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Engineering Division

Adaptation of a Commercial Robot for Genome Library Replication

D.C. Uber and W.L. Searles

January 1994

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Adaptation of a Commercial Robot for Genome Library Replication

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Lawrence Berkeley Laboratory
University of California, Berkeley, CA 94720

January 1994

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Adaptation of a Commercial Robot for Genome Library Replication

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University of California, Berkeley, CA 94720

Abstract

This report describes tools and fixtures developed at the Human Genome Center at Lawrence Berkeley Laboratory for the Hewlett-Packard ORCA™ (Optimized Robot for Chemical Analysis) to replicate large genome libraries. Photographs and engineering drawings of the various custom-designed components are included.

Introduction

The Human Genome Program is a fifteen year project, funded by the U.S. Department of Energy and National Institutes of Health, to map and sequence the human genome. Similar programs are underway to map and sequence the DNA of other plant and animal species. Current sequencing technology requires that the DNA of the target organism be cut into fragments of a few hundred base pairs. To facilitate its manipulation, each fragment is introduced into a bacteria or yeast cell, which replicates this foreign DNA as well as its own when it divides. The DNA of a single human may consist of as many as two hundred thousand such colonies arrayed in microtiter plates, which are plastic dishes with grids of wells in standard formats of 96 or 384 wells each. Such a collection of plates is known as a genome library.

It is frequently necessary to make copies of a library so that several researchers may collaborate on the mapping and sequencing of the same organism. The original material, which took much effort to produce, can then be safely kept in cold storage. While the copies may be made with a hand replicating tool, it is a very tedious job for a library of several hundred plates. Fortunately, the task is automatable on a general purpose robot such as the ORCA.

The ORCA is a benchtop machine designed by Hewlett-Packard primarily for preparing samples and transporting them among analytical laboratory instruments (1). It has a rail-mounted arm with six degrees of freedom, giving it a great deal of dexterity. Its open hardware and software architecture permit it to be adapted to a wide variety of tasks. We chose library replication as the first task to implement on an ORCA at the LBL Human Genome Center.

Custom Hardware

Hewlett-Packard supplies the ORCA with a flexible software development system, and expects third party developers and technically sophisticated end users to develop the necessary hardware and programs for specific applications. Consequently, all the plate replication tools, fixtures, and software were developed at LBL. However, we were able to take advantage of our experience in customizing an earlier model Hewlett-Packard Microassay System robot for the same job (2), and refined those ideas for the ORCA.

We now describe each of the various custom hardware components in detail. Figure 1 shows the layout of the components on the ORCA table. Engineering drawings are found in the Appendixes.

Gripper Fingers

The stainless steel gripper fingers (Fig. 2) enable the ORCA to pick up microtiter plates, move them around the workspace, and remove their lids. They mate to the ORCA hand by means of standard adapters supplied by Hewlett-Packard that allow the robot to exchange tools during a procedure.

Microplate Hotel

The source microtiter plates during a replication run are stored in a Lucite "hotel" consisting of three columns of twelve shelves each, for a total of thirty-six plates. Cutouts at the rear of each shelf permit easy loading by hand. The robot can reach in with its gripper fingers and remove or replace the plates in any order. We use the hotel rather than a stacker because the source plates frequently come with sealing tape under the lids. Once the tape is removed by hand, the sticky residue prevents the robot from removing the lids, so the plates must be individually stored without lids on the shelves of the hotel. The library replication program has the option of removing source plate lids, so source plates without sealing tape may be stored in the hotel with their lids on.

The bottom level of the hotel has countersunk holes so that it may be screwed to the 25 mm grid of tapped holes on the ORCA table. The holes have minimal clearance so that the hotel is precisely located. This is also true for other fixtures such as the stackers, workstations, etc.

The front surfaces of the hotel are beveled to guide the plate into place when being replaced by the robot. We use this technique on all the fixtures where the robot must insert an object into a space with small clearance. This makes the system tolerant of small variations between similar workstations or of imprecisely taught motions, and prevents crashes that would occur if the robot tried to force an object against a blunt surface.

Microplate Stacker

The blank copy microtiter plates for a replication run are stored with lids in Lucite stackers (Fig. 2) that ORCA accesses sequentially. While the stackers can store up to twenty-five plates each, the robot arm can only reach twenty at the distance from the rail we mount the stackers. Lines are scribed on the back of the stackers to indicate stack heights for both standard 96-well and LLNL 384-well plates, which are slightly taller.

To optimize use of the workspace, stackers may be placed 10 cm apart. This spacing allows just enough room for the gripper fingers between adjacent stacks.

Microplate Workstation

The Lucite workstations (Fig. 2) provide temporary storage for microtiter plates and their lids during actual replication. They have the same 10 cm by 15 cm footprint as the stackers, so that they can be packed tightly together on the table.

Multipin Replicating Tools

The ORCA replicates plates with either a 96-pin or 384-pin tool (Fig. 3), depending on the type of plates being used. Replication from one plate size to the other is possible, as well as between like sizes. In addition, the tools may be used to make high density filters. Each tool contains stainless steel captive pins that can slide vertically in holes in a Delrin™ baseplate. An internal stripper plate pushes down on the heads of the pins, so that they do not get hung up in the holes. An aluminum heat shield on the bottom keeps the Delrin base from warping when the tool is heated in the sterilizing station.

Each tool has a polyethylene upper layer that supports two aluminum gripper bars (Fig. 4). Each bar has a centered square hole that mates with a pin on one of the gripper fingers. Both the pins and holes are beveled to assure positive mating. The pins are located on the support bar of the fingers, so that the multipin tool is very stably supported directly beneath the centerline of the ORCA hand.

Since the same gripper fingers are used to hold the multipin tools as well as to move microtiter plates, the robot does not have to waste time changing fingers.

Multipin Tool Park

Two simple Lucite parking stations hold the multipin tools between replication runs. These stations resemble raised microplate workstations with a large cutout so that the pins in the tools can hang freely.

Multipin Tool Sterilizer

The multipin tool in use must be cleaned between source plates, so that the organisms from one source plate do not contaminate the next. We have built a sterilizer (Fig. 4) that consists of two parts: a sonic bath and an electric heater. Under control of the library replication program, the ORCA places the multipin tool on top of the sonic bath, so that the pins are immersed in a sterilizing fluid, such as 70% ethanol, that is toxic to the organisms being replicated. The robot's control computer turns on a sonicator that agitates the fluid and helps knock contaminants off the pins. During this time the ORCA puts finished plates back into hotels and stackers. The computer turns off the sonicator after a programmed delay of several seconds. The ORCA then moves the tool to the electric heater, which the program switches on to evaporate the fluid from the pins. During the heating, the robot gets new plates ready for the next round of replication. The computer switches the heater off after it has been at operating temperature for several seconds.

The sonic bath is kept at a constant level by pumping fluid from an external reservoir. When the fluid in the bath reaches the top of an adjustable dam, the overflow returns the fluid to the reservoir. Level sensors in the bath and reservoir allow the computer to wait while the bath fills, and to alert the operator if insufficient liquid is present. At the end of a replication run, the computer turns off the pump, allowing the liquid to drain from the bath to the enclosed reservoir, to reduce evaporation.

The electric heater contains an electric heating element whose temperature is maintained by a commercial controller, using a thermocouple near the heating wire for feedback. The controller also tells the computer when the heater has reached operating temperature. An over-temp safety switch automatically shuts down the heater if the controller fails. Another safety switch prevents the heater from turning on unless the multipin tool is present, to reduce shock hazard. The computer monitors these switches and shuts down the system if a failure occurs.

Dispensing Station

New copy plates may optionally be filled with growth medium during a replication run. For this purpose, we took Hewlett-Packard G1243A syringe pump drives from the older Microassay System, and interfaced them to a COM port on the ORCA control computer via an RS232 to RS485 converter. The dispensing station and 16-channel head were also taken from the Microassay System and mounted on the ORCA table with a simple Lucite adapter plate. A vacuum pump connected through a trap vessel suctions fluid from a catch basin underneath the dispense head when the dispenser system is being primed.

Input/Output Control

Digital control of external devices such as the vacuum pump and the sterilizer sonicator, temperature control, and reservoir pump, is accomplished by means of a Hewlett-Packard HP3488A Switch/Control Unit with a 44474A 16-bit digital i/o card. The 3488A is controlled by the ORCA computer via the IEEE 488 bus. Eight bits of the i/o card are connected to a control box of our own design that provides latched 115 vac outputs and allows the same eight bits to be used as inputs via tri-state gates. The control box also provides a 5 vdc supply for external circuitry such as the heater temperature control and sonicator level sensor.

Performance

The number of new copy plates that the system can generate per hour is shown in Fig. 5. The throughput increases as more copies of each source plate are made, because the overhead of fetching and storing the source plate and cleaning the replication tool is spread over all the copy plates. The 384-well plates are copied more slowly than 96-well simply because of the longer time needed to dispense growth medium into the larger number of wells. For comparison, the older Microassay System (polar arm) is also shown.

In terms of volume, the ORCA can generate up to 180 new copy plates (e.g., five copies of thirty-six source plates) in a single unattended run using the workspace on only one side of the rail. The Microassay System can generate a maximum of eighty new plates per run.

Conclusions

The custom hardware described above, together with appropriate software, provides a good example of how a commercially available, general purpose robot can be successfully adapted to replicate large genomic libraries. In developing such a system, we have found it essential to have access to a high quality machine shop that can provide rapid turnaround as new ideas are tried. Almost all the items described went through several iterations before reaching final form.

Acknowledgments

We thank Arnold Haus, Steven Rothway, and Donald Thewlis for expert machining and construction of the custom hardware, Joseph Katz and Michael Press for design and construction of the I/O control box, Davey Hudson for design and construction of the sonic bath level sensor, and Michael Osofsky and John Home for preparing CAD drawings.

This work was supported by the Director, Office of Energy Research, Office of Health and Environmental Research, Human Genome Program, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.

References

1. G.B.Gordon, J.C.Roark, A.,Schleifer, "ORCA: Optimized Robot for Chemical Analysis," *Hewlett-Packard Journal*, (June 1993): 6-19.
2. J.M. Jaklevic, A.D.A. Hansen, E.H. Theil, D.C. Uber, "Application of Robotics and Automation in a Genomic Laboratory," Laboratory Robotics and Automation, Vol. 3, 161-168 (1991).

Figure 1. Overview of automated library replication system. The ORCA arm and rail are at right. The ORCA is holding a multipin replicating tool over workstations containing microtiter plates and lids. Furthest from the rail, starting at lower left are

Figure 3. The 96 and 384-pin replicating tools. The captive pins slide in holes in the black Delrin baseplate. An aluminum heat shield keeps the Delrin from warping in the sterilizer heater.

Figure 4. The sterilizing station. The ORCA gripper is holding a multipin tool above the sonic bath. The electric heater is at left; its temperature controller at right. The ethanol reservoir is out of sight beneath the table.

Library Replication Throughput

Figure 5. System throughput for the ORCA and Microassay System (polar) robots.

APPENDIXES

Engineering Drawings

Appendix A: Gripper Fingers

Appendix B: Microplate Hotel

B(1): Assembly, Common Details, & Blanks

B(2): Auxiliary Pieces

B(3): Base I/Hotel $\frac{5}{8}$ Blank 11.80 X 5.630

B(4): Roof I/Hotel $\frac{1}{4}$ Blank 11.800 X 5.630

B(5): Floor II/Hotel $\frac{1}{4}$ Blank 11.800 X 5.630

Appendix C: Microplate Stacker

Appendix D: Microplate Workstation

Appendix E: 96-Pin Replicating Tool

Appendix F: 384-Pin Replication Tool

Appendix G: Multipin Tool Parking Station

Appendix H: Multipin Tool Sterilizer Bath

Appendix I: Multipin Tool Sterilizer Bath Level Sensor

Appendix J: Multipin Tool Sterilizer Bath Sonicator Driver

Appendix K: Multipin Tool Sterilizer Reservoir

Appendix L: Multipin Tool Sterilizer Heater

Appendix M: Multipin Tool Sterilizer Heater Control

Appendix N: I/O Control Box (1 Of 8 Bits)

Appendix A: Gripper Fingers

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF GRIPPER TOOL			
COMPONENT NAME			
DWG. TYPE	ORIGINAL DATE	REV. DATE	
ASSEMBLY	12-1-92	4-20-93	
DWG. BY MICHAEL J. OSOFSKY			
CHK. BY WILLIAM SEARLES		FILE NAME ORCA\GRIPPER\GRIPASS

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION			
HUMAN GENOME INSTRUMENTATION GROUP			
PART OF GRIPPER TOOL			
COMPONENT NAME SUPPORT BAR			
ENG. TYPE	DETAIL	ORIGINAL DATE	REV. DATE
		12-1-92	4-20-93
ENG. BY MICHAEL J. OSOFSKY			
CHK BY WILLIAM SEARLES		FILE NAME ORCA\GRIPPER\SUPRTBAR

SAW OK

6.000"

0.188"

MACHINE BOTH SIDES

0.125" STOCK
STAINLESS STEEL
PLATE

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF GRIPPER TOOL					
COMPONENT NAME ARM					
DWG TYPE	BLANK	ORIGINAL DATE	12-1-92	REV. DATE	4-20-93
DWG BY	MICHAEL J. OSOFSKY				
CHK BY	WILLIAM SEARLES		FILE NAME		ORCA\GRIPPER\GRIPSTOK

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LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP

PART OF GRIPPER TOOL

COMPONENT NAME FOAM RUBBER SPRING PAD

DWG. TYPE DETAIL ORIGINAL DATE 4-20-93 REV. DATE 8-10-93

DWG. BY MICHAEL J. OSOFSKY

CHK. BY WILLIAM SEARLES FILE NAME ORCA\GRIPPER\FOAMPAD

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LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF GRIPPER TOOL			
COMPONENT NAME FINGER			
DWG. TYPE BLANK	ORIGINAL DATE 12-1-92	REV. DATE 7-22-93	
DWG. BY MICHAEL J. OSOFSKY			
CHK. BY WILLIAM SEARLES		FILE NAME ORCA\GRIPPER\FINGBLNK

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION			
HUMAN GENOME INSTRUMENTATION GROUP			
PART OF GRIPPER TOOL			
COMPONENT NAME FINGER			
ENG. TYPE	DETAIL 1	ORIGINAL DATE	12-1-92
		REV. DATE	8-10-93
ENG. BY MICHAEL J. OSOFSKY			
CHK BY WILLIAM SEARLES		FILE NAME ORCA\GRIPPER\FINGDET1

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF GRIPPER TOOL			
COMPONENT NAME FINGER			
DWG. TYPE	ORIGINAL DATE	REV. DATE	
DETAIL 2	12-1-92	8-10-93	
DWG. BY MICHAEL J. OSOFSKY			
CHK. BY WILLIAM SEARLES		FILE NAME ORCA\GRIPPER\FINGDET2	

Appendix B: Microplate Hotel

B(1): Assembly, Common Details, & Blanks

B(2): Auxiliary Pieces

B(3): Base I/Hotel $\frac{5}{8}$ Blank 11.80 X 5.630

B(4): Roof I/Hotel $\frac{1}{4}$ Blank 11.800 X 5.630

B(5): Floor II/Hotel $\frac{1}{4}$ Blank 11.800 X 5.630

Appendix B(1): Assembly, Common Details, & Blanks

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP			LB
PART OF HOLIDAY INNS			
COMPONENT NAME ASSEMBLY ORDER			
DRG TYPE	ORIGINAL DATE 1-22-93	REV. DATE	
DRG BY MICHAEL J. OSOFSKY			
CHK BY WILLIAM SEARLES		FILE NAME ORCA\HOTEL VASSORDER

A

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1

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP

PART OF HOLIDAY INNS
COMPONENT NAME 1/4 FLOOR

DWG TYPE BLANK ORIGINAL DATE 1-22-93 REV. DATE

DWG BY MICHAEL J. OSOFSKY

DWG FILE WILLIAM SEARLES FILE ORCA\HOTEL\FLOORBLK

A

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C

B

A

REAR END 3/HOTEL LUCITE

1/4

ABOUT 12" BY 1.5

REAR SPACER 3/HOTEL LUCITE

5/8 -> .535

ABOUT 12" BY 1.5

FRONT SPACER 2/HOTEL LUCITE

1/4

ABOUT 12" BY .535

STOPS 20/HOTEL LUCITE

1/4

ABOUT 12" BY .25

TIE ROD 2/HOTEL

36" STOCK

1/4-20 SS THREAD ROD

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP PART OF
HOLIDAY INNSCOMPONENT NAME
AUX PIECE

Dwg. TYPE BLANK ORIGINAL DATE 1-22-93 REV. DATE

Dwg. BY MICHAEL J. OSOFSKY

CHK BY WILLIAM SEARLES FILE NAME ORCA\HOTEL\AUXBLNK

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LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF HOLIDAY INNS			
COMPONENT NAME ASSEMBLY			
CHK TYPE DETAIL	ORIGINAL DATE 1-22-93	REV. DATE	
CHK BY MICHAEL J. OSOFSKY			
CHK BY WILLIAM SEARLES		FILE NAME ORCA\HOTEL\ASSDET

ROOF

FLOOR

BASE

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF HOLIDAY INNS			
COMPONENT NAME FRONT BEVEL			
DRG TYPE	ORIGINAL DATE	REV. DATE	
DETAIL	1-22-93		
Dwg BY MICHAEL J. OSOFSKY			
CHK BY WILLIAM SEARLES		FILE NAME ORCA\HOTEL\FRBEVDET	

Appendix B(2): Auxiliary Pieces

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION			
HUMAN GENOME INSTRUMENTATION GROUP			
PART OF HOLIDAY INNS			
COMPONENT NAME AUXILARY REAR END			
DRG. TYPE	DETAIL	ORIGINAL DATE	1-22-93
DRG. BY	MICHAEL J. OSOFSKY		
CHK BY	WILLIAM SEARLES		
FILE NAME	ORCA\HOTEL\AUXRE		

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1

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP	
PART OF HOLIDAY INNS	
COMPONENT NAME AUXILIARY REAR SPACER	
DWG TYPE DETAIL	ORIGINAL DATE 1-22-93 REV DATE
DWG BY MICHAEL J. OSOFSKY	
CHK BY WILLIAM SEARLES FILE ORCA/HOTEL/VUXRSP	

A

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1/4" STOCK

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION			
HUMAN GENOME INSTRUMENTATION GROUP			
PART OF HOLIDAY INNS			
COMPONENT NAME AUXILARY LEFT/RIGHT STOPS			
ENG. TYPE	ORIGINAL DATE	REV. DATE	
FIN. DETAIL	1-22-93		
DMD BY MICHAEL J. OSOFSKY			
CHK BY WILLIAM SEARLES		FILE NAME ORCA\HOTEL\AUXLRSFD

D C B A

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP			
PART OF HOLIDAY INNS			
COMPONENT NAME AUXILIARY REAR STOP			
DRAWN BY	DETAIL	ORIGINAL DATE	REV. DATE
MICHAEL J. OSOFSKY		1-22-93	
CHECK BY	WILLIAM SEARLES		
	FILE ORCA/HOTEL/VAUXRS		

D C B A

Appendix B(3): Base I/Hotel $\frac{5}{8}$ Blank 11.80 X 5.630

Appendix B(4): Roof 1/Hotel 1/4 Blank 11.800 X 5.630

Appendix B(5): Floor II/Hotel 1/4 Blank 11.800 X 5.630

SCOT .090 DEEP
 FINISH 1/2 AND 1/4 PLATES
 TO SIZE BUT ONLY
 FINISH 1/4 PLATE

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF HOLIDAY INNS			
COMPONENT NAME 1/4 FLOOR			
DRG TYPE	DETAIL2	ORIGINAL DATE	1-22-93
REV. DATE			
DRG BY MICHAEL J. OSOFSKY			
CHK BY WILLIAM SEARLES		FILE NAME	ORCA\HOTEL\FLORDET2

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF HOLIDAY INNS			
COMPONENT NAME ROOF			
DRG TYPE	ORIGINAL DATE	REV. DATE	
DETAIL	1-22-93		
DRG BY MICHAEL J. OSOFSKY			
CHK BY WILLIAM SEARLES	FILE NAME ORCAVHOTELVROOFDET		

Appendix C: Microplate Stacker

LAWRENCE BERKELEY LABORATORY
 HUMAN GENOMICS DIVISION GROUP
 MICROPLATE STACKER 25 HIGH
 ORTHO 2
 MICHAEL J. OSOFSKY
 WILLIAM SEARLES
 12-1-92
 4-28-93
 MICROSTAT-ORTHO

5.630" $\begin{smallmatrix} +.005 \\ -.005 \end{smallmatrix}$

0.500"
(STOCK)

3.925 $\begin{smallmatrix} +.005 \\ -.005 \end{smallmatrix}$

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP

PART OF MICROPLATE WORKSTATION
COMPONENT NAME BASE PLATE

DWG TYPE BLANK ORIGINAL DATE 12-1-92 REV DATE 4-21-93

DWG BY MICHAEL J. OSOFSKY

DWG BY WILLIAM SEARLES FILE NAME ORCAWORKSTATWKSTBSI

D C B A

0.125"

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP			
PART OF MICROPLATE WORKSTATION			
COMPONENT NAME BASE PLATE EDGE			
DWG. TYPE	DETAIL	ORIGINAL DATE	REV. DATE
		4-20-93	4-21-93
DWG. BY	MICHAEL J. OSOFSKY		
CHK. BY	WILLIAM SEARLES		
FILE NAME	ORCA\WORKSTAT\BSP\PLAT1		

D C B A C. 3.

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP			
PART OF MICROPLATE WORKSTATION			
COMPONENT NAME BASE PLATE HOLES			
DWG. TYPE	DETAIL	ORIGINAL DATE	12-1-92
REV. DATE	4-29-93		
DWG. BY	MICHAEL J. OSOFSKY		
DWG. BY	WILLIAM SEARLES		
FILE NAME	ORCAWORKSTATBSPLAT2

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF MICROPLATE WORKSTATION			
COMPONENT NAME BASE PLATE & OPTIONAL TAPE SLOT			
ENG. TYPE	DETAIL	ORIGINAL DATE	12-1-92
		REV. DATE	4-28-93
ENG. BY MICHAEL J. OSOFSKY			
CHK. BY WILLIAM SEARLES		FILE NAME ORCA\WORKSTAT\WKSTBS6	

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LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP

PART OF
MICROPLATE WORKSTATION

COMPONENT NAME
BASE PLATE & OPTIONAL TAPE SLOT

ENG. TYPE
DETAIL

ORIGINAL DATE
12-1-92

REV. DATE
4-21-93

ENG. BY
MICHAEL J. OSOFSKY

CHK. BY
WILLIAM SEARLES

FILE NAME
ORCA\WORKSTAT\WKSTB55

D C B A

4 3 2 1

18.000" $\begin{smallmatrix} +.020 \\ -.020 \end{smallmatrix}$

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP			
PART OF MICROPLATE STACKER 25 HIGH			
COMPONENT NAME STACKER BACKS			
DWG TYPE	BLANK	ORIGINAL DATE	12-1-92
CHK BY	MICHAEL J. OSOFSKY	REV. DATE	7-15-93
CHK BY	WILLIAM SEARLES	FILE NAME	ORCA\WORK\STAT\WKSTBS4

D C B A C. 7.

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LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF MICROPLATE STACKER 25 HIGH			
COMPONENT NAME STACKER SIDES			
DWG. TYPE	DETAIL	ORIGINAL DATE	12-1-92
		REV. DATE	7-22-93
DWG BY	MICHAEL J. OSOFSKY		
CHK BY	WILLIAM SEARLES		
	FILE NAME	ORCA\WORKSTAT\WKSTB53D	

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Appendix D: Microplate Workstation

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1

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP

PART OF MICROPLATE WORKSTATION

COMPONENT NAME

DWG. TYPE	ORTHO	ORIGINAL DATE	12-1-92	REV. DATE	4-20-93
-----------	-------	---------------	---------	-----------	---------

DWG. BY	MICHAEL J. OSOFSKY
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DWG. BY	WILLIAM SEARLES	FILE NAME	ORCA\WORKSTAT\ORTHOGI
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D C B A D. 1.

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP			
PART OF MICROPLATE WORKSTATION			
COMPONENT NAME BASE PLATE			
CHK TYPE	ORIGINAL DATE	REV. DATE	
BLANK	12-1-92	4-21-93	
CHK BY	MICHAEL J. OSOFSKY		
CHK BY	WILLIAM SEARLES		
FILE	ORCAWORKSTATWKSTBSI

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION			
HUMAN GENOME INSTRUMENTATION GROUP			
PART OF MICROPLATE WORKSTATION			
COMPONENT NAME BASE PLATE EDGE			
DWG. TYPE	ORIGINAL DATE	REV. DATE	
DETAIL	4-20-93	4-21-93	
DWG BY MICHAEL J. OSOFSKY			
CHK BY	WILLIAM SEARLES		FILE NAME ORCA\WORKSTAT\BSPLAT1

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF MICROPLATE WORKSTATION			
COMPONENT NAME BASE PLATE HOLES			
DOC. TYPE	ORIGINAL DATE	REV. DATE	
DETAIL	12-1-92	4-29-93	
DOC. BY MICHAEL J. OSOFSKY			
CHK. BY	WILLIAM SEARLES		FILE NAME ORCAWORKSTATBSPLAT2

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF MICROPLATE WORKSTATION			
COMPONENT NAME BASE PLATE & OPTIONAL TAPE SLOT			
DWG. TYPE	ORIGINAL DATE	REV. DATE	
DETAIL	12-1-92	4-28-93	
DWG. BY MICHAEL J. OSOFSKY			
CHK. BY WILLIAM SEARLES		FILE NAME ORCA\WORKSTAT\WKSTB56

LAWRENCE BERKELEY LABORATORY			LB
ENGINEERING DIVISION			
HUMAN GENOME INSTRUMENTATION GROUP			
PART OF MICROPLATE WORKSTATION			
COMPONENT NAME BASE PLATE & OPTIONAL TAPE SLOT			
DWG. TYPE	DETAIL	ORIGINAL DATE	REV. DATE
		12-1-92	4-21-93
DWG. BY MICHAEL J. OSOFSKY			
CHK BY WILLIAM SEARLES		FILE NAME ORCA\WORKSTAT\WKSTB55

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Appendix E: 96-Pin Replicating Tool

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP

PART OF MULTIPIN TOOL

COMPONENT NAME

DRG TYPE	ASSEMBLY	ORIGINAL DATE	12-1-92	REV. DATE	4-23-93
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DRG BY	MICHAEL J. OSOFSKY
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CHK BY	WILLIAM SEARLES	FILE NAME	ORCA\MPTOOL\MPASMBLY
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LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION			
HUMAN GENOME INSTRUMENTATION GROUP			
PART OF MULTIPIN			
COMPONENT NAME POLYETHYLENE LAYER			
DWG TYPE	DETAIL	ORIGINAL DATE	12-1-92
		REV. DATE	4-23-93
DWG BY MICHAEL J. OSOFSKY			
CHK BY WILLIAM SEARLES		FILE NAME ORCA\MPTOOL\MPPOLY

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LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP

PART OF MULTIPIN TOOL
COMPONENT NAME PIN

DWG. TYPE DETAIL ORIGINAL DATE 12-1-92 REV. DATE

DWG. BY MICHAEL J. OSOFSKY

CHK. BY WILLIAM SEARLES FILE ORCA\MP\TOOL\MPPIN

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LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION			
HUMAN GENOME INSTRUMENTATION GROUP			
PART OF MULTIPIN TOOL			
COMPONENT NAME HEAT SHIELD			
DWG. TYPE	ORIGINAL DATE	REV. DATE	
DETAIL	4-23-92		
DWG. BY MICHAEL J. OSOFSKY			
CHK. BY WILLIAM SEARLES		FILE NAME ORCA\MPTOOL\HEATSHLD

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF MULTIPIN TOOL			
COMPONENT NAME GRIPPER BAR			
DWG. TYPE DETAIL	ORIGINAL DATE 12-1-92	REV. DATE	
DWG. BY MICHAEL J. OSOFSKY			
CHK. BY WILLIAM SEARLES		FILE NAME ORCA\MPTOOL\GRIPBAR	

Appendix F: 384-Pin Replication Tool

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP

PART OF MULTIPLEX TOOL

COMPONENT NAME

DWG. TYPE	ASSEMBLY	ORIGINAL DATE	12-1-92	REV. DATE	4-23-93
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DWG. BY	MICHAEL J. OSOFSKY
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CHK. BY	WILLIAM SEARLES	FILE NAME	ORCA\MPTOOL\MPSMBLY
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LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF MULTIPIN TOOL			
COMPONENT NAME PIN			
DWG. TYPE DETAIL	ORIGINAL DATE 12-1-92	REV. DATE	
DWG. BY MICHAEL J. OSOFSKY			
CHK. BY WILLIAM SEARLES		FILE NAME ORCA\MPTOOL\MPPIN	

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LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP

PART OF
MULTIPIN TOOL

COMPONENT NAME
HEAT SHIELD

DWG TYPE
DETAIL

ORIGINAL DATE
4-23-92

REV. DATE

DWG BY
MICHAEL J. OSOFSKY

CHK BY
WILLIAM SEARLES

FILE NAME
ORCA\MPTOOL\HEATSHLD

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LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF MULTIPIN TOOL			
COMPONENT NAME GRIPPER BAR			
DWG. TYPE DETAIL	ORIGINAL DATE 12-1-92	REV. DATE	
DWG. BY MICHAEL J. OSOFSKY			
CHK. BY WILLIAM SEARLES		FILE NAME ORCA\MPTOOL\GRIPBAR	

Appendix G: Multipin Tool Parking Station

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF TOOL PARK STATION			
COMPONENT NAME			
DWG. TYPE ORTHOG.	ORIGINAL DATE 7/22/93	REV. DATE	
DWG. BY J. HOME III			
CHK. BY W. SEARLES		FILE NAME ORCAWORKSTATORTHO

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP

PART OF MULTIPIN TOOL PARK STATION		
COMPONENT NAME BASE PLATE HOLES		
DWG. TYPE DETAIL	ORIGINAL DATE 6-3-93	REV. DATE 7/15/93
DWG. BY MICHAEL J. OSOFSKY		
CHK. BY WILLIAM SEARLES	FILE NAME ORCA\WORKSTAT\WKSTBS7	

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LAWRENCE BERKELEY LABORATORY		
ENGINEERING DIVISION		
HUMAN GENOME INSTRUMENTATION GROUP		
PART OF		
MULTIPIN TOOL PARK STATION		
COMPONENT NAME		
TOP PLATFORM		
DWG. TYPE	ORIGINAL DATE	REV. DATE
DETAIL	6-18-93	7-22-93
DWG. BY	MICHAEL J. OSOFSKY	
CHECK BY	WILLIAM SEARLES	FILE NAME ORCAWORKSTATWKSTBS8

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MAKE 4/UNIT

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP

PART OF
MULTIPIN TOOL PARK STATION

COMPONENT NAME
SPACER

DWG. TYPE	ORIGINAL DATE	REV. DATE
DETAIL	6-18-93	7-15-93

DWG. BY MICHAEL J. OSOFSKY

CHK. BY WILLIAM SEARLES	FILE NAME ORCA\WORKSTAT\SPACER
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LAWRENCE BERKELEY LABORATORY			
ENGINEERING DIVISION			
HUMAN GENOME INSTRUMENTATION GROUP			
PART OF MICROPLATE WORKSTATION			
COMPONENT NAME GUIDE			
DWG TYPE	ORIGINAL DATE	REV DATE	
DETAIL	12-1-92	4-20-93	
BY MICHAEL J. OSOFSKY			
BY WILLIAM SEARLES			
FILE ORCA\WORKSTAT\GUIDE

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Appendix H: Multipin Tool Sterilizer Bath

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION			
HUMAN GENOME INSTRUMENTATION GROUP			
PART OF			
STERILIZING BATH			
COMPONENT NAME			
ASSEMBLY DIAGRAM			
Dwg. TYPE		ORIGINAL DATE	REV. DATE
ASSEMBLY		8/10/93	
DWG. BY	J. HOME III	MATERIAL	QJANT.
CHK. BY	W. SEARLES	FILE NAME	SEARLES/DHASMBLY

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP	
PART OF STERILIZER LOCATOR	
DATE 7/13/93	REV. DATE 8/25/93
DESIGNED BY J. HOME III	
CHECKED BY W. SEARLES	
FILE NAME SEARLES\BHLLOCATR

LAWRENCE BERKELEY LABORATORY		
ENGINEERING DIVISION		
HUMAN GENOME INSTRUMENTATION GROUP		
PART OF		
STERILE BATH		
COMPONENT NAME		
GASKET		
DWG. TYPE	ORIGINAL DATE	REV. DATE
MECH.	7/13/93	
DWC. BY J. HOME III		
CHK. BY W. SEARLES		FILE NAME SEARLES\BHGASKT

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EXACT LOCATION
NOT CRITICAL

OVER FLOW

0.500"
(TYP.)

6.938"

4.875"

FLAT ON TOP

3/8" O.D.
S.S. TUBE

CLOSE TO BOTTOM

2.500"

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP

PART OF STERILE BATH			
COMPONENT NAME BATH TANK			
Dwg. TYPE MECH.		ORIGINAL DATE	REV. DATE
DWG BY J. HOME III	MATERIAL		QUANT.
DWG BY W. SEARLES	FILE NAME SEARLES/BHTANK		

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LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP

PART OF
STERILE BATH

COMPONENT NAME
BATH TANK

DWG. TYPE
ORTHOG.

ORIGINAL DATE
7/28/93

REV. DATE

DWG. BY
J. HOME III

MATERIAL
STAINLESS STEEL

QUANT.

CHECK BY
W. SEARLES

FILE NAME
SEARLES\DHORTHG2

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SECTION AA

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION				
HUMAN GENOME INSTRUMENTATION GROUP				
PART OF				
STERILIZER				
COMPONENT NAME				
ENCLOSURE				
DWG. TYPE	ORIGINAL DATE	REV. DATE		
ORTHOG.	8/10/93	8/25/93		
CHK BY	J. HOME III	MATERIAL	ALUMINUM	QUANT.
CHK BY	W. SEARLES	FILE NAME	SEARLES\BHHOLDTK

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION			
HUMAN GENOME INSTRUMENTATION GROUP			
PART OF STERILIZER			
COMPONENT NAME ENCLOSURE			
DRG. TYPE ORTHOG.	ORIGINAL DATE 7/30/93	REV. DATE 8/25/93	
DRG. BY J. HOME III	MATERIAL ALUMINUM	QUANT. 1	
CHK. BY W. SEARLES	FILE NAME SEARLES\BHORTHG3

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION			
HUMAN GENOME INSTRUMENTATION GROUP			
PART OF STERILIZER			
COMPONENT NAME COVER			
DWG TYPE MECH	ORIGINAL DATE 7/15/93	REV. DATE 8/25/93	
DWG BY J. HOME III			
CHK BY W. SEARLES		FILE NAME SEARLES\DHCOVER

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF STERILE BATH			
COMPONENT NAME OVER FLOW			
DWG. TYPE MECH.	ORIGINAL DATE 7/28/93	REV. DATE	
CHK. BY J. HOME III	MATERIAL	QTY.	
CHK. BY W. SEARLES	FILE NAME SEARLES/BHOVERFL		

Appendix I: Multipin Tool Sterilizer Bath Level Sensor

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION			
HUMAN GENOME INSTRUMENTATION GROUP			
PART OF			
STERILIZER BATH			
COMPONENT NAME			
LEVEL SENSOR			
Dwg. Type		Original Date	Rev. Date
SCHEMATIC		7/27/93	7/28/93
Dwg. By		J. HOME III	Material
Chk. By		W. SEARLES	Quant.
		File Name	SEARLES/CIRCUIT

Appendix J: Multipin Tool Sterilizer Bath Sonicator Driver

COIL 1

L1

NOTE (1)

COIL 2

RF+

J1
BNC

TO XDUCTOR

CT40450
BLATEK, INC.
STATE COLLEGE, PA

RF-

NOTE (1)

NOTE (1)
PARTS REMOVED FROM:
BRANSON MOD. 1200
VWR# 21812-119

Title			
SONICATOR POWER SUPPLY			
Drawn	Date	LAWRENCE BERKELEY LABORATORY UNIVERSITY OF CALIFORNIA ENGINEERING DIVISION SCIENCE DEPARTMENT	
Checked	Date		
Approved	Date		
Engineer	Size	Document Number	REV
File Name	A		
Date:		October 18, 1993	Sheet of

Appendix K: Multipin Tool Sterilizer Reservoir

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP

PART OF
STERILE BATH
COMPONENT NAME
HOLDING TANK

DRG. TYPE
MECH

ORIGINAL DATE
7/19/93

REV. DATE

DRG. BY
J. HOME III

CHK BY
W. SEARLES

FILE NAME
SEARLES/DHTANK

Appendix L: Multipin Tool Sterilizer Heater

LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF MULTITOOL DRYER			
COMPONENT NAME ASSEMBLY DIAGRAM			
DWG. TYPE ASSEMBLY	ORIGINAL DATE 8/1/93	REV. DATE	
DWG. BY J. HOME III	MATERIAL	QTY.	
CHK BY W. SEARLES	FILE NAME SEARLES/DRAWING		

DRILL #29 THRU
COUNTERBORE 5/16"
0.100" DEEP

0.490"
30 DEG. CHAMFER

TAP 10-32

2.062"

0.250"

(TYP.)

1.250"

0.370"

3.385"

0.125"

0.125"

USE MODIFIED
CENTER DRILL

0.250"

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP

PART OF
STERILIZER

COMPONENT NAME
LOCATOR

DWG. TYPE
MECHANICAL

ORIGINAL DATE
7/13/93

REV. DATE
8/25/93

CHK. BY
J. HOME III

CHK. BY
W. SEARLES

FILE NAME
SEARLES\BHLOCATR

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION			
HUMAN GENOME INSTRUMENTATION GROUP			
PART OF			
STERILE DRYER			
COMPONENT NAME			
HEATER FRAME			
DRG. TYPE	ORIGINAL DATE	REV. DATE	
MECH.	7/19/93	8/25/93	
DRG. BY J. HOME III			
CHK. BY W. SEARLES		FILE NAME SEARLES/DHHEATER	

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LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION			
HUMAN GENOME INSTRUMENTATION GROUP			
PART OF STERILE DRYER			
COMPONENT NAME HEATING PLATE			
ENG. TYPE ORTHOGONAL	ORIGINAL DATE 7/11/93	REV. DATE 8/25/93	
ENG. BY J. HOME III	MATERIAL	QUANT.	
CHK. BY W. SEARLES	FILE NAME SEARLES\DHORTHG4		

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SECTION AA

LAWRENCE BERKELEY LABORATORY
ENGINEERING DIVISION
HUMAN GENOME INSTRUMENTATION GROUP

PART OF
STERILIZER

COMPONENT NAME
ENCLOSURE

ENG. TYPE
ORTHOG.

ORIGINAL DATE
8/10/93

REV. DATE
8/25/93

DESIGNED BY
J. HOME III

MATERIAL
ALUMINUM

QUANT.

CHECKED BY
W. SEARLES

FILE NAME
SEARLES\BHHOLDTK

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LAWRENCE BERKELEY LABORATORY ENGINEERING DIVISION HUMAN GENOME INSTRUMENTATION GROUP
PART OF STERILIZER COMPONENT NAME ENCLOSURE			
DWG. TYPE ORTHOG.	ORIGINAL DATE 7/30/93	REV. DATE 8/25/93	
DWG. BY J. HOME III	MATERIAL ALUMINUM	QUANT.	
CHK. BY W. SEARLES	FILE NAME SEARLES\DHORTHG3

HEFT

HEATER WIRE GUL

.280
1

TO & OF
.250
CUTTER

.155
 .509
 .864
 1.218
 1.572
 1.927
 2.281
 2.635
 2.989
 3.344

.250
1

MACHINABLE
CERAMIC
(CAVA "A")
2 PER

Appendix M: Multipin Tool Sterilizer Heater Control

Appendix N: I/O Control Box (1 Of 8 Bits)

ORCA I/O CONTROL BOX

1 of 8 bits

From H-P 3488A
44474A Card

**DATE
FILMED**

5 / 4 / 94

END