a) ACME Manufacturing L4 washer/dryer index machine (model L4-94908)
(b) ACME Manufacturing buffing jack (model AL-94918)
(c) ACME Manufacturing tank and blower unit (model D-94910)
(d) 2 Binks Manufacturing 5-gallon pressure tanks, 100 psi (model 83-5460)
(e) 2 Binks Manufacturing air control units (model 85-203)
(f) 2 Paasche Airbrush automatic spray guns (model A-CU)
(g) 2 Graco air filters (model 213-062)
(h) Aget Manufacturing DustKop dust collector (model 3051-D1)
(i) NIST-designed cleaning system interface

3. COMPUTER HARDWARE

The computer hardware listed below compose the equipment controller interface. This computer interface communicates with the various commercial equipment controllers via NIST-developed hardware, to allow for automatic control of functions normally performed manually.

(a) ETI Micro 9-slot ventilated PC-board chassis, Multibus backplane, configured for parallel priority (model 8101 backplane)
(b) Intel single-board computer with floating-point processor (iSBC model 86/30 with 8087 processor)
(c) Intel parallel communication interface module (iSBC model 350)
(d) Intel analog-to-digital conversion module (iSBC model 311)
(e) Intel 3-channel parallel communication expansion board (iSBC model 519)
(f) Ciprico Inc. disk/tape controller board (Rimfire 45)
(g) Plessey Microsystems CMOS memory board (model 512A)
(h) NIST-designed RCS equipment interface
(i) Lord Factory Automation force/torque sensing system (F/T Series model 125/600)
(j) NIST-designed analog signal junction unit
(k) Priam 14" Winchester disk (model 6650)
(l) Cipher Data Products 1/2-inch magnetic tape drive, 1600 bpi data density (Microstreamer

F880640-90-1025U)
(m) 2 TeleVideo Systems computer terminals (model 950)
(n) Black Box (a MICOM company) RS-232 25-pin 4-channel selector

4. SOFTWARE

The part handling robot is not run under RCS, but uses the vendor-supplied robot control software, VAL-II. However, the RCS programming language, SMACRO, is used to program the computer interfaces to the equipment control computers. These computers actuate the rotary vise, cleaning equipment, and tray station lockout mechanisms. The software is as follows:

(a) VAL-II Version 2.0
(b) FORTH Inc. FORTH Programming Language (polyFORTH 1.4)
(c) RCS 2.2 (NIST-developed software)

APPENDIX A. LIST OF SUPPLIERS

ACME Manufacturing Company
650 West 12 Mile Road
Madison Heights, MI 48071-2484
(313) 564-6000

The ARO Corporation
One ARO Center
Bryan, OH 43506

Cipher Data Products Incorporated
10225 Willow Creek Road
San Diego, CA92131
(619) 578-9100

Publications available from:
Cipher Data Products Incorporated
Technical Publications Department
P.O. Box 85170
San Diego, CA92138
(800) 982-8808

Manual:
Model F880 Magnetic Tape Transport, Volume 1-- Operation Maintenance
Technical Manual Number 799816-003, Revision Q, April 1986

Ciprico Incorporated
2955 Xenium Lane
Plymouth, MN 55441
(612) 559-2034

Manual:
Ciprico Product Specification-- Rimfire 45A, Multibus Disk Controller
Publication Number 21010084, Revision A, March 25, 1985

EOA Systems Incorporated
15054 Beltway Drive
Dallas, TX 75244
(214) 458-9886

ETI Micro
6918 Sierra Court
Dublin, CA94568
(415) 829-6600

Manual:
8223 MULTIBUS Chassis User's Manual
Publication Number 832305822313301, 1983

FORTH Incorporated
111 N. Sepulveda Blvd.
Manhattan Beach, CA 90266
(213) 372-8493

Franz Incorporated
1995 University Avenue, Suite 275
Berkeley, CA94704
(415) 548-3600

Intel Corporation
3065 Bowers Avenue
Santa Clara, CA95051
(408) 987-8080

Publications available from:
Intel Literature Sales
P.O.Box 58130
Santa Clara, CA95052-8130
(800) 548-4725

Manuals:
Microsystem Components Handbook, Volumes I and II
Publication Number 230843-002, 1985.

iSBC® 86/14 and iSBC® 86/30 Single Board Computer Hardware Reference Manual
Publication Number 144044-002, 1982.

iSBC® 337AMultimodule™ Numeric Data Processor Hardware Reference Manual
Publication Number 142887-001, 1980.

iSBC® 519 Programmable I/O Expansion Board Hardware Reference Manual
Publication Number 9800385B, 1979.

iSBC® 534 Four Channel Communications Expansion Board Hardware Reference Manual
Publication Number 9800450-02, 1979.

iSBX™ 311 Analog Input Multimodule™ Board Hardware Reference Manual
Publication Number 142913-001, 1981.

iSBX™ 328 Analog Output Multimodule™ Board Hardware Reference Manual
Publication Number 142914-002, 1982.

iSBX™ 350 Parallel Multimodule™ Board Hardware Reference Manual
Publication Number 9803191-02, 1980.

iSBX™ 351 Serial Multimodule™ Board Hardware Reference Manual

Publication Number 9803190-03, 1984.

Lord Corporation, Factory Automation Division
407 Gregson Drive
Cary, NC 27511
(919) 469-2500

Manual:
F/T Series Force/Torque Sensing System-- Instruction and Operations Manual
Revision 2, March 1986

Osborn Manufacturing
5401 Hamilton Avenue
Cleveland, OH 44114
(216) 361-1900

Plessey Microsystems
P.O. Box 154
1 Bluehill Plaza
Pearl River, NY 10965
(914) 735-4661

Manual:
PSM 512AMultibus Error-Correcting DRAM-- User's Guide
Document Number PMUS/HB/10225, Issue 2, January 1984

Priam Corporation
20 West Montague Expressway
San Jose, CA95134
(408) 946-0293

Manual:
Fourteen-Inch Winchester Disc Drives-- OEM Manual, Models 3350, 6650 and 15450
Publication Number 308002, Revision B, January 1984

SUN Microsystems Incorporated
2550 Garcia Avenue
Mountain View, CA94043
(415) 960-1300

Manuals:
Document Set 800-XXXX-03
Revision A, 1986

TeleVideo Systems Incorporated
1170 Morse Avenue
Sunnyvale, CA94086
(408) 745-7760

Manual:

TeleVideo ® Model 950 CRT Terminal Installation and User's Guide
Document Number B300002-001, Revision B, April 1982

Unimation Incorporated
Shelter Rock Lane
Danbury, CT 06810
(203) 744-1800

Manuals: (Preliminary)
Unimate Industrial Robots Programming Manual-- User's Guide to VAL™ II
Document Number 398T1, Version 1.1, August 1984

Unimate Industrial Robots Programming Manual-- User's Guide to VAL ™ Plus
Document Number 398AC1, March 1985

Unimate Industrial Robots 2070 Series Equipment and Programming Manual
Document Number 398M1, February 1984

Unimate Industrial Robots 2070 Series Electrical Drawing Set
Document Number 394K1, November 1983

Unimate Puma ® Mark II Robot 700 Series Equipment and Programming Manual
Document Number 398N1, August 1983

Unimate Puma ® Mark II Robot 700 Series Electrical Drawing Set
Document Number 394M1, April 1984

Unimate Puma ® Mark II Robot 700 Series Mechanical Drawing Set
Document Number 394L1, April 1983

APPENDIX B. LIST OF REFERENCES

1. Proctor, F., and Murphy, K., "Advanced Deburring System Technology", submitted for publication for the ASME Winter Annual Meeting Symposium on the Mechanics of Deburring and Surface Finishing Processes, San Francisco, CA(December 1989).

2. Proctor, F., Murphy, K., and Norcross, R., "Automating Robot Programming in the Cleaning and Deburring Workstation of the AMRF", Proceedings of Deburring and Surface Conditioning '89, San Diego, CA(February 1989).

3. Murphy, K., Norcross, R., and Proctor, F., "CAD Directed Robotic Deburring", Proceedings of the Second International Symposium on Robotics and Manufacturing: Research, Education, and Applications, Albuquerque, NM (November 1988).

4. Norcross, R., "The Cleaning and Deburring Workstation Control Structure", IEEE International Conference on Robotics and Automation, Philadelphia, PA(April 1988).

5. Norcross, R., "The Workstation Controller of the Cleaning and Deburring Workstation", National Institutes of Standards and Technology Internal Report 89-4046 (February 16, 1989).

6. Proctor, F., and Tanguy, P., "CAD Directed Automated Part Handling User's Reference Manual", National Institute of Standards and Technology Internal Report 88-3858 (September 15, 1988).

7. Murphy, K., "Real-Time Control System Modifications for a Deburring Robot User's Reference Manual", National Bureau of Standards Internal Report 88-3832 (August 4, 1988).

8. Leake, S., and Kilmer, R., Editors, "The NBS Real-time Control System User Reference Manual", National Bureau of Standards Technical Note 1250 (August 1988).

9. Murphy, K., Norcross, R., Tanguy, P., and Proctor, F., "Cleaning and Deburring Workstation Operations Manual", National Bureau of Standards Internal Report 88-3804 (June 9, 1988).