DENTON VACUUM, LLC

Explorer® 14 Cryo System

Dartmouth College
Job # 43137

OPERATING MANUAL

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Cryo Pump CTI Cryogenics M p/n n/a M m/n CTI-8 S/N E03149862	Manual Provided
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EQUIPMENT LIST, SERIAL NUMBERS AND VENDOR MANUALS

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DC Power Supply Xantrex M p/n n/a M m/n XFR 1200 S/N 64185	Manual Provided
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Vendor Manual List

DARTMOUTH COLLEGE

EXPLORER® 14

Job #: 43137

Company	Manual
PFEIFFER VACUUM	MANUAL FOR ROTARY VANE PUMP (PK 800 170 BN/D 9910)
XANTREX	OPERATING MANUAL FOR XFR 1200 POWER SUPPLY
MKS INSTRUMENTS	INSTRUCTION MANUAL FOR MASS FLOW CONTROLLER & METER
SEREN	OPERATING MANUAL FOR POWER SUPPLY R600
SEREN	OPERATING MANUAL FOR MATCHING NETWORK AT-6
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CTI-CRYOGENICS	OPERATING, INSTALLATION, & MAINTENANCE MANUAL FOR CRYO-TORR HIGH VACUUM PUMP WITH COMPRESSOR
PC ANYWHERE	MANUAL FOR PC ANYWHERE ON CD
GE FANUC	LICENSE KEY FOR CIMPLICITY ON CD
SAMSUNG DIGITAL	USER'S GUIDE FOR SYNCMASTER MONITOR WITH INSTALLATIONMANUAL FOR MONITOR DRIVE
3COM	NETWORK ASSISTANT FOR OFFICE CONNECT ON CD
WEIDMULLER	INSTALLATION GUIDE FOR TERMINAL BLOCK
WEIDMULLER	INSTALLATION GUIDE FOR SWITCHMODE POWER SUPPLY
HIGH VACUUM APPARATUS	INSPECTION & TEST SHEET FOR GATE VALVE
WHITMAN CONTROLS	INSTALLATION MANUAL FOR VACUUM & PRESSURE SWITCH
SKINNER VALVE	INSTALLATION, OPERATING, & MAINTENANCE INSTRUCTION FOR SOLENOID VALVE
PROTUES INDUSTRIES	MANUAL FOR 100 SERIES FLOW SWITCH
US INC.	OPERATING MANUALS FOR MAK SPUTTERING SOURCE
RELIANCE ELECTRIC	INSTRUCTION MANUAL FOR DC3E DC DRICE (D2-3452)

1. Introduction

The Denton Explorer® 14 Sputtering System is a customized vacuum deposition system designed for thin film research applications. It features a "box coater" design that provides easy access to substrates, sources, and instrumentation while maintaining excellent pumping characteristics. This system is designed to simplify the geometry necessary for coordination of multiple sputter sources, biasable substrate table, and Substrate heat.

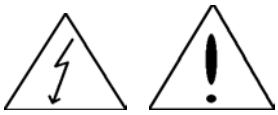
Because Denton uses the finest available subsystems and components, the system is highly reliable and durable. The system's inherent flexibility allows the operation of multiple sputter sources and RF Bias source, the ability to heat and rotate the substrates, and automatically control the process.

The Explorer® 14 system is fully automatic and is controlled by a computer with a mouse running GE Cimplicity® PC control software combined with a GE VERSAMAX programmable logic controller. The computer, keyboard, power supplies, and switches are installed in a single electrical control cabinet. The cabinet is conveniently located next to the chamber on a unit frame for easy installation, observation and operation.

The system offers you a myriad of thin film process options. However, it is important to note that with all of this system's potential there exists safety considerations. **Individuals who are to operate, service, or maintain this system should familiarize themselves with this manual.**

If this equipment is used in a manner not specified by Denton Vacuum, the protection provided by the equipment may be impaired.

2. SAFETY WARNINGS



This vacuum deposition system is comprised of a number of complex subsystems

LETHAL VOLTAGES, HIGH TEMPERATURES, HIGH PRESSURES AND POWERFUL MECHANICAL DRIVE MECHANISMS ARE PRESENT THROUGHOUT THE SYSTEM.

Every attempt has been made to safeguard operating and maintenance personnel. Interlocking of subsystems provides a high degree of operator safety.

SYSTEM/SOFTWARE INTERLOCKS SHOULD NEVER BE DEFEATED UNLESS SERVICING OF THE SYSTEM REQUIRES TEMPORARY INTERLOCK OVERRIDES. HARDWIRED SAFETY INTERLOCKS MUST NEVER BE DEFEATED.

All safety/software interlocks should be returned to operational status when problems have been corrected.

Operating and maintenance manuals have been provided and should be thoroughly understood before any operations are contemplated.

THE SYSTEM SHOULD BE OPERATED ONLY BY PERSONNEL WITH PROPER TRAINING AND PROCESS EXPERIENCE.

IF THE EQUIPMENTS ARE IN A MANNER NOT SPECIFIED BY THE MANUFACTURERS, THE PROTECTIONS PROVIDED BY THE EQUIPMENTS MAY BE IMPAIRED.

2.1 MECHANICAL REQUIREMENTS

Equipment is to be designed to industrial machine tool standards and where applicable to GM Electronics Specifications for Industrial and Clean Room Equipment (WEMA-8403, 4/15/87)

Commercially purchased components are new and of industrial quality. All ferrous or aluminum metals are properly finished to prevent corrosion or oxidation. All pneumatic lines, valves, cylinders and flow controls are to operate at a minimum pressure of 90 psi and a maximum pressure of 110 psi.

2.2 ELECTRICAL STANDARDS

All electrical equipment is in accordance with the National Electric Code and where applicable General Motors ES1 Basic electrical standard. All signal power is isolated from system power; proper shielding and routing practices must be followed. All electrical, electronic, and optical sensors must be adequately protected from process contamination.

Three-phase power distribution is 208 VAC, 60 cycle (all equipment with three phase inputs must be supplied for this voltage); single-phase inputs are 208 VAC and 120 VAC. All equipment has panelized control with a single entrance protection by heavy duty disconnect switch. The disconnect switch has a “lockout” provision to ensure that no electrical power can be delivered to the system during maintenance operations.

2.3 SAFETY INTERLOCKS

The system is equipped with a hardwired safety interlock system, which fully protects operators and maintenance personnel from injury. The following hardwired interlocks are provided:

- Cathode Power: Vacuum safety bellows switch and chamber door.
- Heat Power: Vacuum safety bellows switch and chamber door.

All hardwired safety interlock status will be duplicated by system controller "software" interlocks. The status of all hardwired interlocks is displayed on the control screen.

2.4 MOVING PARTS

Sliding surfaces and pinch points are fully guarded to prevent injury to operators and maintenance personnel. In the event of a power failure, all moving parts come to their home position without damage to the equipment or injury to operators and/or maintenance personnel.

2.5 POWER SYSTEMS

In the event of an interlock dropout or power failure, all power to the internal sources of energy is interrupted. When power is restored, or an interlock is satisfied, a hard, manual reset of the effected subsystem will be required. High voltage transformers, vacuum feedthroughs and interconnecting cabling is enclosed in watertight enclosures (NEMA 12 rating or better).

2.6 ENVIRONMENTAL CONDITIONS

The system is designed and intended for use in the following environmental conditions. If all specifications are not met, system components may malfunction and can possibly cause injuries.

- Altitude up to 2000m
- Temperature range from 5 to 40^{o} C
- Maximum relative humidity 80% for temperature up to 31^{o} C decreasing linearity to 50% relative humidity at 40^{o} C
- Mains supply voltage fluctuations not to exceed +/-10% of the nominal voltage
- Other supply voltage fluctuations as stated by the manufacturer
- Pollution degree 2 in accordance with IEC 664

2.7 SAFETY SYMBOLS

	CAUTION: Risk of Electrical Shock
	CAUTION: This symbol is intended to alert the user to the presence of important operation & maintenance instructions in this manual.
	Protective Conductor Terminal: this symbol indicates where the protective earth ground is connected.

DARTMOUTH COLLEGE
EXPLORER®-14 T/A COATING SYSTEM
SUMMARY SPECIFICATION
&
ACCEPTANCE TEST PROTOCOL

(April 23, 2003)
Job # 43137
REVISION A (5-11-03)

3. SUMMARY SPECIFICATION:

3.1. DEPOSITION CHAMBER:

1.) Discovery SJ/14; 12" (high) x 14" (wide) x 14"(deep).
2.) 304 stainless steel construction (painted).
3.) Large-profile, front-loading door; 12"(high) x 13"(wide).
4.) One complete set of removable, stainless steel shields (multi-piece construction to facilitate removal and installation).
5.) Rear mounted pumping plenum assembly.
6.) Baseplate bolted to chamber assembly.

7.) Multi-piece plenum mounted at substrate stage level.
8.) The following penetrations are provided:

Baseplate:

- ISO 200 flange (center mounted for substrate stage rotation/bias, heater electrical feedthrus, and T.C. probe),

Sidewall:

- (3) 2.75" CF flanges (3-blank, and
- (1) 0.25" compression seal (gas inlet).
- (2) 10" O.D. CF flange (1 blanked for future use) (1 for pump port)
- (1) 16 – NW (capacitance manometer)
- (1) 25-NW (Full Range Gauge)

Door:

- (1) optically shielded 4.0" diameter viewport (front door) to permit unrestricted viewing of all installed deposition sources and substrate fixturing.

Top-plate:

- (1) ½" Compression Seal (spare gas inlet),
- (3) ISO 160 cathode assembly mounting ports,
- (3) cathode mounting flange with the following penetrations:
  - (1) .75" compression seal (sputter cathode), and
  - (1) 0.25" (shutter rotary motion feedthrough).

Pumping Plenum:

- 10" O.D. CF port extension flange,
- (1) NW-25
- (1) 8" I.D. mitered elbow w/ 10" O.D. CF flanges

3.2. PUMPING SYSTEM:

- CTI Cryogenics CT-8 cryogenic pump.
- CTI Cryogenics water-cooled compressor. 10' Helium lines.

- Pfeiffer Duo 10 two-stage, rotary vane pump (7 CFM):
  i. Inlet and exhaust filter

9.) ***High Vacuum Valve:*** Three position gate valve;10" CF flanges.

10.) ***Roughing Valve:*** NW25 bellows-sealed, electro-pneumatic, roughing valve.
11.) ***Regen Valve:*** NW25 bellows-sealed, electro-pneumatic, Regen valve.
12.) ***Cryopump Purge Valve:*** CTI purge valve package.
13.) ***Vent Valve:*** 0.25" VCO, bellows-sealed, electro-pneumatic, vent valve.
14.) ***Leak Check Valve:*** Manual ball valve mounted in foreline.
15.) ***Foreline filter:*** CT-103.

3.3. VACUUM GAUGING & GAS CONTROL:

- (2) Inficon BPG 400 combination Bayard-Alpert ionization gauge transmitters (ISO-25 flanging; main chamber and high vacuum valve body/pump side).
- (1) Inficon SKY Capacitance manometer gauge for process control (chamber).
- (2) MKS 2179A Mass Flow controller:
    i. 100 SCCM with CB 259-5 cables,
    ii. integrated to system PC. with
    iii. PID control
- Gas manifold for (4) positions, (2 will be VCR blanked)

3.4. CABINET:

16.) Fully-enclosed system cabinet (on casters) with a full opening service door:

i. (1) Main cabinet:
- 30" (wide) x 27 3/4" (deep) x 39" (high) steel cabinetry,
- Aluminum swing door with locker, and
- All controls and electrics mounted on service door to facilitate system maintenance and troubleshooting activities.

ii. (1) Extend cabinet:
- 19" (wide) x 27 3/4" (deep) x 39" (high) steel cabinetry, and
- Aluminum swing door with locker.

iii. (1) Control cabinet:
a. 19" (wide) x 23" (deep) x 17 3/4" (high) steel cabinetry.

3.5. SPUTTER SOURCE:

- (3) 2.0" diameter, internal stalk-mount, "US Gun", planar magnetron sputter sources:
    i. RF/DC capability,
    ii. Variable source to substrate distance,
    iii. Clamp/bond target compatibility, and
- (3) independent, electro-pneumatic source shutters (cylinder mounted air flowrate control) interfaced to system PLC for remote open/close operation.

3.5.1. DC POWER GUN SUPPLY:

- (1) Xantrex 1 kW DC power supplies:
    i. (1) switchable between Source #2 and #3,
    ii. Hardwired safety interlock (chamber door, vacuum bellows safety switch, cathode water),
    iii. Interfaced to system controller for remote on/off operation and setpoint control.
- (1) Seren 600 watt R600 Generator with MC-2 controller and match tuning network AT-6
    iv. (1) dedicated to Source #1,
    v. Hardwired safety interlock (chamber door, vacuum bellows safety switch, cathode water),
    vi. Interfaced to system controller for remote on/off operation and setpoint control.

- Cooling water flow sense on cathode's dedicated cooling water circuit (safety interlock). Proteus sensor mounted on rear of cabinet.

3.6. SUBSTRATE STAGE:

- RF-bias substrate stage :
    i. 6.0" substrate platen; pre-machined to accept DVI 150 mm sample transfer holder.
    ii. Table premachined for water cooling circuit
- (2) DVI 150 sample transfer holders (blank).
    I (1) machined SST blank
    Ii (1) machined Copper blank
- (1) DVI high performance, water-cooled, RF-biasable rotary motion feedthrough, ISO 200 NW flanging.

- (1) direct-drive, compact, gear motor:
    i. Speed adjust (0-20 RPM) via set point control, and
    ii. Interfaced to system PLC for remote on/off operation.

3.6.1. SUBSTRATE STAGE RF-BIAS POWER SUPPLY:

NOTE: (OPTION NOT SELECTED, SYSTEM WILL BE CONFIGURED WITH ALL NECESSARY HARDWARE/ MECHANICAL, ELE, AND SOFTWARE FOR FIELD INSTALLATION OF POWER SUPPLY AT A LATER DATE)

- (1) Seren R300 power supply (300 watt output), coupled to a Seren automatic match network (air cooled operation):
    i. Hardwired safety interlock (chamber door, vacuum bellows safety switch),
    ii. Interfaced to system controller for remote on/off operation and setpoint control, and
    iii. Dedicated to RF bias stage.

3.6.2 SUBSTRATE HEAT:

- (2) 1.0 kW, backside quartz heater arrays with reflector and deposition shield.
- 208/110 VAC step-down/isolation transformer to minimize possibility of spurious glow discharges and feedback from sputter power supplies.
- PID temperature control system:
    i. Interfaced to system controller for remote on/off, setpoint.
- (1) sheathed thermocouple positioned internally in chamber.

3.7. DEPOSITION CONTROL:

- PC control for all power supply parameters. Thickness will be based on time and power supply control parameters.

3.8. SYSTEM AUTOMATION:

- Industrial PC (Windows XP® Professional operating system); flat-panel display.
- ProcessPro® control software configured for specific delivered hardware:
    i. activation of pumps, valves, deposition sources, subsystems, gauging, gas/flow control, setpoints, and automatic process sequence activation.
- GE-Fanuc VERSAMAX programmable logic controller interfaced to system host computer.
- Remote access via user-supplied dedicated analog phone line.
- Full remote setpoint capability:
    i. Gas 1 & 2 flowrates,-upgradeable to (4) total MFC's
    ii. Substrate temperature,
    iii. DC power supply setpoints,
    iv. RF power supply setpoints, and
    v. Active cathodes.
    vi. Future RF Bias control
- Multiple operation modes:
    i. Manual,
    ii. Automatic,
    iii. Maintenance, and
    iv. Automatic process sequence generation and editing
    v. Up to 250 process steps per recipe
- Recipe storage for up to 799.
- Data logging for process parameters
- Alarm messaging and interlock notification
- Remote recipe writing capabilities
- Automatic process sequences delivered:
    i. Autopump,
    ii. Autovent,
    iii. Multi layer deposition Recipes
    iv. Cryo Regen process

3.9. UTILITY REQUIREMENTS:

17.) **Electrical:**

- 208 VAC (+/- 5 %), 60 Hz, single-phase, 3 wire, 70 Amps. (estimated).
- Actual electrical requirements determined when schematics are completed.

- Panelized control with single entrance protection by a heavy duty disconnect switch with "lockout" provision, provided by DVI.

18.) **Water:**
- (6) GPM, 60-80 °F, 40-60 psig differentials between supply and return (60 psig maximum inlet pressure).
- Water distribution:
    1) Cathode #1, #2, and #3, and
    2) CTI 8200 water cooled compressor.
    3) Open drain for cooling table water exhaust
    4) Electric solenoid valve control for "heating and cooling" processes on substrate table. PC interfaced.

19.) **Air**:
- Normal dry shop air, 90-110 psi (system valve operation).
- Stand-alone air manifold positioned above the water manifold; solenoid valves incorporating removable plug-type electrical connections.

-

20.) **Argon (99.9995 % purity):**
- 3-15 psi (process gas).

21.) **Nitrogen (optional):**
- Preferentially evaporated from a liquid source.
- 3-15 psi (chamber venting).

3.10. SYSTEM DOCUMENTATION:

22.) Operating instruction manual; to include preventive maintenance procedures/timetable, troubleshooting guides, and spare parts listing (CD-ROM).
23.) One complete set of sub-assembly vendor manuals.
24.) One complete set of electrical schematics (CD-ROM with viewer).
25.) One complete set of mechanical drawings necessary for system maintenance and repair (CD-ROM).

3.11. MECHANICAL REQUIREMENTS:

26.) Commercially purchased components will be new, of industrial quality and demonstrated "best in class" availability.
27.) All ferrous or aluminum metals will have proper finishes to prevent corrosion or oxidation.
28.) All pneumatic lines, valves, cylinders and flow controls are designed to operate at a minimum pressure of 80 psi and a maximum pressure of 110 psi.

3.12. ELECTRICAL STANDARDS:

29.) All electrical equipment shall be compliant with NEC (US) and CE code and regulations.
30.) All signal power will be isolated from system power; proper shielding and routing practices must be followed.
31.) All electrical, electronic, and optical sensors must be adequately protected from process contamination.
32.) Three-phase distribution is 208 VAC, 60 cycle (all equipment with three phase inputs must be supplied for this voltage); single-phase inputs shall be 208/220 VAC and 120 VAC.
33.) All equipment shall have panelized control with a single entrance protection by a heavy duty disconnect switch. The disconnect switch will have a "lockout" provision to ensure that no electrical power can be delivered to the system during maintenance operations.

3.12.1.SAFETY INTERLOCKS:

34.) The system will be equipped with a hardwired safety interlock system, which fully protects operators and maintenance personnel from personal injury. The following hardwired interlocks will be provided:
- Resistance Evaporation Power: Vacuum bellows switch and chamber door, and
- Heat Power: Vacuum safety bellows switch and chamber door.

35.) The status of all hardwired safety interlocks will be displayed to the system operator(s) at all times.
36.) System controller "software" interlocks will duplicate all hardwired safety interlock status.

3.12.2.MOVING PARTS:

37.) Sliding surfaces and pinch points must be fully guarded to prevent injury to operators and maintenance personnel.
38.) In the event of a power failure, all moving parts are to come to a complete stop. Upon initiating a restart cycle, all moving parts are to proceed to their home position without damage to the equipment or injury to operations and/or maintenance personnel.

3.12.3.POWER SYSTEMS:

39.) In the event of an interlock dropout or power failure, all power to internal sources of energy (heat and resistance evaporation power supply) will be interrupted. When power is restored, or an interlock is satisfied, a hard, manual reset of the affected subsystem will be required.

40.) High voltage transformers, vacuum feedthroughs and interconnecting cabling will be enclosed in water-tight enclosures.

4. SYSTEM ACCEPTANCE TEST (DVI Factory)

4.1. HARDWARE REVIEW:

All stated equipment, and subsystems detailed in Summary Specification were present and accounted for.

WITNESS:

_____ _____ _____ Denton

Vacuum LLC Dartmouth College Date

4.2. VACUUM PERFORMANCE:

4.2.1. PUMPDOWN AND ULTIMATE VACUUM:

1.) Clean, dry and empty system pumped overnight (12 hrs minimum).

2.) Chamber to demonstrate ultimate pressure of $\leq 8.0 \times 10^{-8}$ torr .

3.) Chamber vented to atmosphere with dry N_2 gas.
4.) Chamber door to be kept closed. (to avoid uncontrolled environmental conditions)
5.) Chamber door closed and system pumped into high vacuum status using "AUTOPUMP" automatic pumping sequence.
6.) Chamber pressure to be recorded at 30-second intervals during roughing and at one-minute intervals after high vacuum crossover.
7.) Data to be recorded for a period of 30 minutes.

WITNESS:

_____ _____ _____ Denton
Vacuum LLC Dartmouth College Date

4.2.2. PRESSURE RISE DOCUMENTATION:

1.) Clean, dry and empty system pumped overnight (12 hrs minimum).
2.) High vacuum valve and high vacuum bypass valve closed.
3.) Rise in chamber pressure recorded at one-minute intervals for a period of thirty minutes.
4.) Data presented in both a tabular and graphical format.

WITNESS:

_____ _____ _____ Denton
Vacuum LLC Dartmouth College Date

4.3. MANUAL SYSTEM CONTROL:

4.3.1. PUMPS, VALVES, ROTATION AND SHUTTERS:

1.) Individual pump, valve, rotation, and shutter icons selected and then enabled (subject to pre-defined manual mode interlocks).

WITNESS:

_____ _____ _____ Denton
Vacuum LLC Dartmouth College Date

4.3.2. MANUAL SUBSTRATE ROTATION:

1.) Demonstrate rotation control up to 20 RPM

4.3.3. PROCESS GAS:

1.) High vacuum system status.
2.) Process gas isolation valve opened.
3.) Mass flow controller adjusted to achieve a chamber pressure of 5 mtorr.
4.) Process gas isolation valve closed.
5.) Repeat for both mass flow controllers.

WITNESS:

_____ _____ _____ Denton
Vacuum LLC Dartmouth College Date

4.3.4. MANUAL DEPOSITION OPERATION:

1) All test targets (clamp-type) installed; source to substrate distance of 4.00" established.
2) Test coupons (supplied by DVI) placed in sample holder.
3) Chamber pumped into high vacuum status.
4) Substrate rotation energized.
5) Active cathode "#1" selected via PC.
6) Argon introduced into main chamber; process pressure of 5.0 mtorr attained.
7) RF setpoint of 150 W programmed into power supply.
8) RF power supply energized.
9) Target soaked at 150 W for 1 minute.
10) Cathode shutter opened.
11) RF discharge sustained for 5 minutes.
12) During discharge, demonstrate operation at system pressures of 1,3 & 5, millitorr.
13) Cathode shutter closed.
14) RF power supply de-energized.
15) Argon process gas isolation valve closed.
16) Repeat for DC cathodes # 2, 3.

WITNESS:

_____ _____ _____ Denton
Vacuum LLC Dartmouth College Date

4.4. MANUAL SUBSTRATE COOLING:

i. Demonstrate water flow thru table assembly during a 5 minute film deposition

ii. Demonstrate water flow interlock for heat process to show water circuit exhaust.

4.5. MANUAL SUBSTRATE HEATING:

1) Clean dry and empty system; high vacuum status.
2) Remote temperature setpoint input into parameter field (300 degrees Centigrade).
3) Substrate rotation energized.
4) Heater power energized.
5) Substrate temperature (measured by primary internal chamber thermocouple) stabilized at setpoint, +/- 3 degrees, soak for 15 minutes.
6) Heater power de-energized.

WITNESS:

_____ _____ _____

Denton Vacuum LLC Dartmouth College *Date*

4.6. AUTO PROCESSING:

4.6.1. RESIDENT BASELINE PROGRAMS:

1.) Automatic chamber pumping from atmospheric pressure to high vacuum status demonstrated using resident "AUTOPUMP" process sequence.
2.) Automatic chamber venting from high vacuum status to atmospheric pressure demonstrated using resident "AUTOVENT" process sequence.

WITNESS:

_____ _____ _____ Denton

Vacuum LLC Dartmouth College Date

4.6.2. AUTOMATIC SPUTTERING (CATHODES 1 , 2, 3):

1) All test targets (clamp-type) installed, (TBD.); source to substrate distance of 4.00" established.
2) Test samples placed on sample holder.
3) Chamber pumped into high vacuum status.
4) RF setpoint of 150 W programmed into power supply, cathode # 1.
5) Argon flowrate programmed into system controller.
6) Activate cathode #1, selected via system controller.
7) Pre-sputter time period programmed into system timer.
8) Sputter time period programmed into system timer.
9) Automatic sputter process initiated via PC.
10) Steps 1 through 9 repeated for DC cathodes #2, 3.
11) Thickness non-uniformity less than +/- 5.0 % demonstrated over 150 mm substrate diameter.

Definitions:

$$\textbf{"+/- Thickness Non-Uniformity"} = ((T_{max}-T_{min})/T_{avg})/2)*100$$

where:

$\mathbf{T_{max}}$ = Maximum thickness recorded within measurement area
$\mathbf{T_{min}}$ = Minimum thickness recorded within measurement area
$\mathbf{T_{avg}}$ = Average thickness recorded within measurement area

WITNESS:

Denton Vacuum LLC	Dartmouth College	Date

4.6.3 Demonstration Of Process Control During Deposition Layers/ Multi-layers/ Multi Steps.

1) In an Automatic recipe run, demonstrate (3) layer film using each source.
2) In an Automatic recipe run, demonstrate a process run for multiple steps beginning with: Chamber pump, co-sputter deposition with cooling, co-sputter deposition with heating, substrate cool-down step, Chamber vent.
3) In an Automatic recipe run, demonstrate process changes within any given layer while maintaining a plasma at the source(s). This process run will show the following parameter changes: Temperature/system gas control/system pressure/deposition rate/co-sputter/source transition.

WITNESS:

Denton Vacuum LLC	Dartmouth College	Date

4.7 SYSTEM INTERLOCKS:

1.) All system "soft" interlocks tested and functionality verified.
2.) All system "hard" safety interlocks tested and functionality verified.
3.) System Emergency-Stop tested and functionality verified.

WITNESS:

Denton Vacuum LLC	Dartmouth College	*Date*

ACCEPTANCE TEST

VACUUM PERFORMANCE: LEAKUP AND ULTIMATE VACUUM

EXPLORER 14

Procedure:

1 Clean, dry and empty system pumped overnight (12 hours minimum).
2 Base vacuum < thn 5.0 x 10-7 torr (with Ln2).
3 Close high vacuum valve.
4 Rise in chamber pressure recorded at one-minute intervals for a period of thirty minutes.

DATE: 8/26/2003 JOB # 43137 DENTON AT

ULTIMATE PRESSURE 8.3 x -8 **START VACUUM** **HI VAC**

Minute	Vacuum (torr)	Minute	Vacuum (torr)	Minute	Vacuum (torr)	Minute	Vacuum (torr)
1	3.3 x -6						
2	6.2 x -6						
3	9.5 x -6						
4	1.3 x -5						
5	1.7 x -5						
6	2.1 x -5						
7	2.6 x -5						
8	3.4 x -5						
9	3.8 x -5						
10	4.2 x -5						
11	4.7 x -5						
12	5.1 x -5						
13	5.6 x -5						
14	6.0 x -5						
15	6.5 x -5						
16	6.9 x -5						
17	7.4 x -5						
18	7.9 x -5						
19	8.3 x -5						
20	8.8 x -5						
21	9.3 x -5						
22	9.8 x -5						
23	1.0 x -4						
24	1.1 x -4						
25	1.1 x -4						
26	1.2 x -4						
27	1.2 x -4						
28	1.3 x -4						
29	1.3 x -4						
30	1.4 x -4						

Customer: Dartmouth College

ACCEPTANCE TEST

VACUUM PERFORMANCE: PUMPDOWN AND ULTIMATE VACUUM

EXPLORER 14

Procedure:

1 Clean, dry and empty system pumped overnight (12 hrs. minimum).
2 Chamber to demonstrate ultimate pressure of < 3.0E-7 torr LN Trap filled.
3 Chamber vented to atmosphere with dry N2 gas.
4 System pumped into high vacuum status using "AUTOPUMP" automatic pumping sequence.
5 Chamber to reach pressure of 150 mtorr (high vacuum crosover) in < 10 minutes after initiating pumping cycle.
6 All pumpdown data to be recorded on one-minute intervals for a period of minutes.

DATE: 8/18/2003 JOB # 43137 DENTON AT

ULTIMATE PRESSURE 7.3 x -8 **START VACUUM**

	ROUGH		HI-VAC				HI VAC
Minute	Vacuum (torr)	Minute	Vacuum (torr)	Minute	Vacuum (torr)	Minute	Vacuum (torr)
0.5	1.1 x +2	1	5.7 x -6				
1	2.6 x +1	2	3.2 x-6				
1.5	5.1 x +0	3	2.2 x -6				
2	1.1 x +0	4	1.8 x -6				
2.5	3.2 x -1	5	1.5 x -6				
3	1.2 x -1	6	1.3 x -6				
7		7	1.2 x -6				
8		8	1.0 x -6				
9		9	9.5 x -7				
10		10	8.8 x -7				
11		11	8.1 x -7				
12		12	7.8 x -7				
13		13	7.3 x -7				
14		14	7.0 x -7				
15		15	6.7 x -7				
16		16	6.4 x -7				
17		17	6.1 x -7				
18		18	5.9 x -7				
19		19	5.6 x -7				
20		20	5.4 x -7				
21		21	5.2 x -7				
22		22	5.1 x -7				
23		23	4.9 x -7				
24		24	4.7 x -7				
25		25	4.6 x -7				
26		26	4.5 x -7				
27		27	4.4 x -7				
28		28					
29		29					
30		30					

Customer: Dartmouth College

ACCEPTANCE TEST
Section 2.3.5

THICKNESS UNIFORMITY

Non Thickness Uniformity = $((T_{max} - T_{min}) / T_{avg} / 2) \times 100$

Customer:
Dartmouth

Tmax = **Maximum thickness recorded within useful fixture area**
Tmin = **Minimum thickness recorded within useful fixture area**
Tavg = **Average thickness recorded within useful fixture area**

DATE August 20, 2003
Specification: **+/- 5%** **TEST TYPE** Test

	Location on Planet											
Run	**Center**	**1.0**	**2.0**	**3.0**	**Avg.**	**%**	**Avg. #1,#2**	**Avg. #3,#4**	**Max-Min**	**Prog. Thk.**	**Tooling Factor**	**Notes**
C1	1250.0	1100.0	1135.0	1025.0	*1127.5*	**9.98**	1161.7	1025.0	225.0			Alum/RF/300sec/4 Angst/sec
C2	3025.0	2905.0	3005.0	3065.0	*3000.0*	**2.67**	2978.3	3065.0	160.0			Cu/DC/300sec/10 Angst/sec
C3	1675.0	1510.0	1455.0	1425.0	*1516.3*	**8.24**	1546.7	1425.0	250.0			Alum/DC/300sec/5 Angst/sec
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			
C1-1	1120.0	1065.0	1150.0	1160.0	*1123.8*	**4.23**	1111.7	1160.0	95.0			C1 rotated 20 Deg.
C3-1	1285.0	1300.0	1295.0	1240.0	*1280.0*	**2.34**	1293.3	1240.0	60.0			C3 rotated 20 Deg.
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			
					#DIV/0!	**#DIV/0!**	#DIV/0!	#DIV/0!	0.0			

4. Utilities

4.1 UTILITIES:

Utility Requirements

Electrical:
208 VAC (+/- 5 %), 60 Hz, single-phase, 3 wire, 70 Amps.

Water:
- (6) GPM, 60-80 °F, 40-60 psig differentials between supply and return (60 psig maximum inlet pressure).
- Water distribution:
  1) Cathode #1, #2, and #3, and
  2) CTI 8200 water cooled compressor.
  3) Open drain for cooling table water exhaust
  4) Electric solenoid valve control for "heating and cooling" processes on substrate table. PC interfaced.

Air:
- Normal dry shop air, 90-110 psi (system valve operation).
- Stand-alone air manifold positioned above the water manifold; solenoid valves incorporating removable plug-type electrical connections.

i.

Argon (99.9995 % purity):
- 3-15 psi (process gas).

Nitrogen (optional):
- Preferentially evaporated from a liquid source.
  a) 3-15 psi (chamber venting).

4.2 SYSTEM GROUNDING PRACTICE FOR RF AND E-BEAM SYSTEMS:

Electrical Grounding:

ii.  Ground connection must be made between vacuum system and building steel.
iii. Denton supplies 25' of 3" x 0.050" flat copper conductor.
iv. Copper conductor is bolted to vacuum system frame and nearest available building steel.
v. Never interrupt the system ground.

4.3 MECHANICAL REQUIREMENTS:

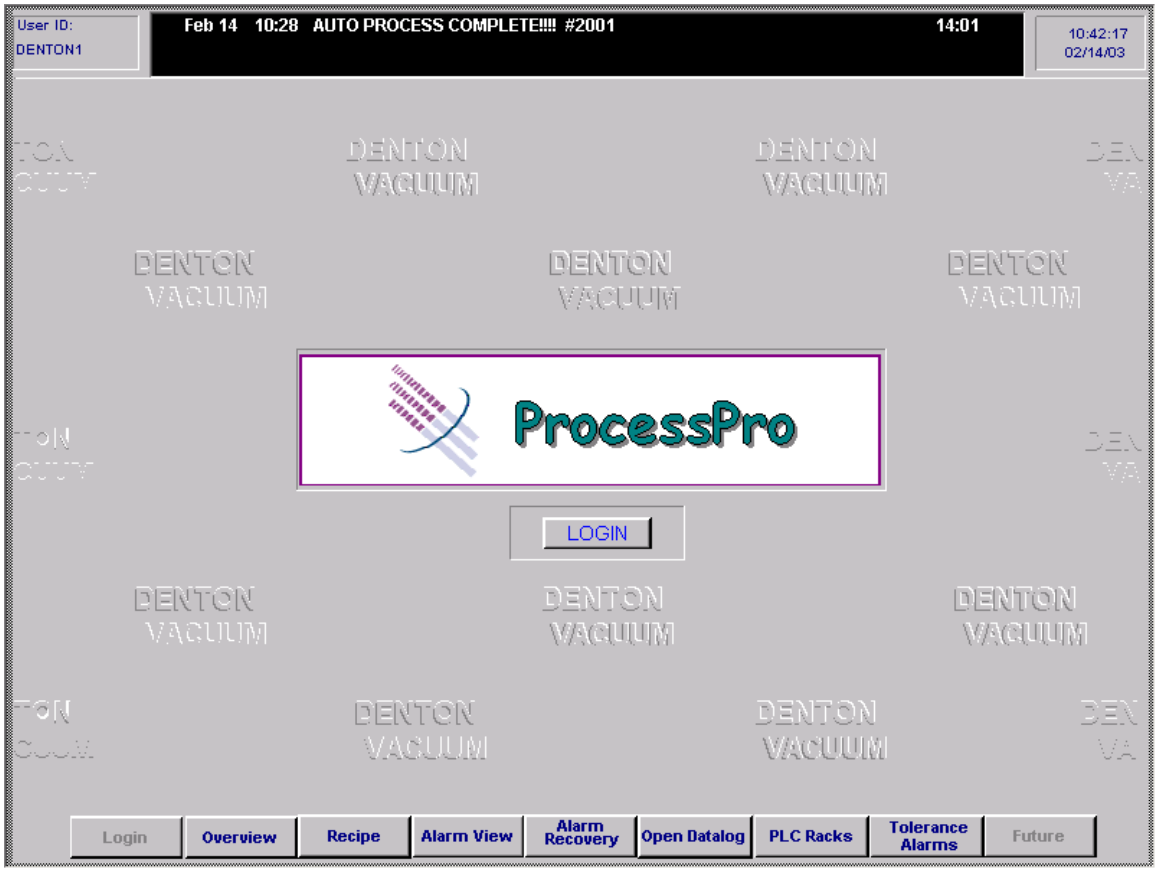
- Commercially purchased components will be new, of industrial quality and demonstrated "best in class" availability.
- All ferrous or aluminum metals will have proper finishes to prevent corrosion or oxidation.
- All pneumatic lines, valves, cylinders and flow controls are designed to operate at a minimum pressure of 90 psi and a maximum pressure of 110 psi.

4.4 ELECTRICAL STANDARDS:

- The equipment will be compliant to C.E. standards.
- All signal power will be isolated from system power; proper shielding and routing practices must be followed.
- All electrical, electronic, and optical sensors must be adequately protected from process contamination.
- Three-phase distribution is 208 VAC, 50/60 cycle (all equipment with three phase inputs must be supplied for this voltage); single-phase inputs shall be 208 VAC and 120 VAC.
- All equipment shall have panelized control with a single entrance protection by a heavy duty disconnect switch. The disconnect switch will have a "lockout" provision to ensure that no electrical power can be delivered to the system during maintenance operations.

5 Software Overview

5.1. Control System



The control system for the vacuum system is GE Cimplicity® HMI (Human Machine Interface). Cimplicity® runs on a Windows XP Professional operating system. This should make the interface between operator and machine familiar and easy to learn.

This software links the operator to the PLC. It allows for data input and data display. Operators can use a mouse to select on-screen graphics by clicking on any active element on a screen. Data is input by pushing on-screen buttons or using the keyboard.

Security is implemented through the Login Panel. Multiple levels of security are available to control access to critical information. The System Administrator has complete access to the entire control system. The System Operator can access everything except the heat PID settings, Service Mode and the Configuration Screens in the Recipe Builder. System Security is described in detail in the System Security section of this manual.

This software is active when power is applied to the system.

Graphic display of the control system is arranged on seven "screens":

- Main Menu (Login)
- Overview
- Recipe
- Alarm View

Main Menu (Login) is the first screen active when power is applied. It gives the operator access to the other screens through push buttons at the bottom of the screen. Access to the Login software is through this screen.

Recipe screens are used to develop, store, and download recipes for automated processes. Recipe screens are fully described in the Recipe Builder section of this manual.

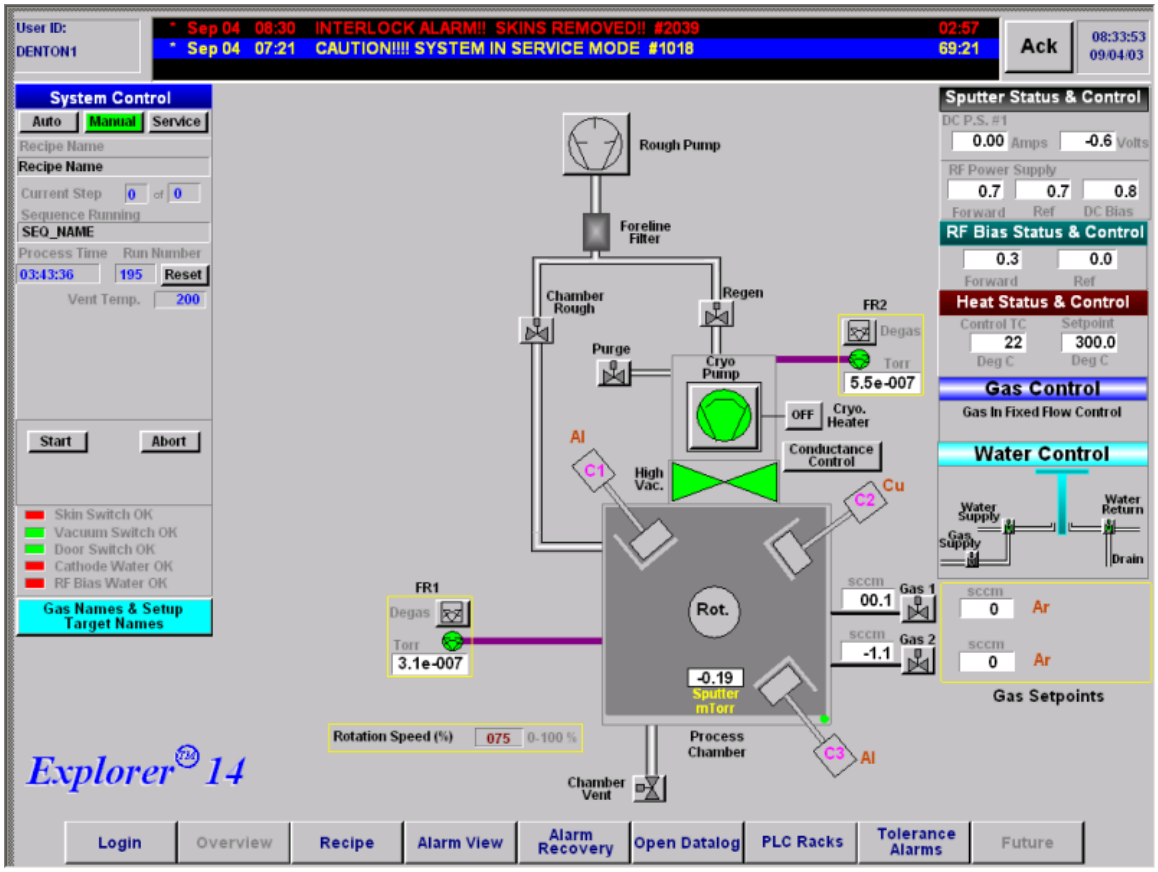
Alarm View is the screen used to display, acknowledge, and clear system alarms. Alarm View is fully described in the Alarm section of this manual.

Alarm Recovery is the screen that displays the data captured when an automatic process is interrupted. This information is used to continue a recipe that has been stopped. Alarm Recovery is fully described in the Alarm section of this manual.

Overview is the primary operating screen. All current system data is displayed on this screen. The operator can access all subsystems through this screen. The Auto, Manual, and Service Modes are selected on this screen. Automatic sequences are Started, Stopped and Reset on this screen. This screen is described in detail in this section of the manual.

This Chapter will describe the **Overview** screen. An understanding of this screen is required to proceed with the operation of the vacuum system.

5.2 Overview Screen



The Overview screen is used to display current system data and provide manual control of subsystems. The system data and security access level are displayed across the top and down the left side of the screen. The current state of the vacuum chamber and the pumping system are graphically displayed in the center of the screen. Subsystem control boxes are accessible on the right side of the screen. Push buttons across the bottom are used to switch to Main Menu, Recipe, Alarm View, Alarm Recovery, Open Datalog, PLC Racks, and Tolerance Alarm screens.

Pushbuttons change color to indicate the state of the switch. Valves, pumps, and interlocks change color to indicate current state. Graphic indicators are displayed on the vacuum system graphic when sputter sources, heater, mass flow controllers or bias table are active.

All operations are familiar Windows operations. All graphics that are accessible to the operator will display a white "lasso" when the cursor is near the graphic. The valves, pumps, timers, and individual control boxes are activated by a single click on the mouse. Data is input into a data box by clicking on the data box, typing in the data, and pressing the ENTER key.

5.3 Top Overview Bar

Displays current security data (User ID & Role), mode of operation (MODE), Recipe name, time of day and date. The User ID and Role are factory set in the control system software. The current Login name is displayed here. The Mode can be Auto, Manual, or Service. The mode is selected on the left of the screen.

The current Recipe is displayed at the top of the screen and on the left side of the screen. The time and date can be adjusted in the Windows Control Panel.

5.4 Left Overview Screen

The left side of the Overview screen is used for System Control, Interlocks, System Control

The System pushbuttons at the top select the mode of operation: Auto, Manual, & Service.

5.4.1 Auto

Auto mode is used to run automatic recipes. The Start, Stop, and Reset buttons are active in this Mode. The current Recipe Running, Current Step, Sequence Running, and Total Process Time will advance as the automatic recipe is running.

The Run Number is incremented every time the Start button is pressed. This feature can be customized to match customer run numbering. Contact Denton Vacuum for more information.

The Start button starts the Recipe that is displayed. The Stop button stops the recipe at the **end** of the current Sequence Running. The Reset button stops the automatic process immediately and resets the recipe back to the beginning and resets the Total Process Time.

All buttons change to green when active or ON.

***Note**: Access to all other on-screen controls is denied in the Auto mode. This interlock is built in to avoid manual operation of a subsystem in the Auto Mode.*

5.4.1.1 Manual

The operator can safely run the system from the Overview screen in the Manual mode. All interlocks are active in Manual mode. Recipes are not active in Manual mode.

All on-screen control systems are available. The state of the valves, motors and fixture rotation can be changed by clicking on the graphic for that item. Clicking will change the state of simple on/off, open/closed devices or open control boxes for more sophisticated controls. The Status & Control boxes on both sides of the screen are all activated by double-clicking. Pop-up boxes are displayed for operator input.

The Total Process Time will not advance and the Start and Stop buttons are inactive in Manual mode. The Reset button is inactive in the Manual mode.

5.4.1.2 Service

CAUTION: *Software Interlocks are inactive in service mode. Caution must be taken to safely operate the vacuum system*

NOTE: *Service Mode is not accessible to System Operators. Service Mode is only accessible to System Administrator. See System Security for complete details*

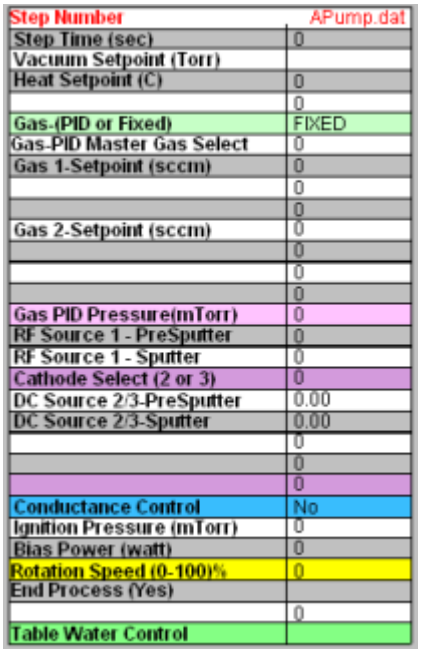
Use Service Mode for maintenance. Software interlocks are **inactive** in this mode. Hardwired interlocks are active in service mode. All control systems are active as in Manual mode.

5.4.2 Interlocks

Sputter guns, heater, bias will not operate if any interlock is open. These are hardwired interlocks.

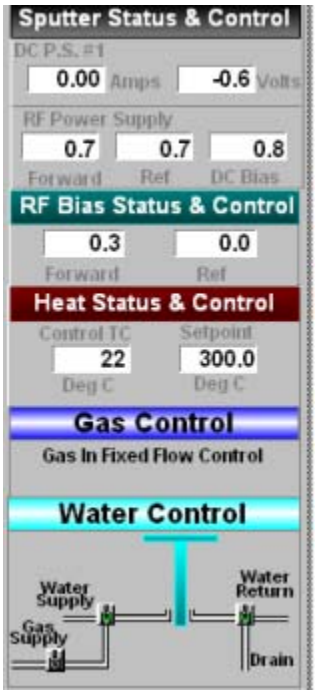
5.4.3 Auto Deposit Info

Step-by-step information is provided during the deposition of a layer. "Standby" is displayed at all other times. These messages are intended to provide the operator with information on the set-up and deposition of a layer.



Step Number	APump.dat
Step Time (sec)	0
Vacuum Setpoint (Torr)	
Heat Setpoint (C)	0
	0
Gas-(PID or Fixed)	FIXED
Gas-PID Master Gas Select	0
Gas 1-Setpoint (sccm)	0
	0
	0
Gas 2-Setpoint (sccm)	0
	0
	0
	0
Gas PID Pressure(mTorr)	0
RF Source 1 - PreSputter	0
RF Source 1 - Sputter	0
Cathode Select (2 or 3)	0
DC Source 2/3-PreSputter	0.00
DC Source 2/3-Sputter	0.00
	0
	0
	0
Conductance Control	No
Ignition Pressure (mTorr)	0
Bias Power (watt)	0
Rotation Speed (0-100)%	0
End Process (Yes)	
	0
Table Water Control	

5.5 Right Overview Screen



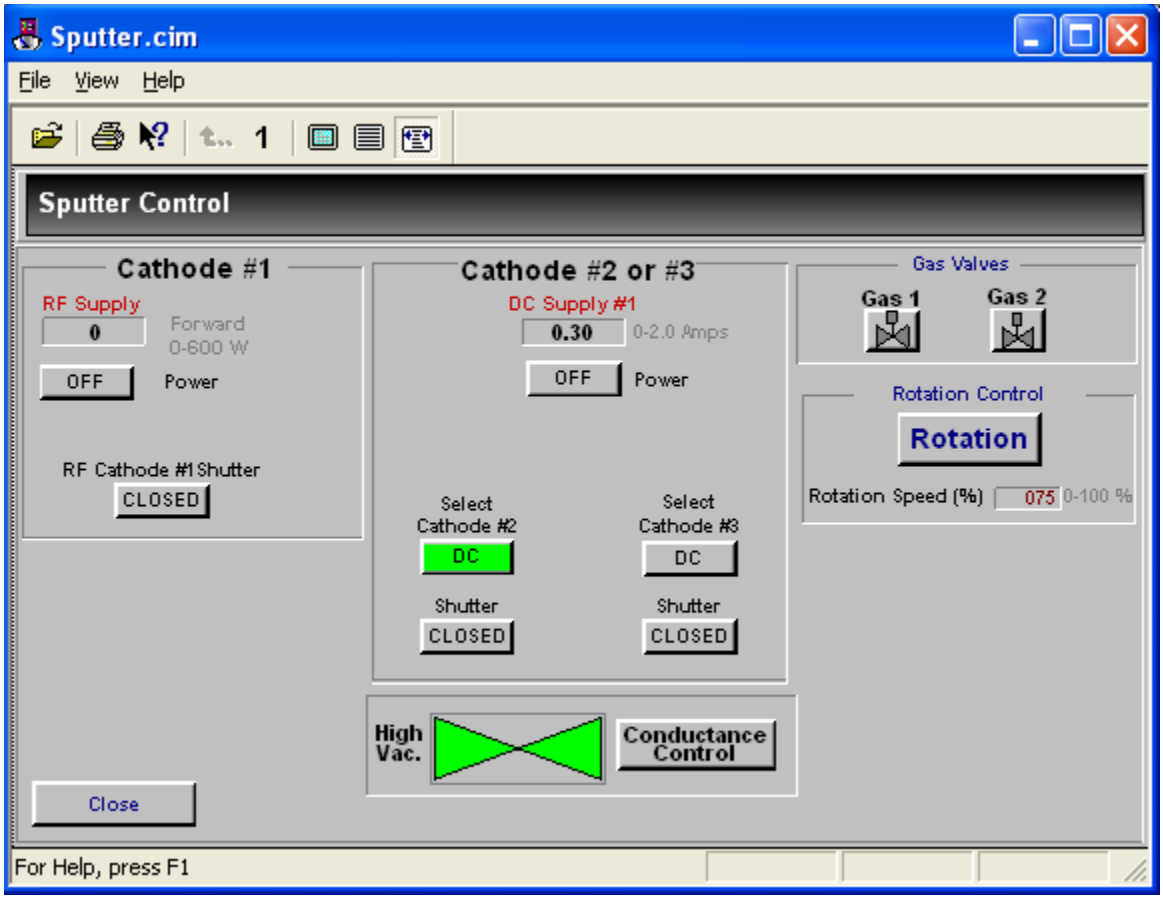
The control boxes for all major subsystems are displayed on the right side of the Overview screen. The current condition of the subsystems is continuously displayed on the right side of the Overview screen in data boxes. The subsystems are accessed by double-clicking on the Status & Control box. A control box will pop-up with input boxes for operator interface with the subsystem. These are accessed in manual mode.

In normal operation the following data is continuously displayed on the Overview screen:

- Sputter Status and Control
- RF Bias Status and Control
- Heat Status and Control

The individual subsystems are described below. The screens are operated in Manual Mode only.

Sputter Status and Control



NOTE: The power supply is interlocked with system vacuum, water , skin switch and rotation

In this box, the operator can select the desired cathode(s) to use. The System is fitted with a DC (2) position switch for the single DC power Supply and (1) RF Power Supply. Therefore, a co-deposition of #1 Cathode using RF and any of the remaining (2) Cathodes may be used with the DC Power Supply.

After the proper Cathode selection is made, by clicking on the Cathode Select Button (which will turn Green in color). The operator can set the Power Setting by clicking on the "window" in the DC or RF supply box. The guns have a Maximum capacity of 600 Watts for the RF and 2.0 Amps for the DC Power Supply.

To "Turn On" the power supply, Click the On/Off button in that block.

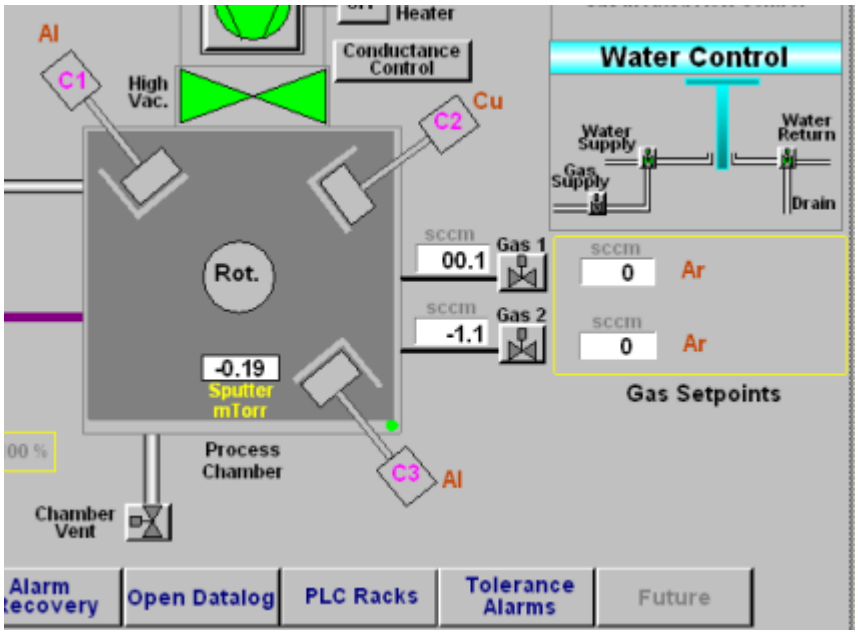
Before Trying to Ignite the gun, you Must First have the Process Gas flowing!!! This is done on the "Overview Page"

To operate the RF power supply from it's front panel refer to the RF Power Supply manuals.

Use the close button to exit the page.

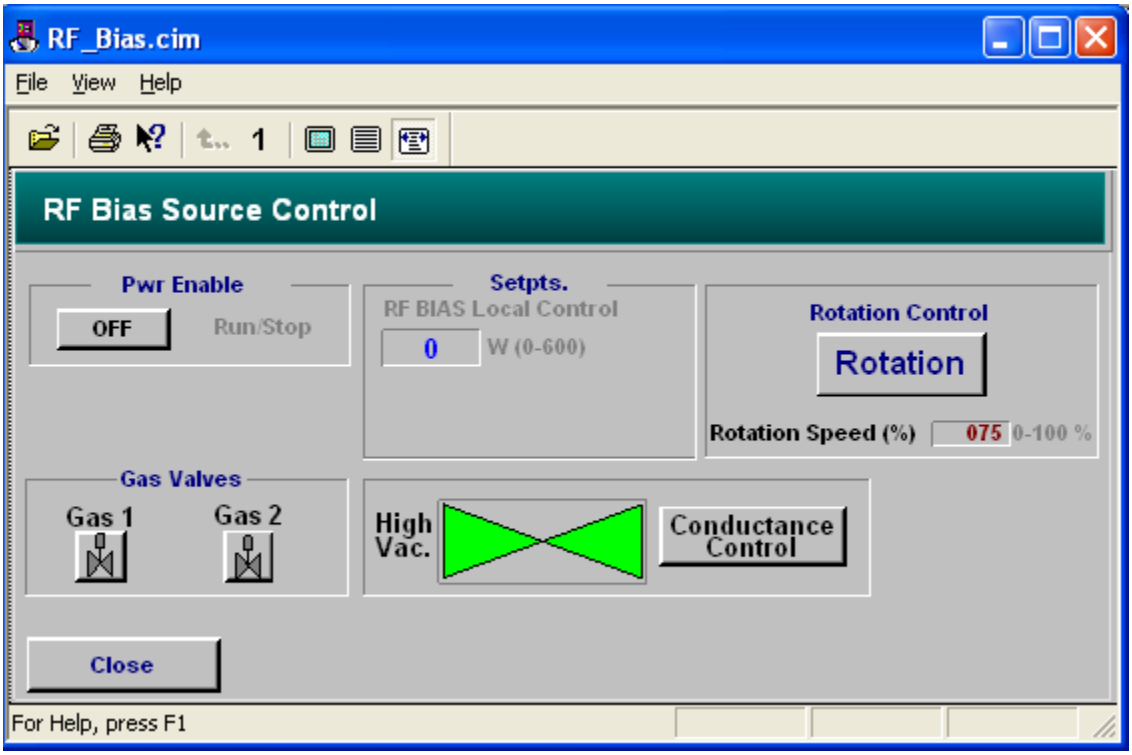
Once the Gun(s) are running, (plasma ignited) you may use this page to open or close the appropriate shutter for deposition, and start or stop the Substrate Rotation Table.

Overview Page, (lower right hand side) Manual Gas Control



Click on the setpoint boxes and type in the gas flow value, then hit enter. Click on the desired gas valve to open valve. Next step would be to set the "chamber to pump" gate valve in the "throttle position". Do this by clicking on the small box labeled "**Conductance Control"** next to the gate valve block. Now you are ready to return back to the control page to turn on the power supply. Since you are in "manual mode", and have a need to raise the chamber pressure higher to ignite the plasma, (as with RF sometimes) you can simply close the gate valve, lite the gun, and set the valve to **"Throttle"** position.

RF Bias Control



Note: The power supply is interlocked with system vacuum, water , skin switch and rotation

This page allows operation of the Biased Substrate Table. 300 watts should be the normal upper limit to operate at. To operate, click on the setpoint box and type in power setting, then hit enter.

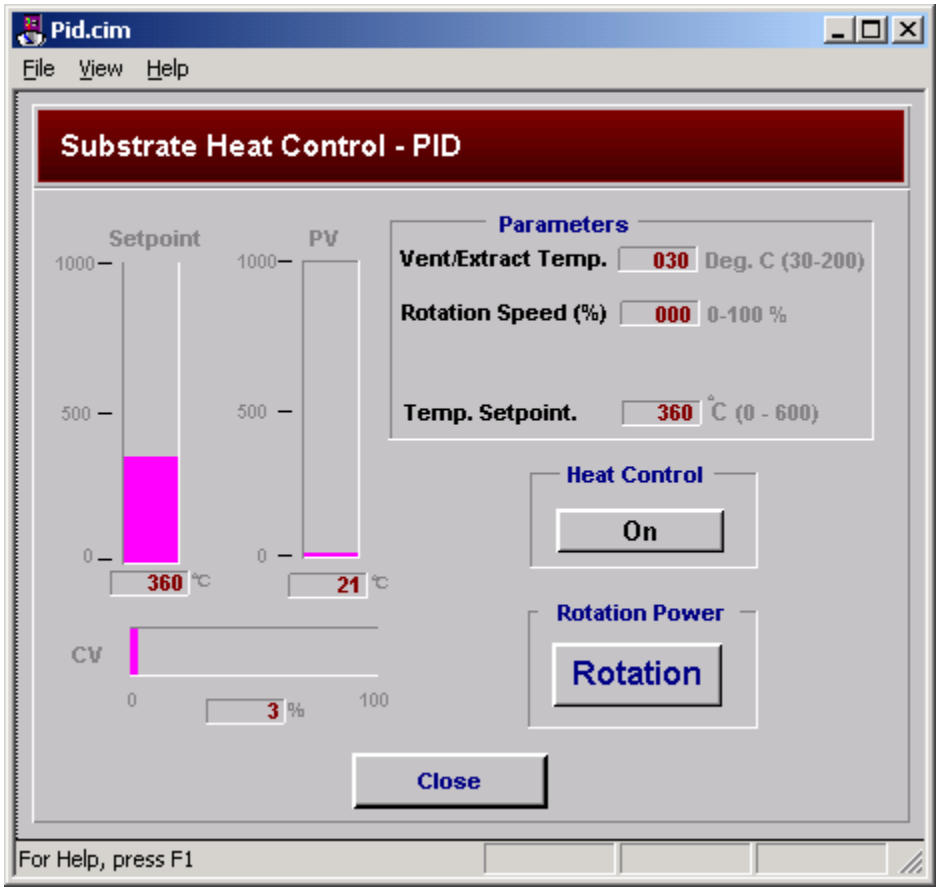
To "Turn On" the power supply, Click the On/Off button in that block.

Before Trying to Ignite the gun, you Must First have the Process Gas flowing!!! This is done on the "Overview Page"

To operate the RF power supply from it's front panel, refer to the RF Power Supply manuals.

Use the close button to exit the page.

Substrate Heat Control

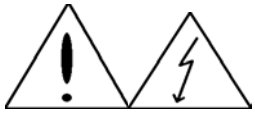


This page can be used to operate and monitor a heat process. All the pertinent controls and system feedback data is present here. The Temperature and Power bar blocks are color dependent based on system condition and control parameters. Standard PID control loop technology is also used.

Note: The power supply is interlocked with system vacuum, water , skin switch and rotation

6. System Operation

6.1. System Startup/Cryopump Regeneration, Manual



Warning!

Do not remove the vacuum system skins or defeat the door or skin switches.

Do not attempt to bypass them.

This is for your safety.

After insuring that all utility connections have been made (See Section 4, Utility Requirements) the system can be turned on. This system has been fitted with a 8" cryogenic pump with air-cooled compressor.

Turn ON the main NEMA power breaker and push the green Power switch located on the door of the computer cabinet ON. The system will power up and the Menu page will be displayed on the computer screen. The control computer must be ON to successfully regenerate the cryopump.

6.1.1. Make sure all valves, pumps, power supplies are OFF or closed. Finish or abort any automatic sequences that may be running.

6.1.2. Insure the cryopump purge has the required nitrogen gas supply.

6.1.3. Insure the chamber is vented.

6.1.4. Enter the Pumping Control screen.

6.1.5. Turn off the cryopump.

6.1.6. Open the cryo purge valve for a minimum of four hours. If the outside of the cryopump has condensed water or ice on it longer purge times are recommended.

6.1.7. Close the cryo purge valve.

6.1.8. Turn on the mechanical pump.

6.1.9. Open the cryo regen valve. Wait until the Cryo TC is below $5.0x10^{-2}$ torr.

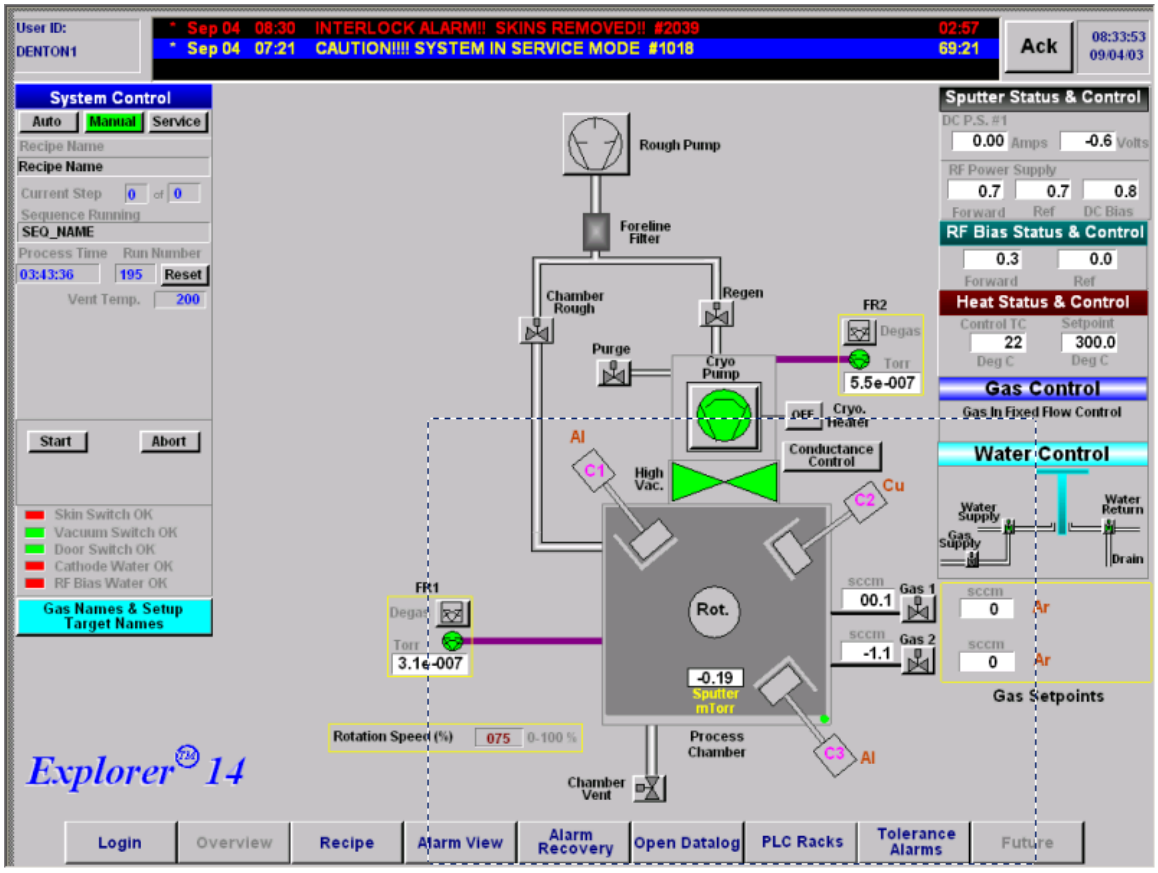
If the cryo TC pressure, $5.0x10^{-2}$ torr, is not achieved in 10 minutes, close the cryo regen valve and turn off the mechanical pump and return to step 6.1.6. but only purge for 1 hour.

If the cryo TC pressure, $5.0x10^{-2}$ torr is satisfied within 10 minutes proceed with the following step.

6.1.10. Close the cryo regen valve and turn off the mechanical pump.

6.1.11. Turn on the cryopump if the pressure does not exceed $1.0x10^{-1}$ torr in 60 seconds and proceed to 6.1.12.

If the Cryo TC pressure exceeds $1.0x10^{-1}$ torr in 60 seconds return to step 6.1.6. and purge for only 1 hour.

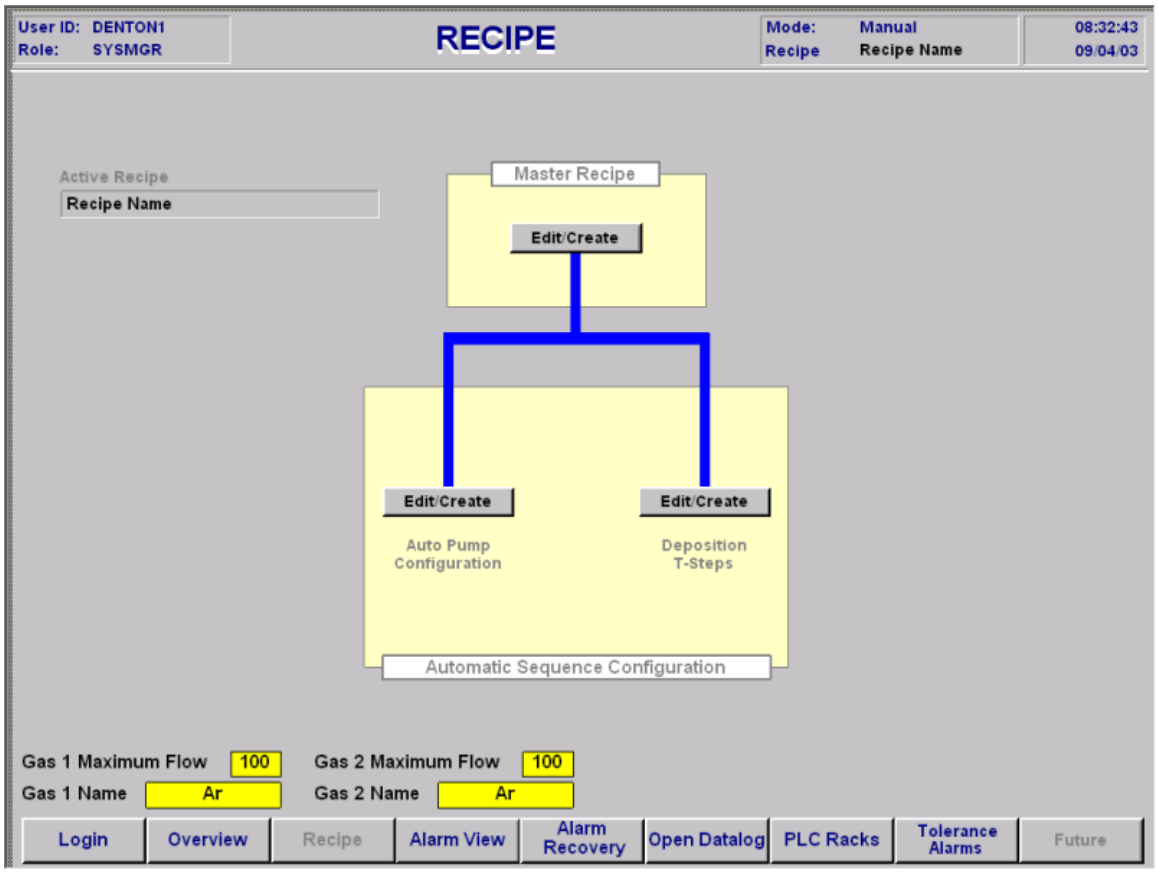


6.2 Cryo Pump Regeneration - Automatic Mode

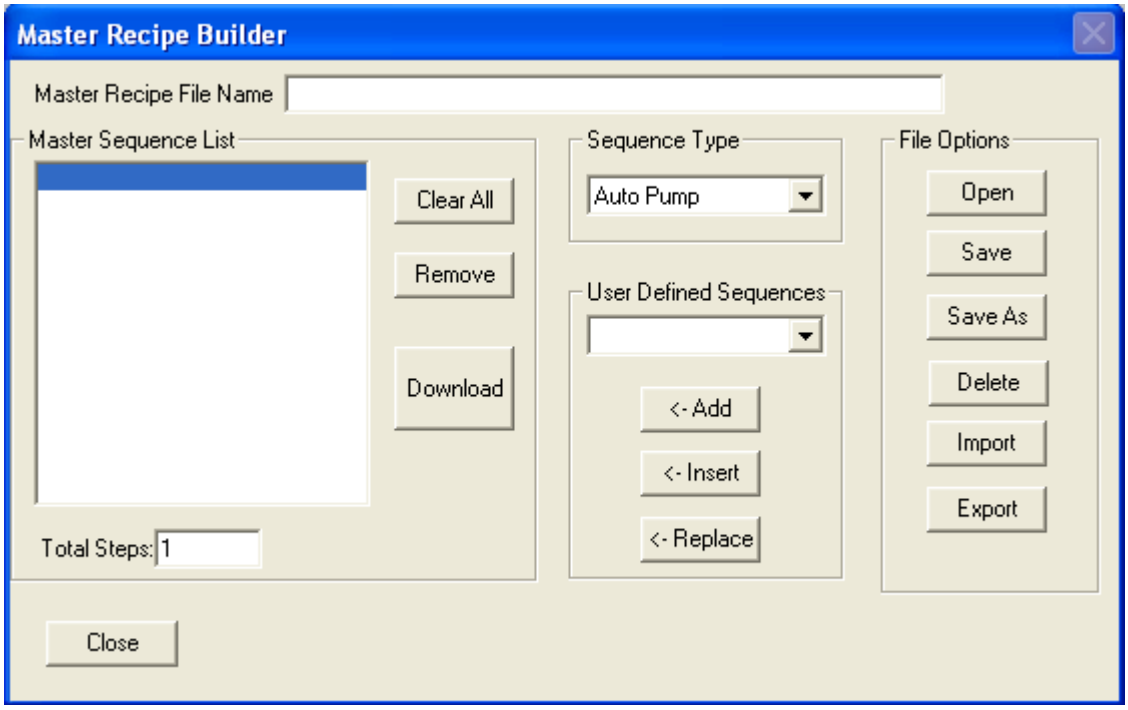
6.2.1 Insure the cryopump purge has the required nitrogen gas supply.

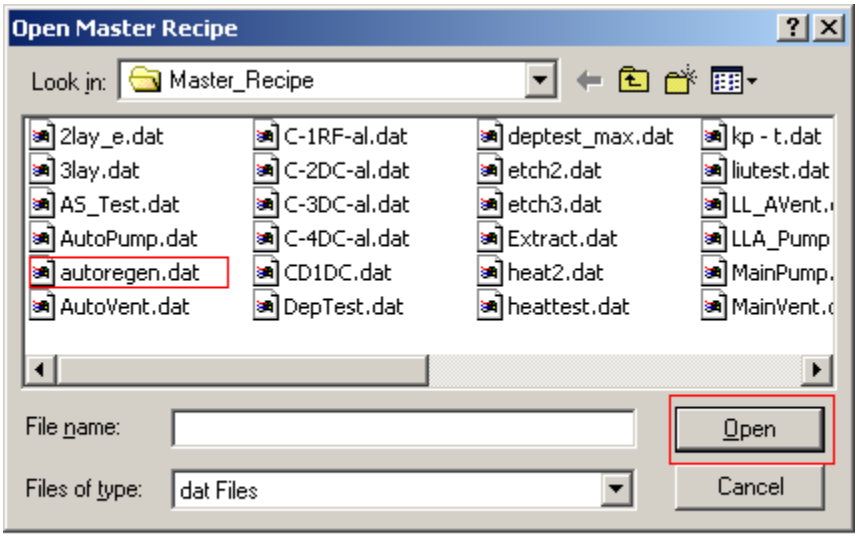
6.2.2 From the Process Display Page select "Recipe" button on bottom tool bar.

6.2.3 Now select the Master Recipe "Edit / Create" button.



6.2.4 From the Master Recipe Page select the "Auto Re-Gen" Recipe and select "open". On next screen select "Download", then "close". When the Main Recipe page appears, use the bottom tool bar and select the "overview" page.





6.2.5 Use the return button to go back to the "Process Display " page.

6.2.6 Start the selected "Cryo Regen" recipe only when you are finished with all system needs. The system will be in a "holding" mode until the selected date and time is achieved. No other functions can be performed, unless the system is aborted.

6.3 Cryo Pump Regeneration Description - Automatic Mode

6.3.1 Reset required system functions to ready state. This closes all gas and chamber valves. Turns off all power supplies.

6.3.2 The cryopump is turned off.

6.3.3 The cryo purge valve is opened and flows gas.

6.3.4 The cryo purge valve is closed after the purge or re-purge cycle has been completed.

6.3.5 The mechanical pump is turned on.

6.3.6 The cryo regen/rough valve is opened. The system waits until the Cryo TC is below $5.0x10^{-2}$ torr. There is also a time delay on some systems that will continue pumping for another 30 seconds to provide further degassing of the pump array.

If the cryo TC pressure, $5.0x10^{-2}$ torr, is not achieved in 10 minutes the cryo regen valve is closed and the mechanical pump is turned off and it returns to step 6.3.4 and the purge gas will flow for another 30 min. This will repeat for up to 3 times upon failure, before the system aborts automatically.

If the cryo TC pressure, $5.0x10^{-2}$ torr is satisfied within 10 minutes it will proceed with the following step.

6.3.7 With the regen/roughing valve closed, a pressure rise test will take place to look for the rate of outgassing in the pump. If the pressure does not exceed $1.0x10^{-1}$ torr in 60 seconds the "rate of rise" test passes, and continues to the next step.

6.3.8 If it fails, it will go back to the purge cycle of 30 minutes. This will repeat for up to 3 times if "rate of rise" tests fail, before the process automatically aborts.

6.3.9 Upon passing, the cryo regen valve is reopened and the system will pump the cryo back down to 50 m/t. When the set point is achieved, the cryo compressor is restarted and the regen/roughing valve will close. Mechanical pump will then turn off. On some systems, the program allows for continued pumping for up to 2 min.

6.4 Main Chamber Pumping - Automatic Mode

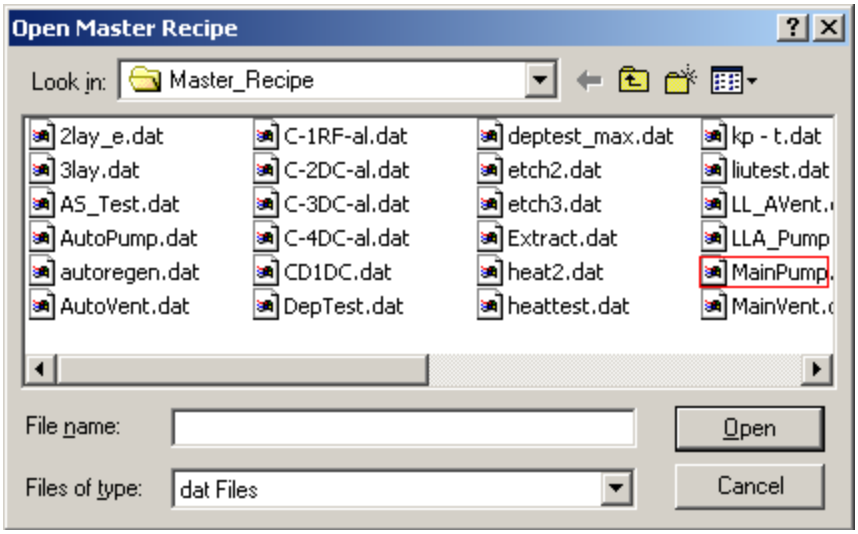
6.4.1 Insure that the Cryo-pump is cold and operational.

6.4.2 From the Master Recipe Page select the "MainPump" Recipe and select "open". On next screen select "Download", then "close" . When the Main Recipe page appears, use the bottom tool bar and select the "overview" page.

6.4.3 Close the chamber door.

6.4.4 Press the START Auto Sequence button to initialize the automatic pump down cycle.

6.4.5 The chamber will be in a state of high vacuum when the cycle is complete.



6.4.6 If the chamber door is open it will pause until it is closed.

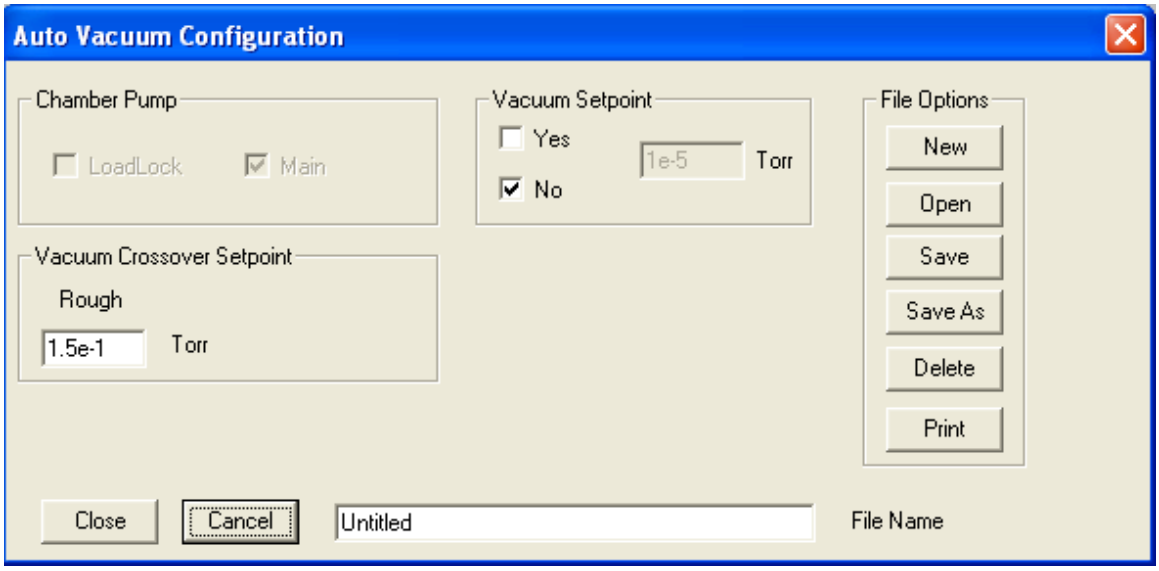
6.4.7 If the high vacuum valve is open it bypasses the chamber rough phase.

6.4.8 If the high vacuum valve is closed and the Chamber TC SP (below crossover) it bypasses the chamber rough phase.

6.4.9 If the chamber pressure is above crossover. (150mtorr or $1.5x10^{-1}$ torr) the mechanical pump is started and the chamber rough valve is opened until the crossover pressure is achieved.

6.4.10 After the crossover is reached the chamber rough valve is closed and the mechanical pump is turned OFF.

6.4.11 Next the high vacuum valve is opened and after one minute.



6.5 Main Chamber Pumping - Manual Mode

6.5.1 Insure that the Cryo-pump is cold and operational. This procedure assumes the chamber is at atmosphere. Make sure all valves, pumps, power supplies are OFF or closed. Finish or abort any automatic sequences that may be running.

Note: Pushbuttons change color to indicate the state of the switch. Valves, pumps, and interlocks change color to indicate current state. Graphic indicators are displayed on the vacuum system graphic when Deposition sources, heaters, shutters, table rotation are active. All operations are familiar Windows operations. All graphics that are accessible to the operator will display a white "lasso" when the cursor is near the graphic. The valves, pumps, timers, and individual control boxes are activated by a single click on the mouse.

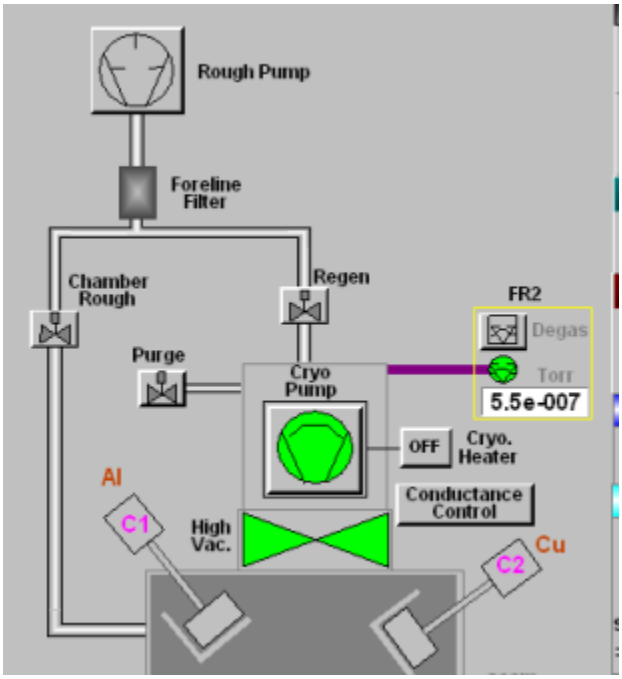
6.5.2 Turn the mechanical pump ON.

6.5.3 Close the chamber door and open the chamber rough valve.

6.5.4 Wait until "Chamber TC SP" is satisfied, chamber thermocouple gauge reading less than 1.5×10^{-1} Torr (crossover pressure).

6.5.5 Close the chamber rough valve and turn OFF the mechanical pump and open the HiVac valve.

6.5.6 Pressure will be displayed in the FR2 gauge box read-out in the graphic. You will also note that gauge cross-over setpoints are signified via the green color on the gauge symbol.



6.6 Main Chamber Venting - Automatic Mode

6.6.1 This procedure assumes the chamber is in high vacuum. Finish or abort any automatic sequences that may be running.

6.6.2 From the Master Recipe Page select the "MAIN CHAM VENT" Recipe and select "open". On next screen select "Download", then "close" . When the Main Recipe page appears, use the bottom tool bar and select the "overview" page.

6.6.3 .WARNING: It is unwise to vent the chamber with the temperature above 200 °C as the internal components may be adversely effected.

6.6.4 Press the START Auto Sequence button to initialize the automatic chamber vent cycle.

6.6.5 The chamber will be at atmosphere when the cycle is complete.

6.7 Main Chamber Venting Description - Automatic Mode

6.7.1 Reset required system functions to ready state. This closes all gas, loadlock, and chamber valves. Turns off all power supplies and IG gauges.

6.7.2 Pauses vent cycle during the Vent Delay.

6.7.3 Opens the Chamber Vent valve until the chamber door is opened.

6.7.4 The chamber vent valve is also interlocked to a temperature setpoint. The value is adjustable (with the correct password) by the operator. On the "Substrate Heat Control" page/screen, the value can be entered from 0 to 200 degrees C.

6.8 Main Chamber Venting - Manual Mode

6.8.1 This procedure assumes the chamber is in high vacuum. Make sure all valves, pumps, power supplies, and gauges are OFF or closed. Finish or abort any automatic sequences that may be running.

6.8.2 Wait until the chamber is at a low enough temperature to vent the chamber.

WARNING: It is unwise to vent the chamber with the temperature above 200 °C as the internal components may be adversely effected.

6.8.3 Close the high vacuum chamber gate valve and Open the vent valve and wait for the chamber door top open.

6.9 Substrate Heat - Manual Mode

There is no stand alone substrate heat automatic sequence. The substrate is automatically heated if required in the auto process. However. a heat process alone can be run.

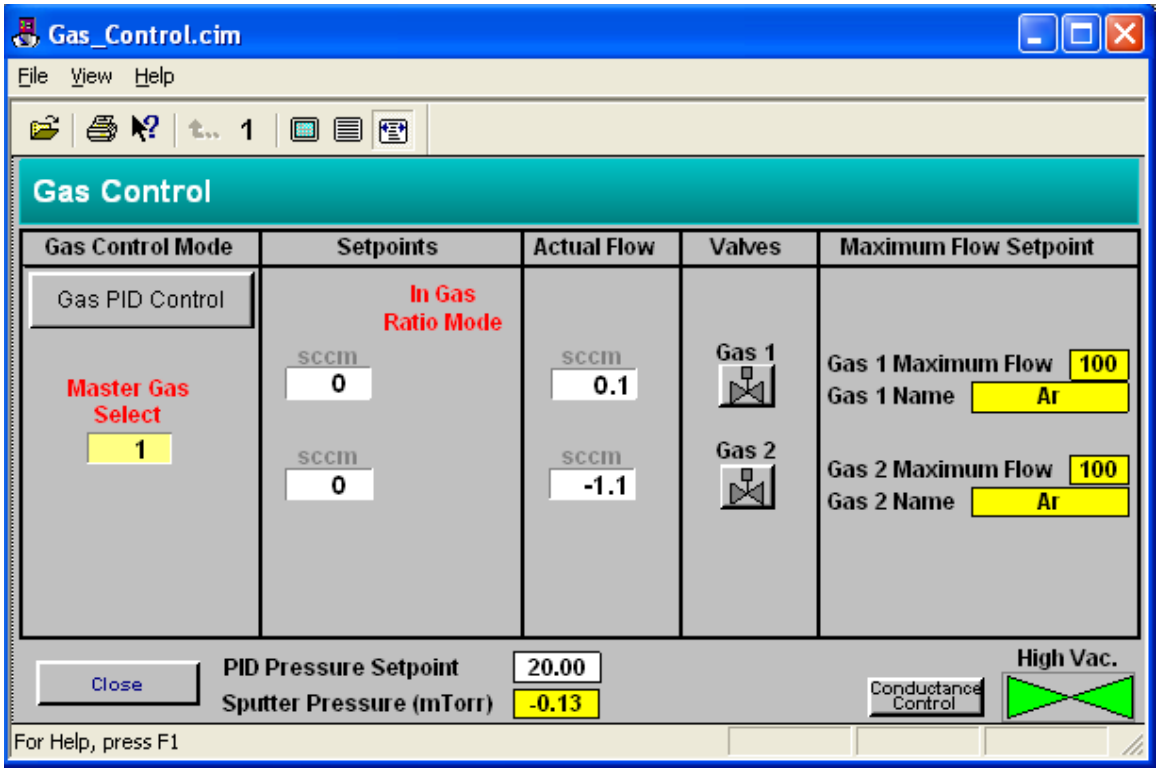
6.9.1 Insure the chamber is in high vacuum.

6.9.2 Select to the Source button from the Process Display screen.

6.9.3 Turn the substrate rotation power ON if off.

6.9.4 Set the desired substrate temperature setpoint.

6.9.5 Turn the substrate heat power ON.



6.10 Gas Control for Sputtering- Manual Mode

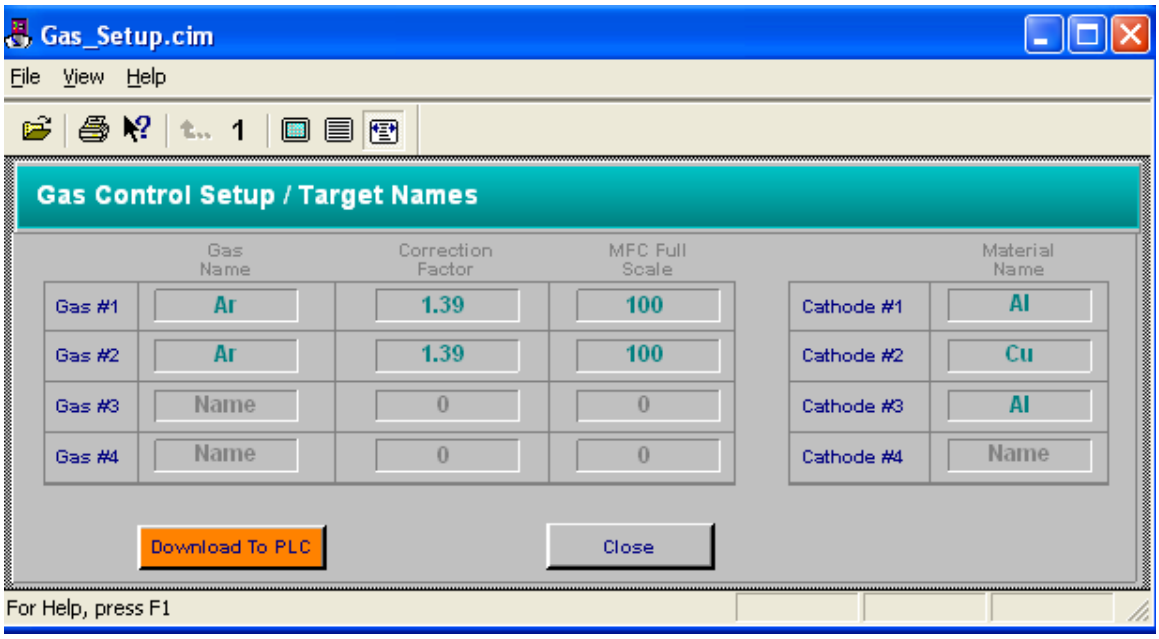
6.10.1 Insure the chamber is in high vacuum.

6.10.2 Select "gas Control" button from the Process Display screen. Set the desired Gas flow setpoint(s). Manual operation has the option of a Fixed Flow or PID flow , which will require a "pressure set point" to be entered. If multiple gases are to be used, Master and Slave assignments must be entered also. In the PID mode, the Master Gas will control the ratio at which the Slave gas set point will flow.

6.10.3 To adjust the Gas correction factors and the mass flow control full range settings, use the "Gas Names and Setup " button on the Process Display Screen.

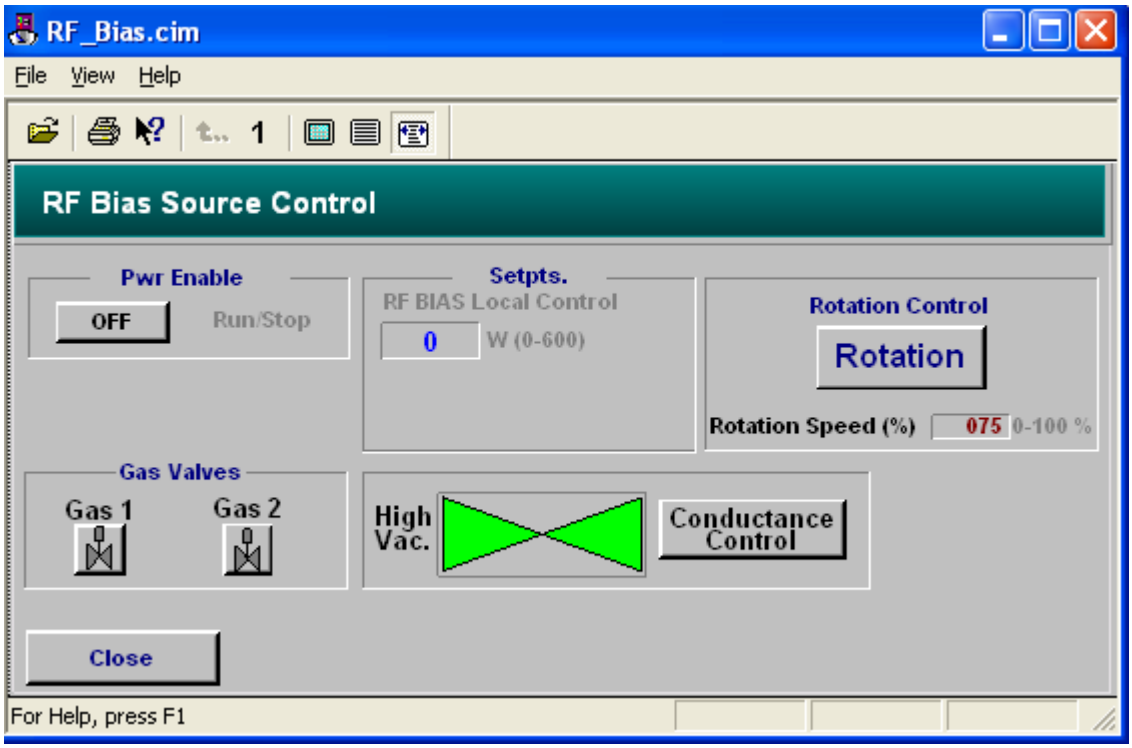
6.10.4 Open the desired Gas isolation valve(s).

6.10.5 Select the conductance control valve to be on or off. This is needed only if the RF Bias or a sputter source is to be used at a pressure that is not suitable for the cryo pump's pumping speed when it is not throttled. Adjust the gas flow setpoint to achieve the desired chamber pressure as measured by the capacitance manometer when using "fixed flow" mode. Enter a "pressure set point" when using PID mode.



6.10.6 The "Service Mode" access will get you into this page. Here you can change the Gun Target material names that show on the process display screen, and Mass Flow Controller settings. This will allow the operator to swap MFC's and re-calibrate the settings to provide accurate software control. Press the "DOWNLOAD" button after making any changes in settings that the PLC will use in executing control signals.

6.11 RF Bias - Manual Mode

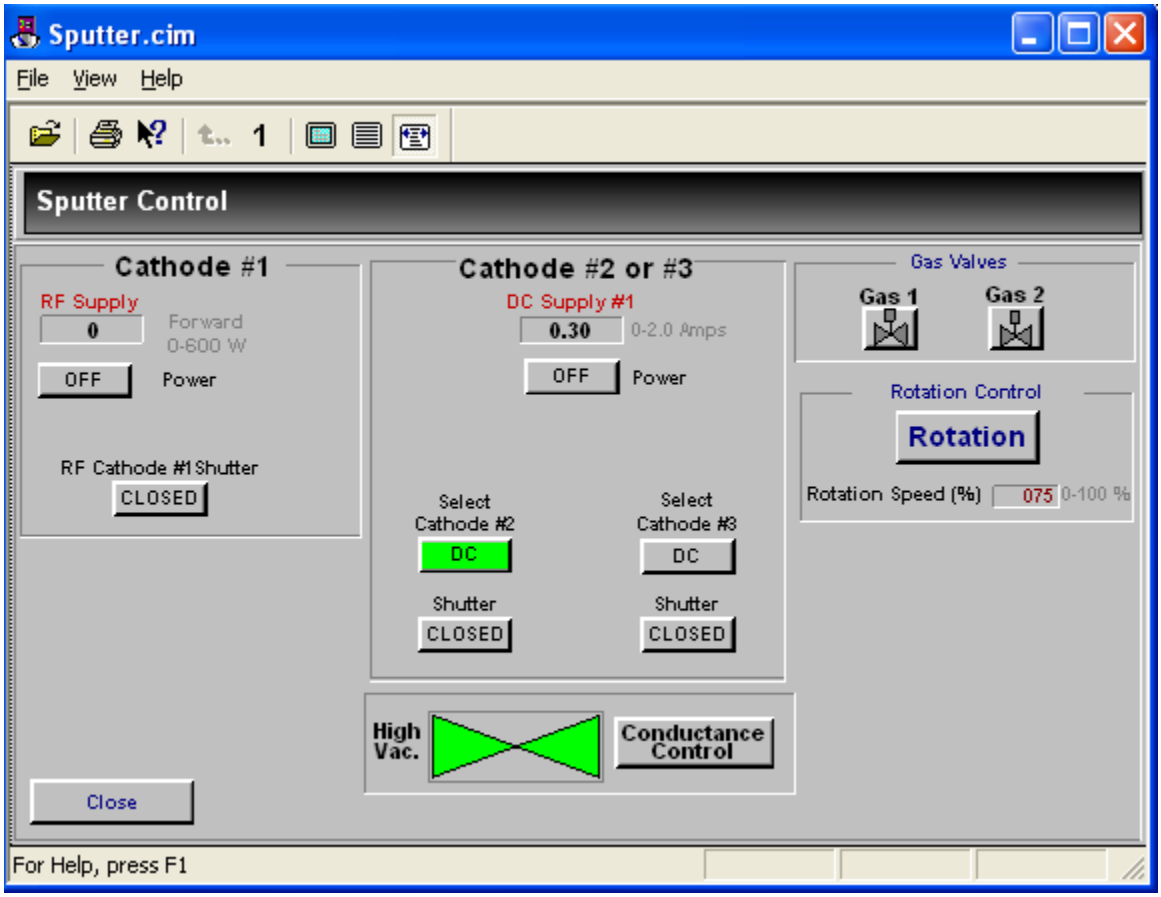


6.11.1 Insure the chamber is in high vacuum.

6.11.2 To operate the bias power, this page will give you all the control that is needed to start the process. The power supply is interlocked thru the software, (unless in service mode) to the table rotation. Rotation must be on. The other step that must be taken, is that the MFC flow setting must be entered on the Process Display Page , in "manual" mode. The "manual" RF Bias Source Control page only works in "FIXED FLOW" , so do not try to use the other 'Gas Control" page for setting flow setpoints.

6.11.3 Select the conductance control valve to be on or off. This is needed only if the RF Bias or a sputter source is to be used at a pressure that is not suitable for the cryo pump's pumping speed when it is not throttled.

6.11.4 Close the High Vac valve if a pressure rise is need to ignite the plasma. Usually the RF plasma lights easily above 20 m/t . After ignition, re-open the valve.



6.12 Sputtering - Manual Mode

6.12.1 Insure the chamber is in high vacuum and a gas flow gas flow set points have been established on the Process Display Page.

6.12.2 Turn on gas flow and Select the conductance control valve to be on or off. This is needed only if the RF Bias or a sputter source is to be used at a pressure that is not suitable for the cryo pump's pumping speed when it is not throttled. Turn the substrate rotation power ON if off for interlock setting.

6.12.2 Select to the SOUCES by using the "Select" buttons on the Sputter Control screen.

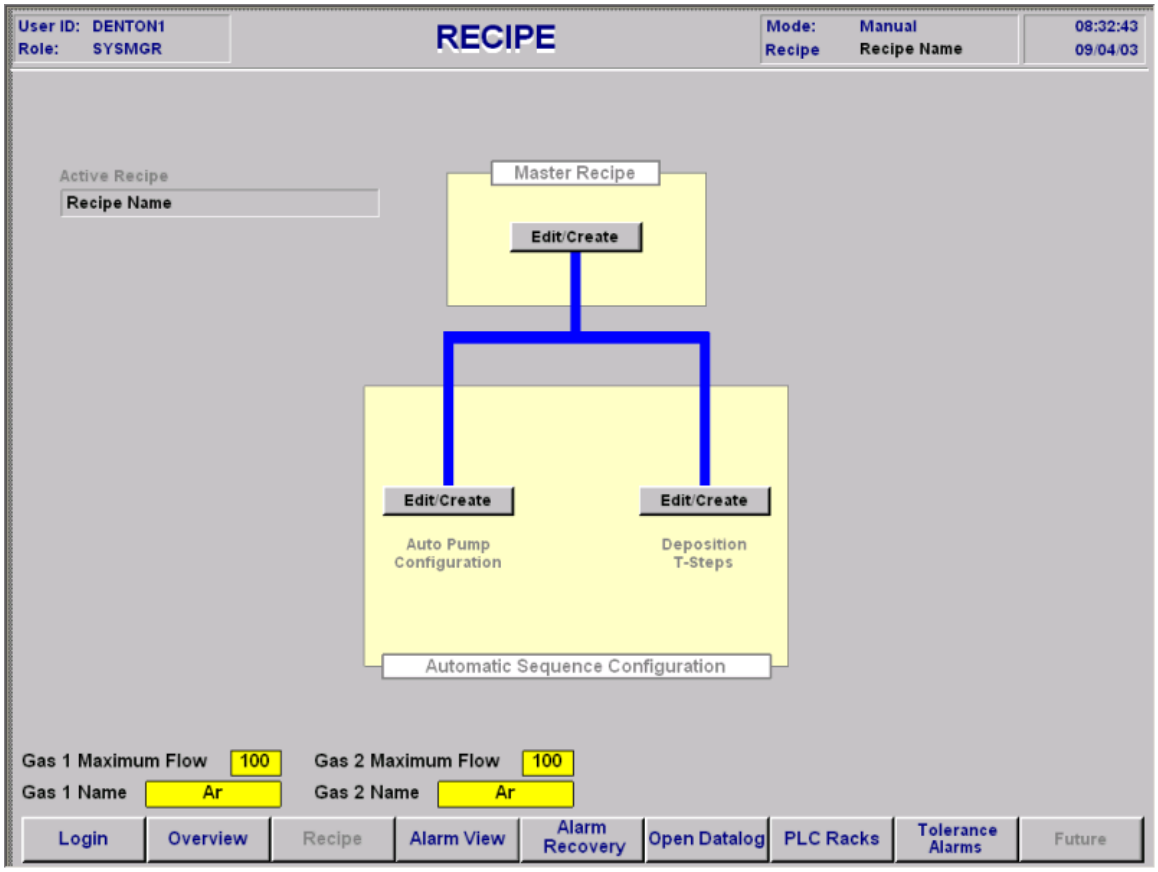
6.12.4 Set the desired DC / RF setpoint for the required cathode/s.

6.12.5 Turn ON the required power supply now for **DC** cathodes.

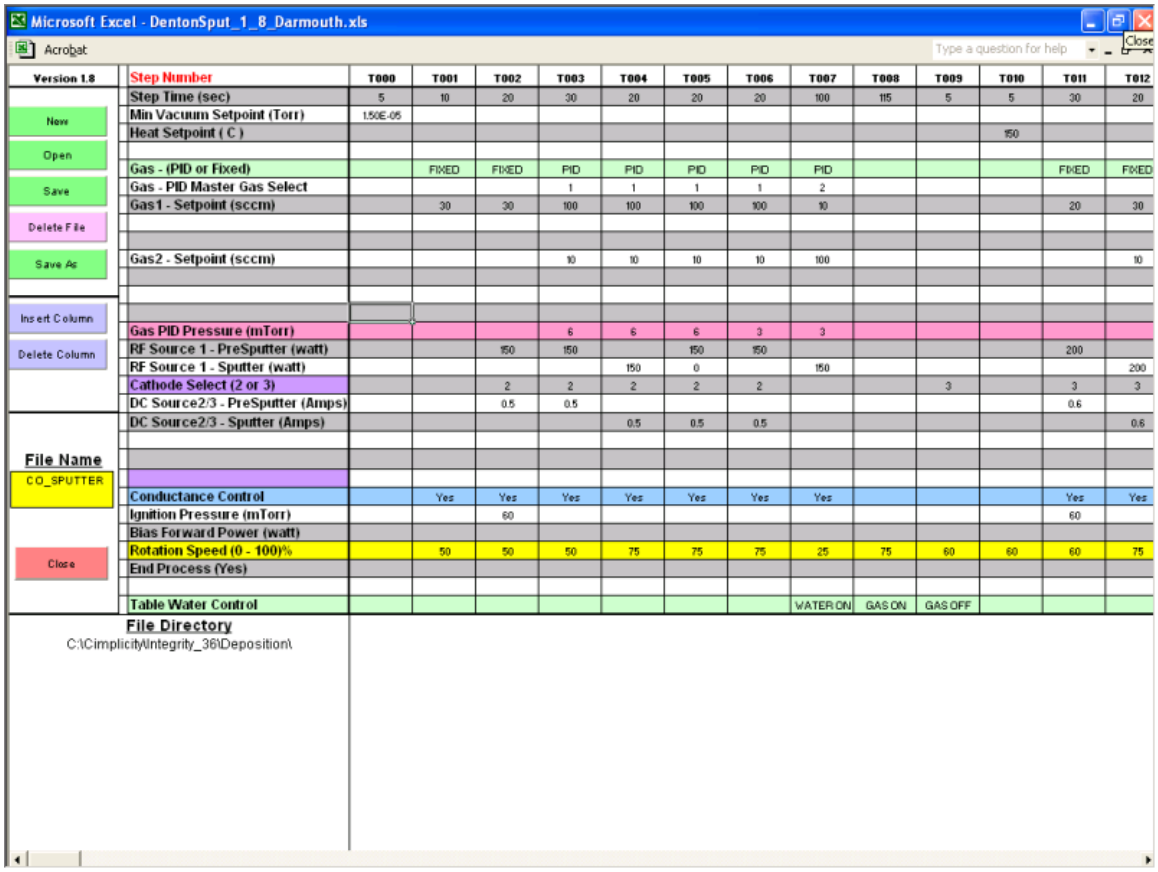
6.12.6 Close the High Vac valve if a pressure rise is need to ignite a plasma. Usually the **RF** plasma lights easily above 60 m/t . Turn on the power supply. After ignition, re-open the High Vac valve.

6.13 Auto Sputter - Automatic Mode

6.13.1 Program the Auto Sputter sequence. Start by opening the Recipe Page.



And select the Deposition T – Step file by clicking the edit / create button.



Step Number	T000	T001	T002	T003	T004	T005	T006	T007	T008	T009	T010	T011	T012
Step Time (sec)	5	10	20	30	20	20	20	100	115	5	5	30	20
Min Vacuum Setpoint (Torr)	1.50E-05												
Heat Setpoint (C)											150		
Gas - (PID or Fixed)		FIXED	FIXED	PID	PID	PID	PID	PID				FIXED	FIXED
Gas - PID Master Gas Select				1	1	1	1	2					
Gas1 - Setpoint (sccm)		30	30	100	100	100	100	10				20	30
Gas2 - Setpoint (sccm)				10	10	10	10	100					10
Gas PID Pressure (mTorr)				6	6	6	3	3					
RF Source 1 - PreSputter (watt)			150	150		150	150					200	
RF Source 1 - Sputter (watt)					150	0		150					200
Cathode Select (2 or 3)			2	2	2	2	2			3		3	3
DC Source2/3 - PreSputter (Amps)			0.5	0.5								0.6	
DC Source2/3 - Sputter (Amps)					0.5	0.5	0.5						0.6
Conductance Control		Yes	Yes	Yes	Yes	Yes	Yes	Yes				Yes	Yes
Ignition Pressure (mTorr)			60									60	
Bias Forward Power (watt)													
Rotation Speed (0 - 100)%		50	50	50	75	75	75	25	75	60	60	60	75
End Process (Yes)													
Table Water Control								WATER ON	GAS ON	GAS OFF			

6.13.2 From this page, begin by selecting the OPEN or NEW buttons in the upper left hand corner of the page. Either select an existing recipe or create a new one.

6.13.3 To create a new process, you only need to follow a couple guidelines.

6.13.4 **(1)** Each column is a TIME SEGMENT of the process. The entry on the 1st line (top) in each column sets the duration of that step. Certain functions will delay the countdown of this timer however! These are: system waiting to achieve minimum vacuum level (line # 2), Heat Temp setpoint (line # 3), Ignition pressure setpoint (line # 24).

6.13.5 **(2)** The gas control mode must be selected when using the MFC's, (light green line). When in fixed mode , you need not input a gas PID pressure setpoint, (pink line). When PID mode is selected, (light green line), you must input MASTER or SLAVE. These inputs are selected via a "drop down" box which requires a mouse click in the box. If you are using multiple MFC's, you must also assign MASTER or SLAVE. Only one gas can be MASTER. When using a MFC in the PID mode, you must enter a setting in the GAS SET POINT row. When using only GAS 1, you must only assign any numeric value, (1, or 5, or 3, or 11, etc). This tells the MFC to open, then it will go to the flow needed to meet the pressure setpoint entered in the PINK row. If you are using multiple MFC's, the numeric value is more significant. The values that you enter will set up the GAS RATIO between the multiple MFC's.

6.13.6 **(3)** The rotation speed must always be entered, (yellow line) if you want continuous substrate rotation.

6.13.7 **(4)** The CONDUCTANCE CONTROL valve, (light blue line) must be entered for all steps if required. This box also has a "drop down" feature to offer a selection.

6.13.8 **(5)** You cannot change the gun selection, (purple color box), while a gun is in operation, (if a setpoint has been entered "pre-sputter" or "sputter" watts). You must turn-off in one T-Step, and switch in the next T-Step, then turn-on the selected gun.

6.13.9 **(6)** When running a gun, the SELECTION line, (purple rows), must have an entry.

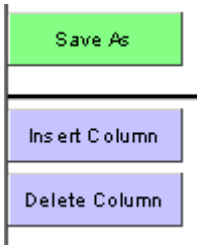
6.13.10 **(7)** To signify the end of the process, you must use the last row, END PROCESS (YES). In this T-Step, you must enter a time, (line # 1) of at least **5 seconds**.

6.13.11 With these guidelines in mind, you will be able to program all desired functions for heat , etching , depositions with and without bias multiple gas flow and control modes, and multiple cathode selections / usages. Film thicknesses are controlled via the power settings and the length of time (sum of T-Steps) in which the gun has a power entry.

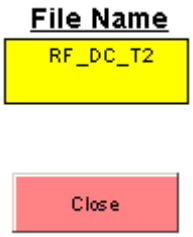
6.13.12 To save a recipe, simply click the SAVE button, assign a name and click OK. Then click the close button to go back to the MASTER RECIPE page.

6.13.12.1 To create a new recipe from an existing one, use the OPEN button and click on a recipe to highlight it and use the OPEN button on that page. The spread sheet will populate the data boxes with the stored information in that file. You may edit the values and the T-Step commands to suit.

6.13.12.2 Using the COLUMN buttons you can insert steps as needed or delete steps Once the appropriate changes are made, click on the SAVE AS button, edit the recipe name for a new one, and ENTER.

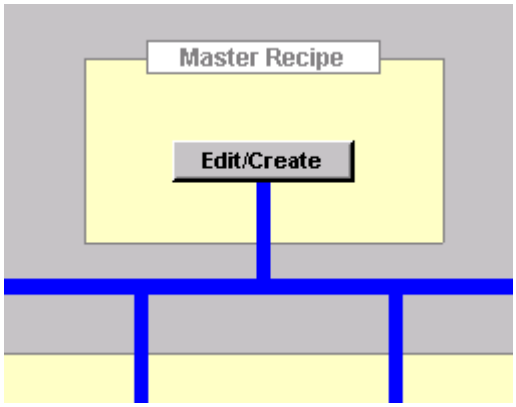


6.13.12.3 The new recipe name will show in the file box now. Click the CLOSE button to bring you back to the MASTER RECIPE screen.



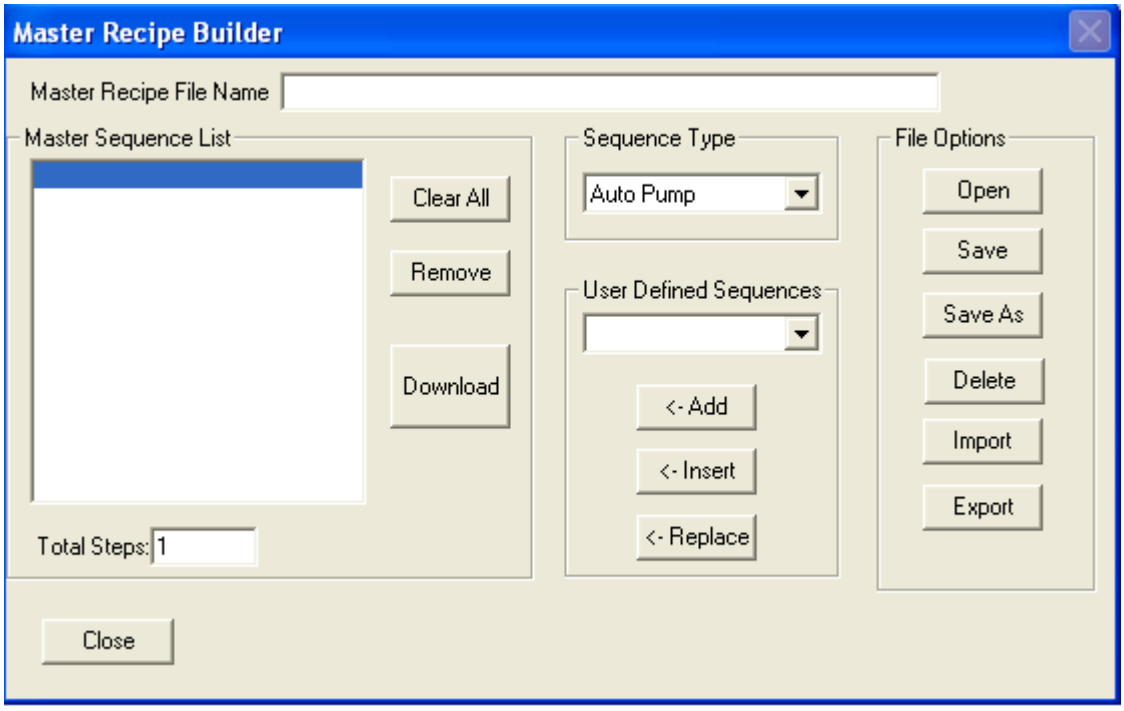
6.13.13 Once you have assigned a name and saved it, the recipe will be downloaded to the MASTER RECIPE FILE. It can now be retrieved in that page, by clicking on the EDIT/CREATE button.

6.13.14 Under the "SEQUENCE TYPE" drop – down menu of "Depositions", highlight and click. Then , scroll thru the SEQUENCE LIBRARY to find it.

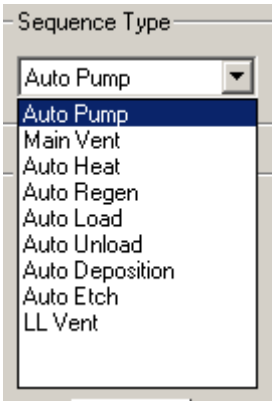


Scroll thru the recipes that are listed in the "USER DEFINED SEQUENCES" drop – down box until you see the one you just created.

To BUILD a complete process to run you must chose the items you wish in the correct sequence you wish to have them executed. Use the steps listed in the "User Defined" box to build the "MASTER Sequence List". Highlight the defined sequence and the click the ADD button. This will move the item onto the MASTER list. The INSERT and REPLACE buttons are convenient tools for editing recipes or steps.



In the SEQUENCE TYPE box, you will find all the standard operations and categories for the "libraries of recipes".

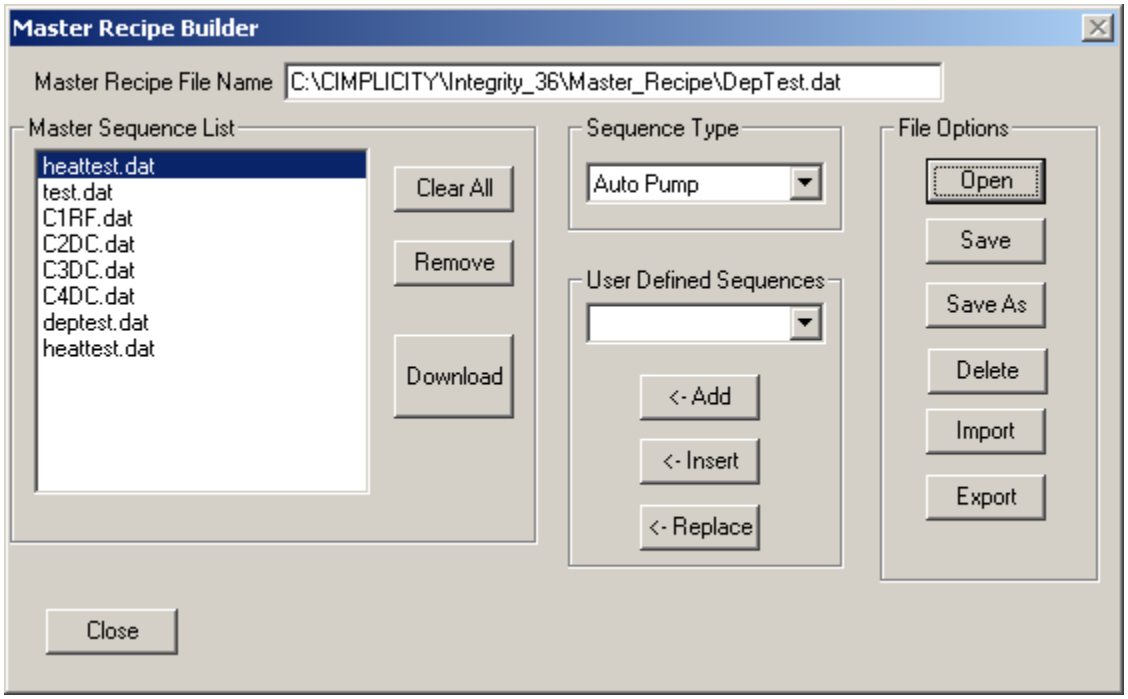


STANDARD OPERATIONS

These standard operations are used for Pumping the Load Lock down, Loading and Unloading the substrates after the T-Step process runs are done, and then Venting the Load Lock for substrate removal.

LIBRARIES OF RECIPES

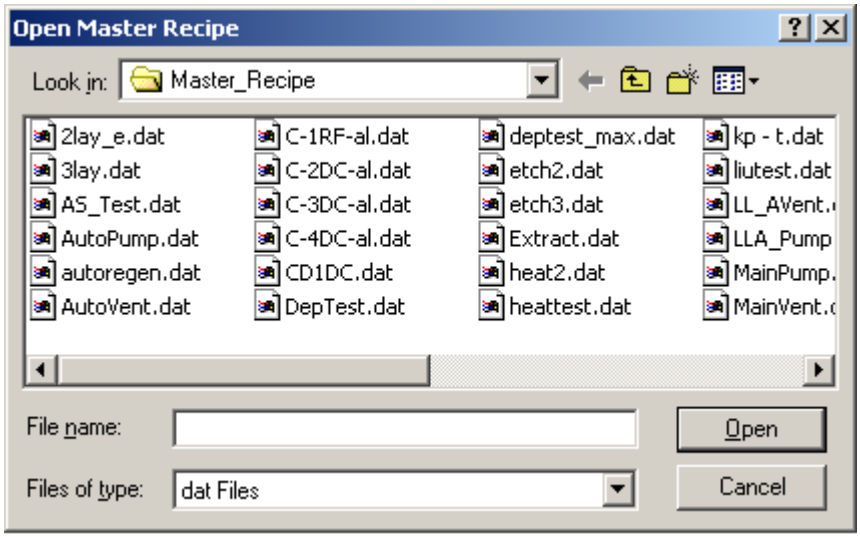
(user defined sequences)



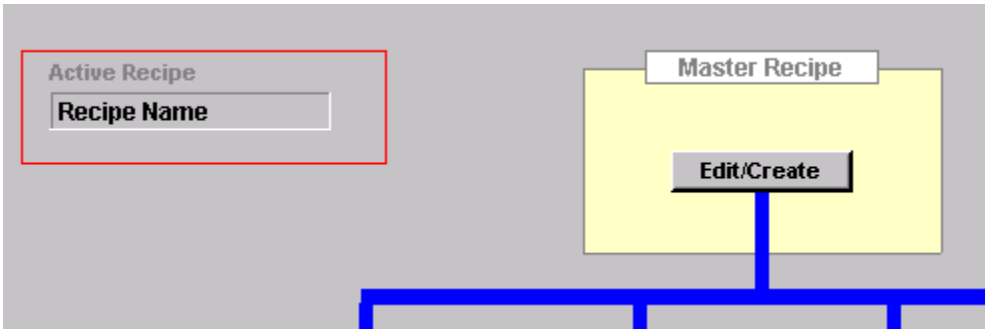
6.13.15 Once you have loaded all the required steps in the MASTER SEQUENCE LIST area, you must click the "Save As button" . This will bring up the MASTER RECIPE screen. Type in a name, and click SAVE.

6.13.16 If you want to run an existing recipe, just click the OPEN button on the MASTER RECIPE BUILDER page.

6.13.17 Highlight the desired recipe on the OPEN MASTER RECIPE screen and click OPEN . This will download the file back to the previous screen, where all the steps can be reviewed.

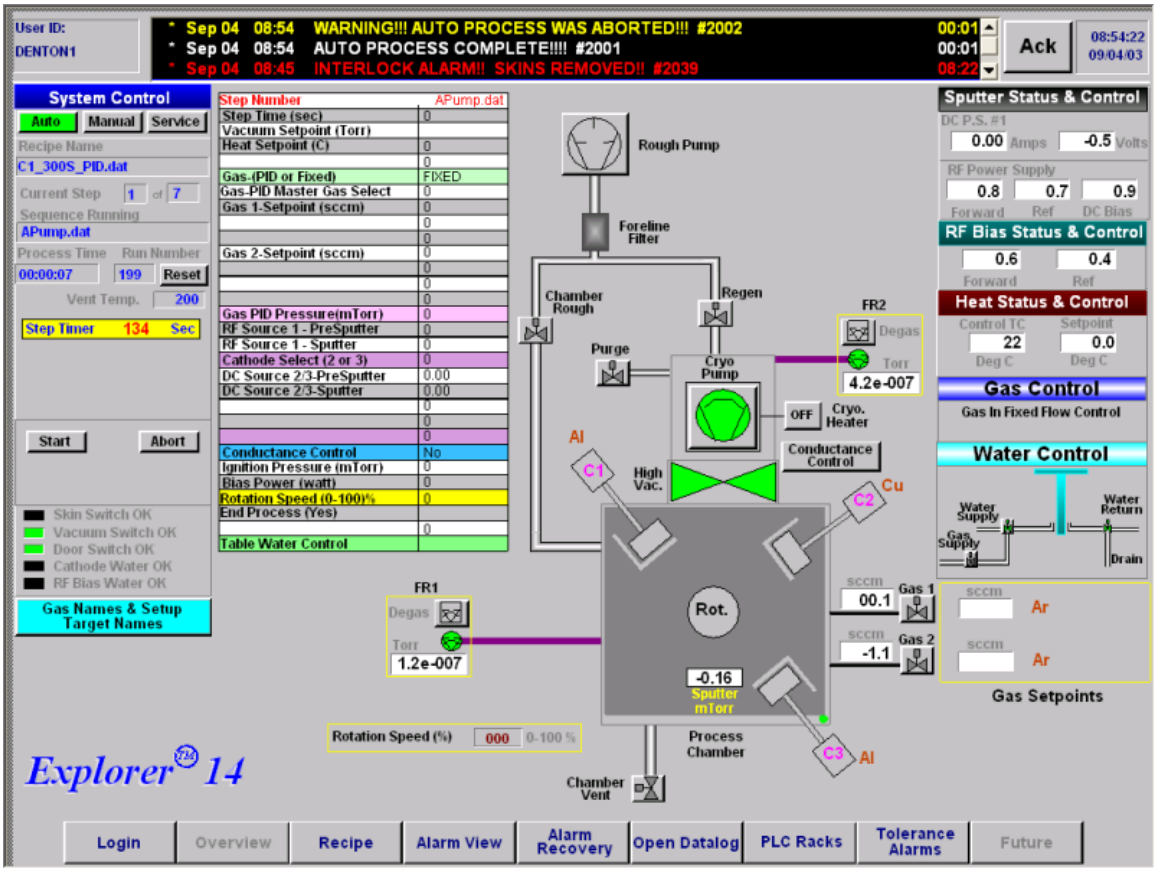


6.13.18 Now that you have named and saved your new recipe, or have selected an existing recipe, and it is loaded in the MASTER SEQUENCE LIST box on the MASTER RECIPE BUILDER page, just click the DOWNLOAD button, o load it in the main RECIPE page. The recipe's name will appear in the ACTIVE RECIPE block. It will also now appear on the system overview screen in the RECIPE NAME block , (upper left hand corner), located in the SYSTEM CONTROL zone.



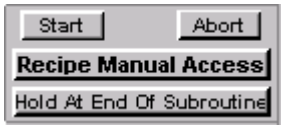
6.13.19 Press the START Auto Sequence button to initialize the Auto deposition process.

6.13.20 The automatic process selected will be executed. When the T – Step portion of the process begins, the recipe steps will be displayed next to the "System Control" zone.



6.14 Auto Sputter Description - Automatic Mode

The AutoSputter process sequence is capable of all of the system functions required to sputter multi-layer, with or without substrate heat, with or without RF Pre-clean.



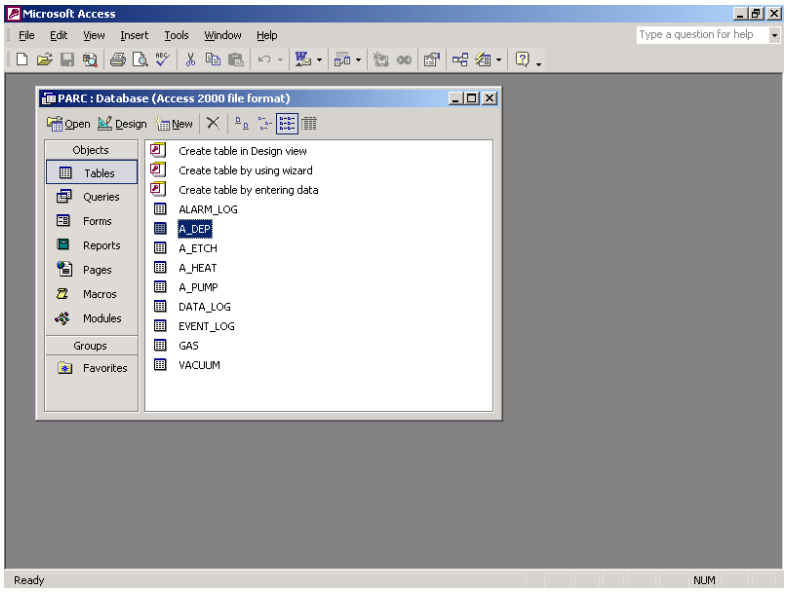
6.14.1 The system has options that can be used during the Auto Process Runs. These selections can be made during the run and are located in the SYSTEM CONTROL zone on the overview page.

6.14.2 The ABORT button will stop the system in a safe state. All power supplies and gas sources will be turned off. The system will leave the high vacuum valve open and continue to maintain the vacuum operation. Using the ABORT button will require MANUAL intervention, for re positioning the substrate or manipulation mechanisms.

6.14.3 HOLD AT END OF SUBROUTINE button, will pause the system after auto processes that do not take place in the T – Step recipes. For example, Heat

and Etch subroutines. A new recipe will have to be run to continue on, if this is selected, or use the MANUAL mode to continue processing.

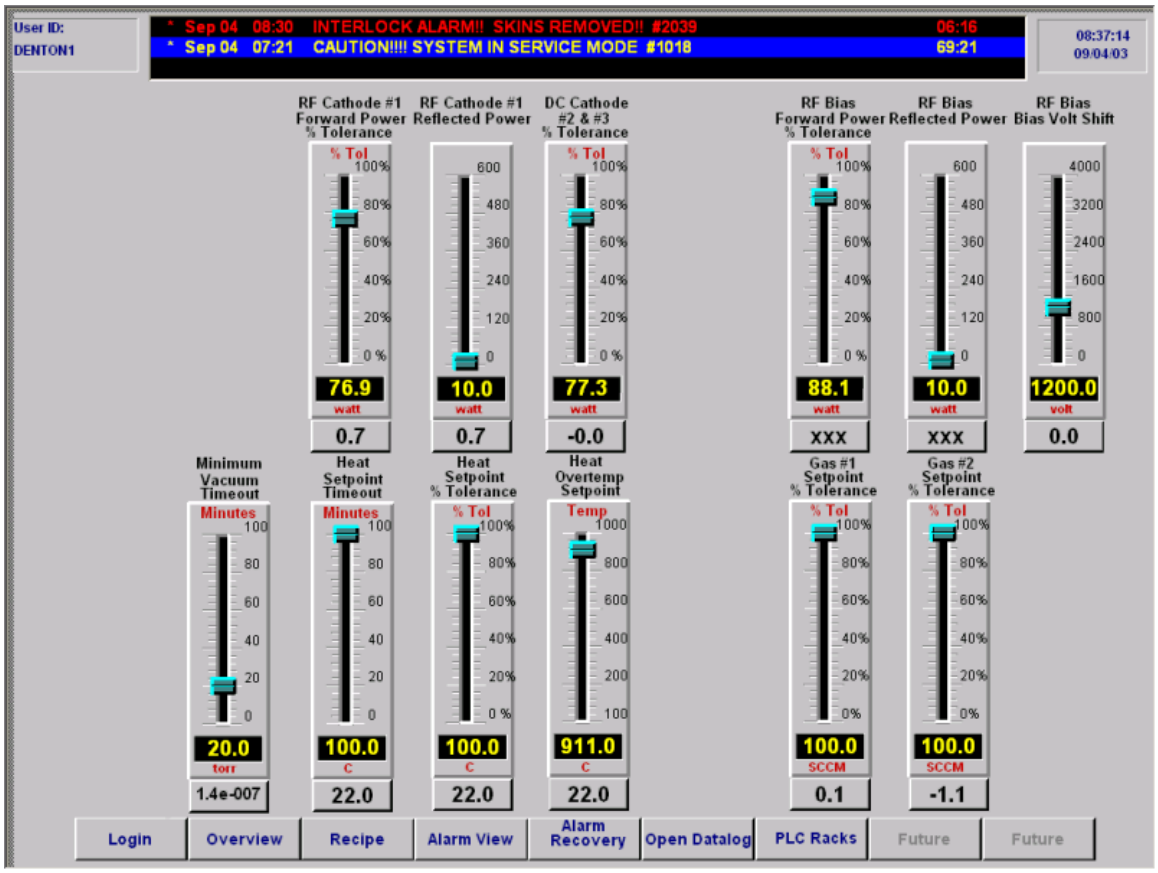
6.14.4 The RECIPE MANUAL ACCESS button can be used during the T – Step processes. It allows you to change the values in that step via the MANUAL control screens for the power supplies and gas flow controllers. At the end of that step, the recipe values in the next T- Step will be re-entered.



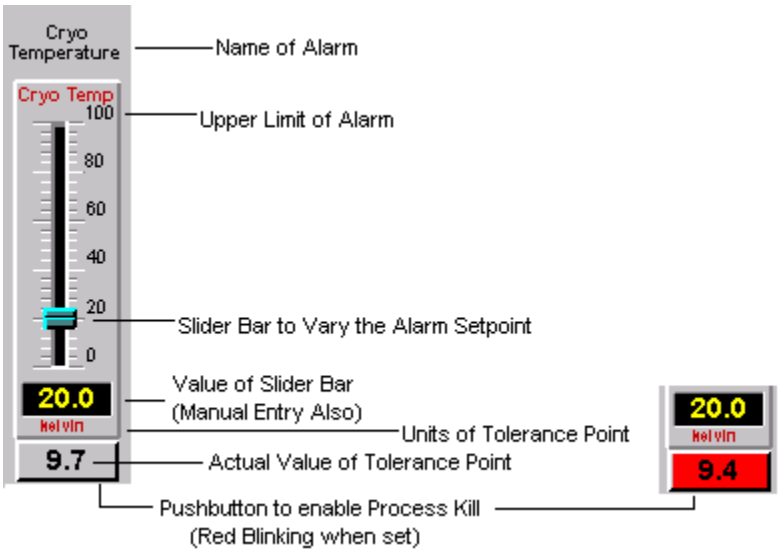
7. System Alarms

Purpose: The purpose of this section is to outline the manual steps required to correct an alarm condition in a Explorer® 14 vacuum system.

7.1 Programmable Tolerance Alarms:

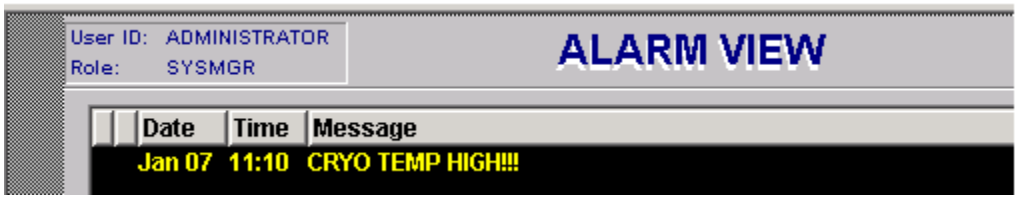


Process Pro has the ability for the User to set several programmable tolerance alarms. These alarms, by the use of a slider bar, can be varied to meet tighter or wider tolerances for the specific process. These alarms are always enabled regardless of mode of operation.



The alarm can be varied by using the mouse and moving the Slider Bar to the desired level or the value of the slider can be varied by clicking the Value and entering the value by the use of the keypad. The Process Kill pushbutton, when set, will be a red **blinking** button that will end an automatic process upon the set of the alarm. When first set, the alarm will appear on the Alarm View with text describing the alarm and will be **blinking** Red.

When acknowledged from the operator, the alarm will be **blinking** yellow. These Alarms are considered HIGH alarms and will be the only alarms **blinking**.



The following list contains Programmable Tolerance Alarms for operation and a brief explanation of the alarm message.

Alarm Message	Explanation	Recommended Action
RF #1 P.S. SPUTTER SETPOINT!! OUT OF TOLERANCE #1002	RF sputter power supply setpoint is out the programmed tolerance. The tolerance is the percentage (%) above and below the setpoint	Make sure the chamber is at the required pressure (above 2 mtorr). The RF Bias may require higher pressure to ignite. Close the high vacuum bypass valve until the cathode ignites. Typically 8-12 mtorr is sufficient
RF1 SPUTTER REFLECTED POWER!! OUT OF TOLERANCE #1003	RF sputter programmed Reflected Power tolerance point has been exceeded.	
DC #1 P.S. SPUTTER #2 OR #3 SETPOINT!! OUT OF TOLERANCE #1004	DC sputter power supply #1 setpoint is out the programmed tolerance. The tolerance is the percentage (%) above and below the setpoint	
DC #2 P.S. SPUTTER #4 SETPOINT!! OUT OF TOLERANCE #1005	DC sputter power supply #2 setpoint is out the programmed tolerance. The tolerance is the percentage (%) above and below the setpoint	
RF #2 P.S. BIAS SETPOINT!! OUT OF TOLERANCE #1006	RF Bias power supply setpoint is out the programmed tolerance. The tolerance is the percentage (%) above and below the setpoint	
RF2 BIAS REFLECTED POWER!! OUT OF TOLERANCE #1007	RF Bias programmed Reflected Power tolerance point has been exceeded.	
BIAS VOLTAGE OUT OF TOLERANCE #1008	RF Bias Voltage programmed tolerance point has been exceeded.	
VACUUM ALARM!! MIN. VACUUM SETPOINT TIMEOUT #1009	During an Auto Process the minimum vacuum setpoint has not been reached within the programmed time limit.	

Alarm Message	Explanation	Recommended Action
AUTO HEAT ALARM – TEMPERATURE SETPOINT TIMEOUT!! #1010	During an Auto Heat Process the heat setpoint was not reached within the programmed time limit	
HEAT ALARM – SETPOINT TOLERANCE LIMIT!! #1011	The heat setpoint is out the programmed tolerance. The tolerance is the percentage (%) above and below the setpoint	Tune PID
HEAT ALARM!! DANGER!! OVERTEMP ALARM #1012	The actual heat temperature in the main chamber has exceeded the programmed setpoint. The temperature in the chamber is dangerously high.	
TRANSFER TEMP TOO HIGH!! #1013	The main chamber temperature is too HOT for transfer in or out	
GAS #1 SETPOINT OUT OF TOLERANCE!!! #1014	Gas #1 setpoint is out the programmed tolerance. The tolerance is the percentage (%) above and below the setpoint	
GAS #2 SETPOINT OUT OF TOLERANCE!!! #1015	Gas #2 setpoint is out the programmed tolerance. The tolerance is the percentage (%) above and below the setpoint	
TOLERANCE ALARM PROCESS KILL!! #1017	NON-Programmable Alarm. Informs operator that a Programmable Alarm HAS ended a Automatic Process.	N/A
CAUTION!! SYSTEM IN SERVICE MODE #1018	NON-Programmable Alarm. Informs operator that system is now in a non-interlocked Service Mode. Qualified personnel only!!	Service Mode for Qualified personnel only!!

The following list contains Alarms for system operation and a brief explanation of the alarm message. These alarms are considered MEDIUM Alarms and will be a **steady** Red until acknowledged, when they turn to a **steady** Yellow. These MED alarms consist of system interlocks, equipment interlocks and system operation.

Alarm Message	Explanation	Recommended Action
AUTO PROCESS COMPLETE!! #2001	Automatic process has ended.	No action required.
WARNING!! AUTO PROCESS WAS ABORTED #2002	Automatic process has ended because the STOP button was depressed.	No action required.
RF BIAS INTERLOCK ALARM!! DOOR OPEN!! #2003	The main chamber door is open and the BIAS Power Supply was initiated either manually or by an automatic process	Check door sensor. The hardware sensor, if satisfied and working, has an LED that illuminates when satisfied.
RF BIAS INTERLOCK ALARM!! NO ROTATION!! #2004	The main chamber rotation is NOT on and the BIAS Power Supply was initiated either manually or by an automatic process	Check rotation.
RF BIAS INTERLOCK ALARM!! NO VACUUM!! #2005	The main chamber vacuum is not set and the BIAS Power Supply was initiated either manually or by an automatic process	Check vacuum switch
RF BIAS INTERLOCK ALARM!! NO WATER!! #2006	The BIAS water sensor is not set and the BIAS Power Supply was initiated either manually or by an automatic process	Check water switch
Cathode #1 Water Not Satisfied #2008	Cathode #1 water was lost while the power to the cathode or the Heat was on.	Check water switch
Cathode #2 Water Not Satisfied #2009	Cathode #2 water was lost while the power to the cathode or the Heat was on.	Check water switch
Cathode #3 Water Not Satisfied #2010	Cathode #3 water was lost while the power to the cathode or the Heat was on.	Check water switch

Alarm Message	Explanation	Recommended Action
DC 1 SPUTTER INTERLOCK ALARM!! DOOR OPEN!! #2012	The main chamber door is open and the DC #1 Power Supply was initiated either manually or by an automatic process.	Push door closed.
DC 1 SPUTTER INTERLOCK ALARM!! NO ROTATION!! #2013	The main chamber rotation is NOT on and the DC #1 Power Supply was initiated either manually or by an automatic process.	Push door closed.
DC 1 SPUTTER INTERLOCK ALARM!! NO VACUUM!! #2014	The main chamber vacuum is not set and DC #1 Power Supply was initiated either manually or by an automatic process	Check vacuum switch
DC 1 SPUTTER INTERLOCK ALARM!! NO WATER!! #2015	The DC #1 water sensor is not set and the DC #1 Power Supply was initiated either manually or by an automatic process	Check water switch
HEAT INTERLOCK ALARM!! NO ROTATION!! #2020	The Heat was initiated by a manual PB or a auto process and there was no rotation on.	Turn rotation on. Check fuses.
HEAT INTERLOCK ALARM!! NO VACUUM!! #2021	The Heat was initiated either manually or by an automatic process and the vacuum switch is not set.	Check vacuum switch.

Alarm Message	Explanation	Recommended Action
HIVAC VALVE ALARM!! ROUGH VALVE OPEN INITIATED #2022	The hivac valve is open and either the rough pb was initated or an auto process called for the rough valve open.	No Action
VENT VALVE ALARM!! ROUGH VALVE OPEN INITIATED #2023	The hivac valve is open and either the vent pb was initated or an auto process called for the vent valve open.	
RF SPUTTER INTERLOCK ALARM!! DOOR OPEN!! #2026	The main chamber door is open and the RF Power Supply was initiated either manually or by an automatic process	
RF SPUTTER INTERLOCK ALARM!! NO ROTATION!! #2027	The main chamber rotation is NOT on and the RF Power Supply was initiated either manually or by an automatic process.	Push door closed.
RF SPUTTER INTERLOCK ALARM!! NO VACUUM!! #2028	The main chamber vacuum is not set and RF Power Supply was initiated either manually or by an automatic process	Check vacuum switch
RF SPUTTER INTERLOCK ALARM!! NO WATER!! #2029	The RF Sputter water sensor is not set and the RF Power Supply was initiated either manually or by an automatic process	Check water switch

Alarm Message	Explanation	Recommended Action
REGEN ALARM!! 3RD setpoint Failure!!	Cryopump has been purged and pumped three times and has not made minimum vacuum setpoint. Auto Regen program stops after third failure.	
REGEN ALARM!! RATE OF RISE TEST FAIL!!	Cryo-pump will not hold vacuum setpoint for one minute.	
REGEN ALARM!! 20 MIN PURGE CYCLE START!!	Cryo-pump has not made minimum vacuum setpoint. Failed after first or second purge & pump cycle.	
AUTO PUMP ALARM - CROSSOVER SETPOINT TIMEOUT!!	Crossover setpoint not reached in preset amount of time.	Check for possible cause (i.e. leak). Check mechanical pump. Correct and proceed.
AUTO PUMP ALARM - PROCESS PRESSURE SETPOINT TIMEOUT!!	Process pressure setpoint not reached in preset amount of time.	Check for possible cause (i.e. leak). Check cryopump. Correct and proceed.

The following list contains Cimplicity software alarm messages as they appear on the Alarm Screen and a brief explanation of the alarm message. (%s indicates the name of a point in the system database.)

NOTE: Some alarms are built into the software and are used to control the transfer of information into and out of a database. Others are built into the software to handle network control. These alarms require little or no action on the part of the operator.

Alarm Message	Explanation	Recommended Action
Logging failure on database table %s	Failure of data logging into the database: internal alarm	Acknowledge, Delete & Ignore
Comm error or dynamic disable, device %s	XTC/2 Deposition Controller is not communicating with system.	Reboot the system.
Failing over to redundant device %s	Device Failover alarm for PLC redundancy.	Acknowledge, Delete & Ignore
Log file almost full	Network alarm.	Acknowledge, Delete & Ignore
User ID %s disabled, computer %s	User disabled due to bad login.	Acknowledge, Delete & Ignore
User %s Logged ON	Network alarm.	Acknowledge, Delete & Ignore
User %s Logged Out	Network alarm.	Acknowledge, Delete & Ignore
%s of the redundant pair is down	Alarm for PLC redundancy.	Acknowledge, Delete & Ignore
The process %s has lost its database connection to %s	Database connection failed.	Reboot the system.
The process %s has begun to forward data to %s	Database communication error.	Reboot the system.
Process %s Terminated on %s Process name %s	Process terminated unexpectedly.	Reboot the system.

8. System Interlocks

The following interlocks are active in manual and automatic modes. The operation of the following functions will be blocked without satisfying its interlocks. Interlock messages are given alerting the operator as to the reason for the limitation.

The below software interlocks can be defeated by enabling the Service Mode. CAUTION: ONLY Maintenance Level access can enable the Service Mode. The Service Mode control is found in the Maintenance screen.

Device	Limitation	Reason
Mechanical Pump	Can't turn ON or OFF if	Chamber rough is open LL rough is open
Cryo Pump	Can't turn ON or OFF if	Cryo regen is open Cryo purge is open Cryo pressure above 100mtorr
Chamber Rough valve	Can't open if	Chamber door is open Mech. Pump is off Hivac valve is open Chamber vent valve is open LL rough valve is open
	To Close	No Interlocks.
Chamber Hivac valve	Can't open if	Chamber pressure above 150mtorr Chamber door is open Chamber vent valve is open Chamber rough valve is open Cryo pump is off
	To Close	No Interlocks.
Chamber Vent valve	Can't open if	Chamber door is open Chamber rough valve is open Chamber hivac valve is open Heat power is on Any Sputter power on RF Bias power is on
	To Close	No Interlocks.

Device	Limitation	Reason
Cryo Purge valve	Can't open if	Cryo pump is on Cryo regen valve is open
	To Close	No Interlocks.
Cryo Regen valve	Can't open if	Cryo pump is on Cryo purge valve is open
	To Close	No Interlocks.
Gas Valves	No interlocks	
Sputter Power 1-4, RF Bias power	Can't be turned on if	Skin switch not satisfied Bellows switch not satisfied Chamber door open Water switch not satisfied
	To Turn OFF	No Interlocks.
Heat Power	Can't turn on if	Skin switch not satisfied Bellows switch not satisfied Chamber door open Any water switches not satisfied
	To Turn OFF	No Interlocks.

9. System Maintenance

9.1 ProcessPro Total Solution Server

DVI Service using MS Terminal Service

MS Internet Explorer and creating a private network between DVI and customer for up to the minute options of DVI Service
Real Time Process evaluation and diagnostics
Remote monitoring for needed periodic access to system information for a higher level of support
Support person has the ability to diagnose and resolve configuration problems, as well as online training

High performance Ethernet Modem located anywhere (wireless)

Better service connectivity creates a better dialogue between customer and manufacturer using a direct connection.
DVI Service can receive emails from alarms, view reports, diagnose computer system resources
Calendar based control operations for Preventive Maintenance

Security Authorization

Allow only authorized Users, including DVI Service, to view secured areas or data
Interactive access for several users for read-only viewing

Report Manager / Data Reporter

Built-in scheduler allows unattended reporting
Schedule periodically, daily, weekly, monthly reports
Maintain an internal database for
- Standard deviation from run to run
- SPC
  - *Collect, measure, analyze and warn of possible quality control problems*
- Process related reports
- Display multiple reports for simultaneous for accurate comparison
- Available through Intranet and/or email via dedicated phone line to DVI

Use MS SQL V7.0 for data logging applications
- Integration becomes easier into existing networks

Computer System Sentry

Superior monitoring of the computer system
- Monitors and records parameters and statistics like alarm frequency, device communications, data collection and throughput and user registration.
- Monitors critical operating system and network information, such as CPU performance, memory consumption, and process time, to give you a complete and current status of your system's health.

"Open" (OPC) software architecture

Easy integration of plug and play interface with individual or 3rd party software
OPC is an emerging standard to provide interoperability between software, hardware systems and devices.

9.2 Chamber Cleaning

1. Change shields when coating begins to flake off the metal.

2. Partial shield changes can be made when required.

3. All shields must be cleaned using a beadblaster to remove built-up coating. Care must be taken to prevent contact with oils or grease.

4. After cleaning in a beadblaster, the shields must be wiped down with isopropyl alcohol or acetone before being reinstalled.

5. Any exposed chamber areas must be scrubbed with Scotchbrite and wiped with isopropyl alcohol or acetone.

9.3 Mechanical Pump

1. Check oil level daily. **Do this when pump is <u>not</u> operating.**

2. Check the color of the oil monthly. Compare it with a sample of new oil. **If the oil is brown, black or smell "burnt", it has deteriorated.** Drain the pump and change the oil.

3. See the Troubleshooting section of the subsystem operating manual.

9.4 Cryogenic Pump

1. Check the temperature gauge daily. A reading above 20K indicates the pump requires regeneration.

2. Check and record the operating pressures monthly.

3. Replace the seals and inspect the valve stems at 10,000 hours of operation.

4. Replace the adsorber unit at 30,000 hours of operation.

5. See the Troubleshooting section of the subsystem operating manual for specific instructions.

9.5 High Vacuum Valve

1. Check main o-ring seal annually. This requires disassembly of the valve. Replace o-ring seal if it is scored or brittle.

9.6 Rotary Feedthroughs

1. Fixture Drive and Shutter Drive should be disassembled and inspected every 6 - 12 months.

2. Replace all damaged, brittle, or worn seals. Clean and lubricate all seals before reassembly.

9.7 Overall System Maintenance

1.  Refer to instrument manuals.

9.8 Fuse Ratings

FUSE	RATING *ALL FUSES ARE SLOW-BLOW*	CIRCUIT
FU-3	2 Amps	24 VDC Power Supply Primary
FU-4	2 Amps	24 VDC Power Supply Primary
FU-5	5 Amps	24 VDC Power Supply Primary
FU-6	2 Amps	Auxiliary Power (Rec 1)
FU-7	0.5 Amps	Signal Transformer-T1 Primary
FU-8	0.5 Amps	Signal Transformer-T1 Primary
FU-9	0.25 Amps	Signal Transformer-T1 Secondary
FU-10	10 Amps	Heat Power
FU-11	10 Amps	Heat Power
FU-15	1 Amps	Rotation Control
FU-15A	1 Amps	Rotation Control
FU-16	10 Amps	Mechanical Pump
FU-17	10 Amps	Mechanical Pump
FU-18	20 Amps	Cryo Pump CTI 8
FU-19	20 Amps	Cryo Pump CTI 8
FU-20	15 Amps	DC 1 Power
FU-21	15 Amps	DC 1 Power
FU-25	10 Amps	RF 1 Power
FU-26	10 Amps	RF 1 Power
FU-28	2 Amps	PLC Power
FU-40	1 Amps	12 VDC Power Supply Primary
FU-41	2 Amps	Cryo Heater Blanket
FU-46	1 Amps	± 15 VDC Power Supply Primary

FUSE	RATING *ALL FUSES ARE SLOW-BLOW*	CIRCUIT
FU-47	1 Amps	± 15 VDC Power Supply Primary
FU-48	5 Amps	RF 2 Power
FU-49	5 Amps	RF 2 Power
FU-50	0.5 Amps	Capacitance Manometer

10. Troubleshooting

10.1 Safety Warnings:

WARNING!

DUE TO THE NATURE OF THE SUBSYSTEMS, THERE ARE MANY TYPES OF VOLTAGES ON A VACUUM SYSTEM. **LETHAL HIGH VOLTAGES ARE PRESENT!**

READ THE OPERATING MANUALS SUPPLIED WITH THE SYSTEM BEFORE ATTEMTING ANY TYPE OF TROUBLESHOOTING ON THE VACUUM SYSTEM. REFER TO THE PROPER SECTIONS OF THE OPERATING MANUALS TO VERIFY THAT THE SYSTEM IS BEING OPERATED IN THE PROPER MANNER.

INTERLOCKS ARE BUILT IN TO THE CONTROL SYSTEM. RATHER THAN ASSUMING A SYSTEM FAILURE, VERIFY THE PROBLEM IS NOT AN INTERLOCK INTENDED TO PREVENT UNSAFE OPERATION.

NOTE ON JEWELRY

WHEN WORKING AROUND A VACUUM SYSTEM, THERE IS ONE GOOD PRACTICE:

DO NOT WEAR JEWELRY!

AN ARC MAY BE DRAWN FROM A HIGH VOLTAGE SOURCE!

10.2 Required Tools:

Tool	Use
Multimeter (Analog or Digital)	A. To read AC or DC Voltages B. To read low AC or DC Current C. To read resistance (Ohms)
Hand-held Current Meter (Amp Probe)	Clamps around an AC line read current.
Screwdrivers (Flat & Phillips)	For disassembly and assembly.
Wrenches (Box Type)	For disassembly and assembly: 3/8” to 1”
Allen Wrenches	For disassembly and assembly: 1/16” to 3/8”

10.3 Vacuum System Control Rack:

Problem: *No activation of subsystems when main switch is toggled.*

Cause: No +24V DC power from DC power supply.

Solution:

1) Check to see if there is 208V AC, 3 phase power at main breaker of vacuum system.

2) Turn ON main breaker.

3) Turn ON aux. breaker.

4) Press green "START" button.

5) Check the fuse F2 for the 24 volt DC supply located in the NEMA enclosure. Replace if blown.

6) Check the fuse F1 for the AC power to the DC power supply located in the NEMA enclosure. Replace if blown.

7) Pull out 24 volt fuse from panel. Then with voltmeter, check output terminals of the +24 volts at power supply. These terminals can be found on the 24 volt supply P.C. board.

8) Check AC input on transformer of DC power supply to see if 120V AC is present

9) If there is 120V AC input power, but no 24V DC output, replace the power supply.

10) If there is no AC power at this point, call Denton Vacuum (856-439-9100).

Problem: S*ubsystems activated, but no control of pumps, valves and subsystems.*

Cause: 24V Relays.

Solutions:

1) Be sure all relevant interlocks are satisfied *before* proceeding.

2) Pumps, valves and subsystems are controlled through the PLC by relays. Each relay is numbered. Identify the correct relay according to the schematic and check correct position (OPEN/CLOSED) of the relay. Visually verify the proper operation of the relay against the schematic.

3) If the relay fails to operate, remove it and use an Ohm meter to read the resistance of the coil. Verify that the coil is not shorted.

4) Verify that the contacts are not fused and preventing movement.

5) If there is a problem with a relay, replace it.

6) Use a volt meter to determine if a signal is going to the relay.

7) If the relay is not receiving a signal to open or close, contact Denton Vacuum (856-439-9100).

10.4 Valves and Shutters:

The source shutter and all vacuum valves on the vacuum system are pneumatically controlled. The valve opening procedure is as follows:

There is a 24V DC signal from an output relay that feeds into a DC solenoid (electromagnetic) coil. The electromagnetic field created by the coil pulls up a "plunger valve" mounted to the air flow manifold. When this "plunger" is pulled up it permits air pressure (80 - 100 psi) to pass through the manifold into an air operated cylinder. The air pressure going into the air cylinder becomes greater on one side than the other. The side of the cylinder with the greater air pressure will move a "diaphragm" the opposite way. Depending on which way the diaphragm is traveling the valve is opened or closed.

Problem: *When the assigned output is activated, the valve or shutter associated with it does not respond. The on-screen indicator changes state.*

Causes:

A. No air pressure to the air manifold.

B. No power at the valve or shutter solenoid.

C. Valve or shutter solenoid defective.

Quick Test: Before going on to the solutions for the above causes, there is a quick way to verify that a solenoid valve has +24V DC and the solenoid is active:

Place a common metal screwdriver on top of the solenoid with the valve output ON. If the screwdriver is slightly magnetized to the top of the solenoid, the coil is good and there is most likely a mechanical problem such as no air or a stuck plunger. **Remember this is only a quick test. It is not 100% fool-proof**.

Solutions (Cause A):

1) Verify that there is 90 - 100 psi of air pressure to the vacuum system. Inspect air lines and filter for water.

2) Prove that there is air to the valve in question.

- Each valve has two air lines attached to it: one for air in and one for return. These air lines are attached by special fittings that make it easy to detach or reattach an air line. These fittings are called "LEGRIS" fittings.

- While holding one of the air lines firmly in your hand, push in the red collar on the Legris fitting, pull out air line while pushing the red collar of the Legris fitting inward.

- **NOTE: There might be 90 - 100 psi of air pressure in the line. Make sure that you have a firm grip on it so it does not "whip" out of your hand.**

- While holding air line, activate and deactivate power to the solenoid.

- Air should flow out of the Legris fitting mounted in the air manifold when power is at one state (ON/OFF), and air should stop flowing when the power to the solenoid is in the other state (ON/OFF).

- Repeat steps 2 through 5 for second air line to see if it operates the same way.

- If both Legris fittings operate with alternating air ON/OFF, the problem is internal to the valve assembly.

- Disassemble valve in question and inspect for foreign matter or broken seals.

3) If the air flow from the Legris fitting did not change from one port to the other or when switched ON/OFF, then follow Solutions (Cause #2) below.

Solutions (Cause B):

1) Locate the solenoid valve attached to the air manifold.

2) Open the black plastic enclosure that holds the wires connecting to the solenoid.

3) When the wires have been located, expose the connectors that join the signal wires to the solenoid.

4) Place a voltmeter across the wires at the crimp connectors.

5) Disconnect the solenoid from the output leads and try to read +24V DC power at the ends of the two wires.

6) If there is NO power at the solenoid when the output is high, use the system schematic and a voltmeter, trace the signal lines and inspect for breaks.

7) If there IS power on the signal lines when disconnected from the solenoid and the solenoid is not operating, see Solutions (Cause C).

Solutions (Cause C):

1) Disconnect solenoid from signal leads.

2) Use an Ohm meter to read the resistance of the solenoid.

3) A reading of approximately 65 - 85 Ohms (+/- 10%) indicates a good solenoid.

4) A reading of 00.0 Ohms indicates a shorted solenoid.

5) Replace the solenoid, then try the valve.

6) A reading of infinity indicates the solenoid is burnt out (open coil).

7) Replace the solenoid, then try the valve.

10.5 Rotation:

Problem: *When rotation is powered ON it does not rotate, or it stops rotating in the middle of a run*

Causes:

A. Fuse blown.

B. Power to and/or from the motor controller is not active.

C. Rotation is mechanically jammed.

Solutions (Cause A):

1) Locate B&B Nova Motor Controller in the control rack. Read the subsystem operating manual to become familiar with the Nova Controller.

2) Shut power to the Motor Controller OFF before proceeding.

3) At the rear of the Motor Controller under the P.C. board locate the fuse holder and 8 Amp fuse.

4) Remove the fuse and check it with an ohm meter. If blown, replace.

5) Examine the traces on the P.C. board around the fuse holder. If they are burnt, replace the Nova controller.

Solutions (Cause B):

1) Use a voltmeter to measure the 120 VAC power going into the Nova controller on the terminals "L-1" and "L-2".

2) If NO power is present, use the use the system schematic and a voltmeter, trace the signal lines and inspect for breaks.

3) If there IS power coming in to the controller, then the DC output power from the controller must be checked for both the field and armature.

4) Disconnect the four motor wires from the terminals marked "A1, A2, F1, &F2".

5) Set the volt meter to DC Volts and read the output power on terminals "F1 & F2" (field). There should be a constant voltage of 135 VDC no matter where the control pot is set.

6) Set the volt meter to DC Volts and read the output power on terminals "A1 & A2" (armature). Take readings while adjusting the control pot from zero to full scale. The output should vary from zero to 100% output as the control pot is varied. Full power should be 120 VDC to 135 VDC.

7) If either or both DC outputs are disabled for the field or armature, replace the motor controller.

Solutions (Cause C):

1) Inspect main bearings in the planetary drive for damage.

2) Disconnect the motor from the rotation so that the substrate drive can turn freely.

3) Push the planetary with your hand. It should rotate freely for 3 to 5 revolutions after one firm push. Rotation motion should be smooth.

4) If the rack does not rotate, or it is very hard to move, disassemble the planetary and replace the bearings.

5) Reassemble the system and try again.

10.6 Mechanical Pump:

Problem: *Rough out times are increasing; Auto regen program fails to complete; mechanical pump pressure is high. Mechanical pump is not able to hold ultimate pressure.*

Cause: Low oil level. Mechanical pump seals bad.

Solution:

1) Place system in Manual Mode.

2) Close all valves and turn ON Mechanical pump.

3) Observe pressure on Denton DV-23 thermocouple controller. This controller is used as a redundant pressure sensor. It is used to evaluate mechanical pump performance.

4) The pressure should quickly go to less than 1 militorr (off the bottom of the scale).

5) This is the baseline or ultimate pressure of the mechanical pump. The lowest pressure that the mechanical pump can attain isolated from the rest of the vacuum system.

6) If the ultimate pressure is above this reading, Check the oil level in the mechanical pump. Refer to the operating manual. Add to or change the oil as required.

7) The mechanical pump may require ballasting if the mechanical pump oil has been contaminated. Refer to the operating manual for specific instructions.

8) If the oil level is correct and the oil is not contaminated, but the ultimate pressure is still above 1 militorr contact Denton Vacuum (856-439-9100).

10.7 Substrate Heat:

DANGER HIGH VOLTAGE!

Problem: *Heat lamps do not turn on. No heat control.*

Cause:

A. Fuse blown.

B. Contactor #1 is not closing.

C. SCR #1 LED's not glowing in proportion to output.

D. Lamp is burnt out.

E. Thermocouple defective or not connected.

NOTE: *Verify that temperature setpoint is higher than current temperature before proceeding.*

Solutions (Cause A):

1) Sheet #3 of the wiring diagram contains the heater circuit diagram.

2) Locate heater fuse in the control rack.

3) Shut power to the heaters OFF before proceeding.

4) Remove the fuse and check it with an ohm meter. If blown, replace.

Solutions (Cause B):

1) Sheet #3 of the wiring diagram contains the heater circuit diagram.

2) Toggle the heater power pushbutton on the Overview page. Check Rack 0, Slot 5, Pin 3 of the PLC. Verify that the "2" LED on the PLC toggles with the pushbutton.

3) If LED does not toggle, use an ohm meter to verify the heater interlock string on Sheet #3 of the wiring diagram.

4) If LED toggles, replace contactor.

Solutions (Cause C):

The silicon control rectifier (SCR) controller is a solid state device designed to control a large AC power level with a small DC control signal.

The input of the SCR is 208V AC; protected by a fuse to limit the current that will be seen by the SCR controller. As the DC signal to the gate of the SCR increases so does the output of the SCR controller. The SCR controller is about 95% efficient. This means for a given input, the output voltage will achieve 95% of the actual input voltage. AN SCR has a preset gain and span set on it. If these parameters are readjusted, it will limit the control range of the SCR either at the low end or the high end.

Besides being able to control the SCR with an external 0 - 10 Volt DC source, it can be controlled by an internal signal from it's own source of power. This can be done by removing the 0 - 10 Volt DC signal from the "W" and "CCW" terminals, then attaching a 1K ohm potentiometer to the "CW", "W", and "CCW" terminals of the SCR. An SCR controller has one unusual property. If there is no "LOAD" attached to the output, the SCR will pass full voltage no matter where the DC control voltage is set.

1) Sheet #3 of the wiring diagram contains the heater circuit diagram.

2) Use a DC Voltmeter on terminals W and CCW on the SCR. Red lead on W and black lead on CCW.

3) If a minus (-) voltage is displayed, reverse the wires on the W and CCW terminals.

4) If there is no voltage at the SCR, check Rack 0, Slot 10 of the PLC for 0-10 Volt DC output.

5) If there is a 0-10 Volt signal at Rack 0, Slot 10 of the PLC, replace the SCR.

Solutions (Cause D):

1) Use Ohm meter to test continuity in individual heater lamps.

2) Replace heater lamp if it is defective.

Solutions (Cause E):

1) Verify thermocouple connections with Ohm meter. Reconnect or repair if necessary.

2) Use Ohm meter to test continuity in thermocouple.

3) Replace thermocouple if it is defective.

10.8 Summary:

Steps for troubleshooting should follow a logical order.

Vacuum systems are constructed from many different vendor parts and subassemblies: everything from electrical valves to electron beam guns. Each subsystem is supplied with a manual of operation. Familiarize yourself with all the operating manuals supplied with the vacuum system. Refer to these manuals for trouble shooting procedures on the individual equipment in question.

This manual reviews the most common problems experienced with similar vacuum systems. Possible causes are described and solutions are presented in a step-by-step procedure. Most problems can be identified and corrected with a similar approach.

If after a reasonable time the problem cannot be identified, call Denton Vacuum (856-439-9100) to assist with troubleshooting and repair. We can also provide system training to facilitate system maintenance and reduce down time.

11. List of Electrical Schematics

0)	Cover Page	
1)	Power Distribution	EXP140201-43137.DWG
2)	Power Distribution	EXP140202-43137.DWG
3)	Power Distribution	EXP140203-43137.DWG
4)	Heat Control	EXP140302-43137.DWG
5)	Heat Control	EXP140301-43137.DWG
6)	Low Voltage Control Wiring Diagram	EXP140401-43137.DWG
7)	Low Voltage Control Wiring Diagram	EXP140402-43137.DWG
8)	Vacuum Control Gauging	EXP140501-43137.DWG
9)	Vacuum Control Gauging	EXP140502-43137.DWG
10)	Spare	EXP140601-43137.DWG
11)	Substrate Rotation Control	EXP140701-43137.DWG
12)	Pumping Control	EXP140801-43137.DWG
13)	Pumping Control	EXP140802-43137.DWG
14)	Pumping Control	EXP140803-43137.DWG
15)	Gas Control	EXP140901-43137.DWG
16)	Gas Control	EXP140902-43137.DWG
17)	Source Control	EXP141001-43137.DWG
18)	Source Control	EXP141002-43137.DWG
19)	Source Control	EXP141003-43137.DWG
20)	Source Control	EXP141004-43137.DWG
21)	Deposition Control	EXP141101-43137.DWG
22)	Deposition Control	EXP141102-43137.DWG
23)	Spare	EXP141201-43137.DWG
24)	Glow Discharge Control	EXP141301-43137.DWG

25) Glow Discharge Control	EXP141302-43137.DWG
26) Spare	EXP141401-43137.DWG
27) PLC Control	EXP141501-43137.DWG
28) PLC Control	EXP141502-43137.DWG
29) PLC Control	EXP141503-43137.DWG

12. List of Mechanical Drawings

1)	General Arrangement & Floor Plan	D-0131-173-002
2)	Air Piping Assembly	D-0131-173-012
3)	Water Piping Assembly	C-0131-173-014
4)	Vacuum Piping Assembly	D-0131-173-013
5)	Biasable Table w/ Welded Water Table	C-0044-017-008
6)	Heater Assembly	B-0131-073-015
7)	2" MAK Vertical Dimensions	L200DIMV

13. Spare Parts Lists (NOT Included – for Reference Only)

SPARE PARTS LIST **8033-513**

DENTON VACUUM

Dartmouth College

Explorer® 14 Cryo System **J # 43137**

	PART NO.	DESCRIPTION	LOCATION	QTY.
	GSK002-0015	COPPER GASKET	CHAMBER	2
	GLS001-0007	SIGHT GLASS	CHAMBER	1
	ORG004-0214	O-RING	DOOR	1
	ORG004-0125	O-RING	DOOR	1
	VFT002-0078	O-RING	CHAMBER	1
	VFT002-0002	C-RING	CHAMBER	1
	VFT002-0003	C-RING	CHAMBER	1
	GSK002-0010	COPPER GASKET	CHAMBER	1
	FTG010-0003	GASKET NICKEL	CHAMBER	1
	ORG005-0011	SEAL U-CUP	ROTATION	1
	ORG004-0057	O-RING	ROTATION	1
	BSH001-0003	BRUSH	ROTATION	2
	CRU001-0013	ELECTRODE	ROTATION	4
	LMP001-0016	LAMP 1000W	HEATER ASSY	2

DENTON VACUUM

SPARE PARTS LIST

Dartmouth College

Explorer® 14 System

J# 43137

	PART NO.	DESCRIPTION	LOCATION	QTY.
	FUS001-0089	1/4A, 250V, TIME DELAY, MIDGET		1
	FUS001-0090	1/2A, 250V, TIME DELAY, MIDGET		3
	FUS001-0091	1A, 250V, TIME DELAY, MIDGET		5
	FUS001-0092	2A, 250V, TIME DELAY, MIDGET		5
	FUS001-0023	5A, 250V, TIME DELAY, MIDGET		3
	FUS001-0058	10A, 250V, TIME DELAY, MIDGET		6
	FUS001-0024	15A, 250V, TIME DELAY, MIDGET		2
	FUS001-0025	20A, 250V, TIME DELAY, MIDGET		2
	FUS001-0026	25A, 250V, TIME DELAY, MIDGET		0
	FUS001-0027	30A, 250V, TIME DELAY, MIDGET		0
	FUS001-0080	40A, 600V, TIME DELAY, J TYPE		0