Kurt J. Lesker Company

PVD 75

THIN FILM DEPOSITION SYSTEM
OPERATION MANUAL

~ Version 8.0 ~
~ November 2012 ~

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WARRANTY

EQUIPMENT WARRANTY AND REMEDY: COMPANY warrants that the Equipment fabricated and furnished by COMPANY hereunder shall be free from material defects in workmanship and materials. If any of the Equipment fabricated and furnished by COMPANY materially fails to conform to the warranty set forth in the preceding sentence, CUSTOMER's remedy shall be limited, at COMPANY's option, to either (i) repair or replacement of the non-conforming Equipment, F.O.B. point of repair or replacement, with shipping charges prepaid by CUSTOMER; or (ii) repayment of the portion of the contract price paid by CUSTOMER attributable to such non-conforming Equipment. Dismantling and reinstalling work is excluded from this Equipment Warranty and Remedy.

SERVICES WARRANTY AND REMEDY: COMPANY warrants that any engineering, design or software development and programming services furnished under COMPANY's proposal or quotation will conform to standards of practice generally accepted in the profession and/or industry for services of a similar nature. If the services provided by COMPANY materially fail to conform to the warranty set forth in the preceding sentence, CUSTOMER's remedy shall be limited to revision, replacement or reperformance, at COMPANY's expense, of those services which COMPANY reasonably determines fails to so conform.

SOFTWARE WARRANTY AND REMEDY: COMPANY warrants that any Equipment furnished hereunder which is comprised of software, when used with COMPANY-specified hardware, shall conform to the specifications set forth in COMPANY's proposal or quotation or, in the case of standard software, with published specifications prepared, approved and issued by COMPANY's headquarters in Clairton, Pennsylvania. If any software furnished by COMPANY hereunder materially fails to conform to the warranty set forth in section 3, CUSTOMER's remedy shall be limited to correction of the non-conformance by COMPANY, without charge to CUSTOMER. COMPANY makes no representation or warranty, express or implied, that the operation of the software will be uninterrupted or error free, or that the functions contained therein will meet or satisfy CUSTOMER's intended use or requirements.

WARRANTY PERIOD: The warranties set forth in sections 1 and 3 above shall be effective for a period of twelve (12) months from the date of shipment of the Equipment from COMPANY's plant. The warranty set forth in section 2 above shall be effective for a period ending twelve (12) months from the date of performance of the services.

WARRANTY CONDITIONS AND LIMITATIONS: CUSTOMER's right to enforce the foregoing warranties is expressly conditioned upon CUSTOMER notifying COMPANY in writing during the Warranty Period of any alleged non-conformity or defect, stating specifically the nature of the alleged non-conformity or defect. COMPANY shall have the right, upon such notification, to review, inspect and/or examine the Equipment indicated by CUSTOMER, and CUSTOMER shall make the Equipment available to COMPANY for such purposes.

The foregoing warranties shall not apply if COMPANY's review, inspection or examination discloses that the Equipment (i) has not been installed, maintained or operated in accordance with COMPANY's instructions; (ii) has been used by CUSTOMER in a manner or for applications not recommended by COMPANY; (iii) has been repaired, altered or modified by CUSTOMER; (iv) has been subjected to other than normal use, storage, handling, installation, operation or maintenance; or (v) has been damaged by fire, act of God, any cause covered by CUSTOMER's insurance or any other event or occurrence not caused by COMPANY.

The foregoing warranties shall not apply to Equipment, or parts or components thereof, which are not manufactured or processed by COMPANY, or which are purchased by COMPANY from another party or partied. The manufacturer's warranty for such Equipment, parts or components, if any, shall be assigned to CUSTOMER without recourse to COMPANY.

The foregoing warranties shall not apply to designs, materials or specifications furnished or specified by CUSTOMER and incorporated into the Equipment.

THE EXPRESS WARRANTIES AND REMEDIES SET FORTH IN THIS SECTION ARE EXCLUSIVE AND ARE CONDITIONED UPON TIMELY NOTIFICATION BY CUSTOMER. THEY ARE GIVEN BY COMPANY AND ACCEPTED BY CUSTOMER IN LIEU OF ANY AND ALL OTHER REMEDIES, WARRANTIES, AND GUARANTEES, EXTOUCHED OR IMPLIED, AND IN LIEU OF ANY IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, ALL OF WHICH ARE HEREBY SPECIFICALLY EXCLUDED AND DISCLAIMED.

COMPANY neither assumes, nor authorizes any representative or other person to assume for it, any obligation or liability other than such as is expressly set forth in this section. Any change, modification, extension or addition to the foregoing warranties, remedies or limitations shall not be binding upon COMPANY unless in writing and duly executed by an authorized officer of COMPANY.

TRADEMARKS

Every attempt has been made to identify the owner of product trademarks and registered trademarks that appear in this manual. Changes of company ownership affecting the named trademark holder may not be identified.

ATX	Advanced Energy
Baratron	MKS Instruments, Inc.
Conflat	Varian Vacuum Products
Convectron	Granville Phillips
Cryo-Torr	CTI-CRYOGENICS – Helix Technology Corp.
XTC/XTM	Leybold Inficon
Delrin	E.I. DuPont de Nemours & Co., Inc.
EcoDry	Leybold Vacuum Products Inc.
Fomblin	Ausimont
Inconel	Inco Alloys International Inc.
KF	Leybold Vacuum Products Inc.
Lexan	General Electric Co.
Magidrive	UHV Designs Ltd.
MagiGear	UHV Designs Ltd.
MDX	Advanced Energy
Micromaze	Kurt J. Lesker Co.
OFHC	American Metals Climax Inc.
On-Board	CTI-CRYOGENICS – Helix Technology Corp.
PBR260	Pfeiffer
Pinnacle	Advanced Energy
Pyrex	Corning Glass Works
Radak	Luxel Corp.
RFX	Advanced Energy
SID-242	Sigma Instruments
SmartMotor	Animatics Corporation
Teflon	E.I. DuPont de Nemours & Co., Inc.
TMH261	Pfeiffer
TORUS®	Kurt J. Lesker Co.
VCO	Cajon Co.
VCR	Cajon Co.
Viton	E.I. DuPont de Nemours & Co., Inc.

SERVICE INFORMATION

Prior to contacting KJLC Systems Support for assistance, utilize the Troubleshooting procedures provided in the individual system component manuals and this Operator's Manual.

For Service and support within and after the warranty period, contact KJLC System Support:

North America
Phone: 800-245-1656, ext. 7311 or 7557
Fax: 412-384-2745
E-mail: systemscustomerservice@lesker.com

Europe
Phone: +44 1424-458100
Fax: +44 1424-458103
E-mail: systemcustomerserviceeu@lesker.com

Asia
Phone: 01186-21-50115900
Fax: 01186-21-50115863
Email: systemscustomerservicecn@lesker.com

For all other regions, contact North America customer service.

OVERVIEW

The PVD 75 System is a versatile, value-engineered vacuum system which can be configured to suit a variety of thin film deposition applications. Standard features include a front-loading box chamber, turbomolecular pump package and an integrated touch-screen control.

Source flange options include magnetron sputtering, electron beam evaporation, thermal evaporation and low temperature evaporation furnaces. To ensure product reliability, the system is built using proven process modules from other standard Kurt J. Lesker Company thin film deposition systems.

GENERAL SPECIFICATIONS

System Footprint (nominal)	47” (1194mm) wide x 35” (889mm) deep x 75” (1905mm) high
Cabinet Construction	Carbon Steel, Fully Enclosed, Gray Powder Coat Finish
Chamber - Volume (nominal) - Configuration - Construction	 75 liters 4” (356mm) wide x 14” (356mm) deep x 24” (610mm) high D-Shaped, 304L Stainless Steel with O-ring Sealed Hinged Aluminum Front Door
Substrate Fixturing - Platen Size - Rotation (optional) - Cooling (optional) - Heating (optional) - Heating Temperature Range (optional)	Base on selected options Up to 12” (305mm) diameter Variable up to 20 RPM Water or LN_2 (LN_2 static only) Quartz Lamp or Resistive Element 150° - 600°C
Deposition Capability (optional)	Sputtering Up/Down or Evaporation Up
Process Gas (optional)	2 Channels, Needle Valves or Mass Flow Control
System Control - Standard - Optional	 PC-Based HMI with CWare Software Recipe Control and Datalogging
Warranty	12 months after shipment
Certifications (optional)	CE marking, CSA, NRTL
Shipping Weight (estimated – exclusive of packing material)	1,800 lbs (816kg)

UTILITY REQUIREMENTS

1) System Power Configurations
    a) North America/Europe/Asia - 208-220VAC, 1 phase, 50/60Hz, 3 wire, 30 amps
    b) North America (Optional) - 208/220VAC, 3 phase, 60Hz, 5 wire, 60 amps
    c) Electron Beam Gun (2nd Power Drop, if applicable) - 208/220VAC, 1 phase, 60Hz, 4 wire, 40 amps
    d) Europe/Asia (Optional) - 380/400VAC, 3 phase, 50Hz, 5 wire, 30 amps
    e) Electron Beam Gun (2nd Power Drop, if app) - 380/400VAC, 3 phase, 50Hz, 5 wire, 30 amps
2) System Utilities
    a) Main System Water (typ) - 2.0-6.0 gpm (7.6-22.8 l/min), 7-9 pH, 50µm particle filtration, 1” FNPT
    b) Cryogenic Compressor Water - 0.5 gpm (1.9 l/min), 6-8 pH, 50µm particle filtration, ½” FNPT
    c) Compressed Air - 80 psi (552 kPa), ¼” tube connection
    d) Chamber Vent - 10 psi (69 kPa), ¼” tube connection
    e) Cryo Purge - 40 psi (276 kPa), ¼” tube connection
    f) Process Gas - 5-7 psi (35-48 kPa), ¼” VCR connection
3) Communications: Analog Modem Port and/or 10/100 Ethernet Port (optional)–RJ type connector

SAFETY SYMBOLS

The following safety symbols will be used throughout this manual:

⚠ DANGER This notation indicates an imminently or potentially hazardous situation that may cause serious injury or death if not avoided. This notation is only used for extreme situations.

⚠ CAUTION This notation indicates a potentially hazardous situation that may result in injury if not avoided. It is also used to alert against unsafe practices that may result in damage to the equipment.

☝ This notation is used to highlight any technical requirements, operations, procedures, or conditions that should be emphasized.

SAFETY

Safe use of the system requires familiarity with the individual system components and adherence to the safety precautions presented in this section. Each operator must have appropriate training and all supplemental component manuals should be reviewed prior to the use of the equipment.

OPERATOR RESPONSIBILITIES

Safe operation is the responsibility of the system user:

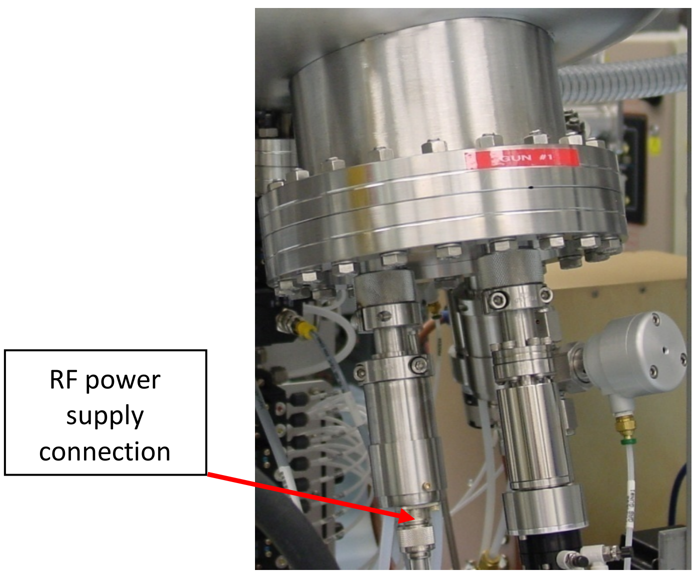
1) The operator must adhere to all safety notes, cautions, and dangers presented in this manual.
2) All system component manuals are included. The operator must adhere to all safety recommendations presented in each of these manuals.
3) Failure to comply with these and all precautions violates the safety standards of intended use of this system and may impair the protection provided by the system.
4) The Kurt J. Lesker Company assumes no liability for failure to comply with these requirements.
5) Please contact KJLC Systems Support prior to attempting any modifications. Only qualified personnel should perform component substitutions, modifications to, or service on the system.

☝ KJLC assumes no responsibility for equipment additions or modifications without KJLC's written consent. In-house performance of component repair or replacement during the warranty period without direction or approval from KJLC Systems Support can result in termination of the warranty.

SAFETY GUIDELINES

1) High voltage and electrical energy hazards exist for the power distribution cabinet and all power supplies.

DANGER High voltage and electrical energy hazards can cause serious injury or death through electrical shock. Avoid contact with power supplies and all power distribution hardware. All personnel involved with power supply service or maintenance must have appropriate electrical training. Service and maintenance personnel must read each component part manual before working on the equipment to determine the potential present on each circuit. Power must be disconnected and the equipment must be grounded before service or maintenance work is performed. Never work alone on live electrical circuits. You must be within sight or calling distance of another employee who has the proper qualifications.
Do not wear rings, wristwatches, or other jewelry on your person while working on live electrical circuits. Wear eye protection while working on live electrical circuitry where a flash might occur. DO NOT WEAR CONTACT LENSES.



2) High frequency hazards exist at the RF power supplies/connections.

DANGER High frequency fields may cause irregular performance of pacemakers, which can cause abnormal heartbeat or death. Persons with pacemakers should avoid exposure to all processes involving the high frequency hazards.

3) The permanent magnets create *magnetic field hazards*.

⚠ DANGER Magnetic fields may cause irregular performance of pacemakers, which can cause abnormal heartbeat or death. Persons with pacemakers should avoid exposure to all processes involving the magnetic field hazards.

⚠ CAUTION Strong magnetic fields can destroy watches or magnetic cards. Keep watches, magnetic cards, and other metal objects away from magnetic field hazards. Do not use magnetic tools when performing service or maintenance work on the system.

4) Chemical hazards exist when potentially harmful chemicals are introduced or emitted from the system.

⚠ DANGER Exhaust gas may be poisonous and may require special measures of elimination. Ensure adequate ventilation and appropriate exhaust regulation when working with potentially poisonous exhaust gases. Deposition sources may emit poisonous gases if not maintained properly. Read all safety data sheets and follow the documented maintenance procedures.

☝ Some cleaning fluids may leave a flammable or toxic residue. Observe all instructions provided with cleaning fluids.

5) Mechanical hazards exist because moving parts can cause personal injury or instrument damage.

⚠ DANGER Before actuating the hoists or slit valves, all personnel must be clear of moving parts. Use extreme caution when working around moving parts.

6) Compressed gas used for processes can create high-pressure hazards throughout the gas plumbing lines and process chamber.

⚠ DANGER High pressure can cause personal injury and property damage. The compressor unit and associated hoses contain compressed helium and must not be mechanically or thermally stressed. Before accessing a cryogenic pump, read the operator's manual and follow all safety guidelines. Process gas tanks must be kept according to manufacturers' specifications and local codes.

7) Heating elements (quartz lamps, composite, etc.) used for sample heating can create *high temperature hazards* on chamber walls, viewport surfaces and chamber internals.

⚠ DANGER High temperatures can cause harm to personnel and equipment. Do not vent chamber until temperature is low enough to facilitate safe handling of parts. High temperatures can also cause damage to materials if the system is vented prematurely.

SITE PREPARATION

The purpose of this section is to provide new tool owners with the information necessary to prepare their facility for their new tool and to ensure the tool start up can go as efficiently as possible. Typical required utilities will include electrical power, compressed air, Nitrogen, cooling water and applicable process gases to be used in the system. In addition, hazardous gas exhaust or other customer specific safety regulations may be required, which may not be covered in this manual.

☝ It is the customer's responsibility to install this equipment in accordance with current local electrical and mechanical codes, in addition to any national regulations.

KJLC engineers are responsible for the start-up of the tool only. Equipment unpacking, locating and site preparation is the customer's responsibility. The customer is also required to prepare all required utilities and make those connections to the equipment. Failure to have this work completed will delay the scheduling of start-up and training (if purchased) by KJLC. Verification from the customer that all utilities are completed is required before KJLC will schedule the tool start-up or service.

If system start-up is purchased, connect all utilities but DO NOT turn power on. Water and gas may be turned on <u>to</u> the system to check for leaks but do not turn ON any gas or water valves <u>on</u> the system. If you did not purchase a start-up, after all utilities are installed and verified you may initiate startup of the system as required. A KJLC Service Representative can assist you in assuring the tool is ready for start-up.

☝ KJLC requires a minimum of 2 weeks' notice for scheduling a start-up. Additionally, if a start-up was purchased as part of the contract, then any items removed for shipment will be re-installed by the KJLC engineer during that time. However, if the customer has the ability to re-install some items, this should be coordinated with KJLC and can make the start-up and training period more productive.

During the start-up period, the KJLC engineer may need full access to the tool outside of normal working hours, including evenings and weekends. Unattended overnight operation of the tool will also be required. All relevant permissions and security clearances must be in place to facilitate these requirements. During this period, the intended system operator(s) should be present at all times for training and to assist the KJLC engineer whenever necessary.

Upon completion of the start-up and training, a final acceptance document should be signed by the KJLC engineer and authorized customer representative.

The following are general facility requirements, utility requirements, connection details and typical parts required for site preparation. If you have any questions regarding these requirements, please contact the applicable Process Equipment Division (PED) Customer Service Department.

North America
Phone: 800-245-1656, ext. 7311 or 7557
Fax: 412-384-2745
E-mail: systemscustomerservice@lesker.com

Europe
Phone: +44 1424-458100
Fax: +44 1424-458103
E-mail: systemcustomerserviceeu@lesker.com

Asia
Phone: 01186-21-50115900
Fax: 01186-21-50115863
Email: systemscustomerservicecn@lesker.com

For all other regions, contact North America customer service.

RECEIPT INSPECTION

Depending on the tool platform and configuration, the tool may be crated, mounted to a wooden base or protection wrapped only. In addition, peripheral components, shielding or any additional parts may be packaged separately. Smaller packages could be located inside frames or enclosures for safe shipping.

If the tool is not to be unpackaged immediately upon receipt, it must be stored in an enclosed, dry area meeting environmental requirements as listed in the following sections.

Most of the instrument racks and enclosures have locks. The keys for these locks are typically attached to the tool computer (located in the control instrument mounting portion of the tool) in a small plastic package.

Visually inspect all crates and boxes for signs of shipping damage or mishandling. Any significant damage must be photographed and KJLC notified immediately.

DO NOT discard any packing materials until receipt inspection bas been completed. If any damage is found during uncrating, these materials may be needed to file shipping claims.

Inspect all tip and impact indicators attached to the system crate.

1) Prior to shipment, tip indicators are placed on the walls of each crate.
2) Prior to shipment, impact indicators are placed on or near each major component, (i.e. instrument rack, deposition chamber, etc.)
3) If any indicator has been set off, KJLC should be notified immediately.

Assure that the content of each crate and package match the supplied Packing List. (Refer to Packing List included with shipment). If any discrepancies occur between the received parts and the Packing List, KJLC should be notified immediately. KJLC will not take responsibility for any missing items after 3 days of shipment arrival.

⚠ CAUTION When possible, chambers are shipped under vacuum to preserve their integrity and cleanliness. Care should be taken to ensure viewports or F/T's are not damaged, which could produce an unsafe condition.

UNCRATING

⚠ CAUTION The system crating contains screws and nails for construction. Caution should be exercised during uncrating to assure no injuries occur from sharp edges or splitting wood.

1) Carefully remove the crate lid and inspect the condition of internal tip and impact indicators.
2) If applicable, unscrew the internal braces from inside the crate that surround the instrument rack and system for support (see Figure 1.)
3) Carefully remove sidewalls of crate.
4) If applicable, unscrew the lower braces from the instrument rack.

⚠ CAUTION Due to the weight of the system and mode of travel, crate contents may shift. Extreme caution should be exercised when removing all internal and external supports.

5) Remove the nuts from the pieces of stainless steel all-thread that hold the system to the crate (See Figure 2). Do NOT discard the pieces of all-thread. They may be part of the leveling foot assemblies for the system framework.

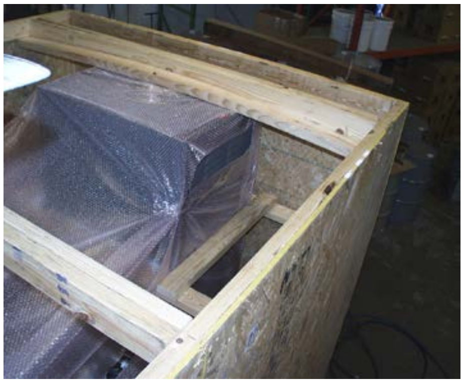


FIGURE 1

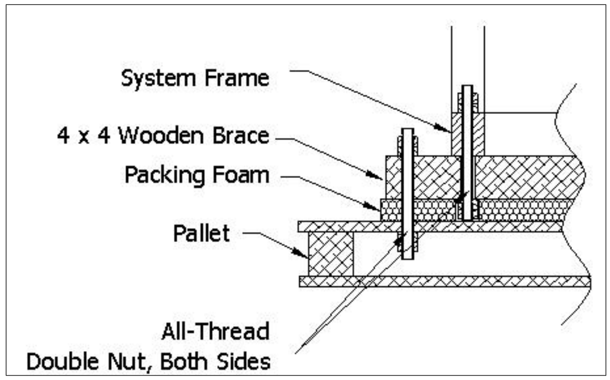


FIGURE 2

6) Use a fork-truck to separately lift the instrument rack and system off of the shipping base if applicable. Approach both pieces from the SIDE and lift from the lower frame members, unless otherwise instructed.

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⚠ CAUTION Only a properly trained and licensed fork lift operator should remove the instrument rack and deposition system from the shipping base. Improper removal of the components can result in equipment damage. Be cautious of electrical cable, gas lines, etc. when placing forks under the system framework and the instrument rack. Also be aware of the length of the cables between the instrument rack and the system (if applicable).

7) Lift the system up far enough to allow the shipping base to be pulled out from underneath the system.

⚠ DANGER DO NOT put any part of your body under the lifted system or serious injuries could occur.

8) Before placing the system on the ground, insert the all-thread (removed in Step 5) into the mounting pads on the underside of the system frame. Once the all-thread is fully inserted, install the leveling feet onto the all-thread.
9) Gently place the system on the ground. Any damage to the system or its components incurred during un-crating should be reported to KJLC immediately.

☝ Shipping bolts may be installed on the chamber door or chamber top plate. These bolts must be removed prior to opening the door.

INSTALLATION CONSIDERATIONS

When moving the tool to its new location, it is important to consider passageways, doorways and floor loadings to allow easy and safe handling of the equipment.

The height and width of the system varies, depending on the platform and configuration purchased. Therefore, the tool General Assembly schematic should be referenced for approximate dimensions. It is highly recommended that the path intended to be used when moving the equipment from the uncrating area to the final location is checked for height and width limitations; specifically dimensions of, doors, elevators and corners.

☝ The General Assembly schematics only show major components and may not indicate items such as cables, plumbing, connectors or brackets that may extend outside of the referenced dimensions. Therefore, contact KJLC if the tool location has severe space constraints to ensure there will not be any interference.

The weight of the system varies, depending on the platform and configuration purchased. Standard platforms typically range between 1500 to 4500 lbs (680 to 2100 Kg). Custom and cluster tools may weigh more. If there are weight limitations within the travel path or final location of the tool, KJLC should be contacted for more detailed weight information.

ENVIRONMENTAL CONDITIONS

☝ Facility and local safety codes may also have more stringent requirements that must be met for equipment placement. It is the responsibility of the customer to ensure these requirements are met.

The location of the tool should be given careful consideration. The tool is designed for indoor use only and is not protected against harmful ingress of moisture. It is designed to operate in a laboratory environment that contains minimal shock and vibration. The following are recommended conditions and are applicable to all KJLC platforms.

There should be adequate space around the tool to easily gain access to all required components for routine services and preventative maintenance. It is recommended that the minimum distances listed below be maintained.

AREA	DISTANCE
FRONT	36 INCHES (0.9 M)
SIDES	24 INCHES (0.6 M)
REAR	24 INCHES (0.6 M)

Custom systems may require increased distances and should be considered when installing the tool. The General Assembly schematic should be referenced.

There should also be adequate air flow around the equipment. It is recommended that the ambient temperature be maintained as below.

RANGE	TEMPERATURE
MINIMUM	60°F (16°C)
MAXIMUM	85°F (30°C)

Relative humidity should be less than 65% non-condensing. The combination of the ambient temperature, relative humidity and inlet water temperature must not result in any condensation on any of the water cooled components.

Additionally, large temperature changes can affect the pressure readings when operating at UHV pressures. This is due to o-ring permeation and material temperatures (out gassing).

CAUTION If condensation does occur, serious damage to the equipment may occur. In addition, a safety hazard could be created.

KJLC equipment racks may include cooling fans and ventilation holes at the top and/or rear. Please allow adequate spacing for air flow. Also refer to all system component Operation Manuals for additional ventilation requirements as detailed by the manufacturer.

Care must also be taken to ensure the tool is not placed in a location that can be exposed to corrosive, harmful materials or excessive vibration sources such as nearby cranes, elevators, folding doors and heavy machinery.

☝ If the mechanical pump is not integrated into the system framework, keep the distance between the pump and system to a minimum. A longer roughing line will reduce the effective pumping speed and increase pump down time.

GROUNDING SYSTEM

A correct grounding system is necessary to ensure safe and proper operation of the deposition system. KJLC systems have been tested and are built to EMC (Electro Magnetic Compatibility) standards using the highest level of grounding determined for a system. An electrical and earth ground are required.

ELECTRICAL GROUND

A standard electrical ground that runs with the power cable to the main power disconnect power plug. This ground can be incorporated into the same SO cable supplying power to the system and must meet minimum requirement specifications as outlined by applicable state and local electrical codes.

EARTH GROUND

BEST (RECOMMENDED)

The grounding system is comprised of dedicated grounding electrode(s) providing 3 ohms resistance or less (see earth ground installation below) and connection from it to the deposition system using copper strap (see below for description) or copper tube with equivalent surface area. This level is a requirement for RF or E-beam systems.

GOOD

The grounding system is comprised of dedicated grounding electrode(s) providing 25 ohms resistance or less (see earth ground installation below) and connection from it to the deposition system using copper strap (see below for description) or copper tube with equivalent surface area. A solid conductor wire can also be used as listed in the table below.

ALTERNATIVE

For equipment installed in multistory buildings, other types of grounding electrodes permitted by applicable regulatory codes can be used (i.e., building structural steel or designated electrical ground points) provided the resistance specification is still met.

⚠ DANGER Braided wire has high impedance to radio frequency. Do not use braided wire for grounding connection. Use the copper conductors indicated below:

DISTANCE	CONDUCTOR
0 - 20 feet (0 - 6 meters)	#4 AWG (5.19 mm) wire
20 - 60 feet (6 - 28 meters)	Copper strap (as described below)
over 60 feet (over 28 meters)	Consult KJLC personnel

Recommended copper strap for Earth Ground:

KJLC PART NUMBER	DESCRIPTION
RSHUC01324	0.032 X 2.5 INCH (1 MM X 6.5 CM) COPPER STRAP, 8 FT (2.5 METERS)

EARTH GROUND INSTALLATION

If possible, dedicated grounding electrode(s) should be installed. The electrodes should be ¾ inch (2 cm) diameter copper rod or pipe, driven 8 ft (2.5 meters) into the ground, no less than 6 ft (2 meters) apart, located as close to system as possible. Bonding jumpers between the electrodes should be copper strap (as listed above). Measure the resistance between the two ground rods using an accurate resistance bridge. Add salt water or copper sulfate to the earth to lower the resistance to one ohm. See Figure 3 for illustration of grounding electrodes. Grounding connection to the deposition system should follow KJLC wiring diagrams and should only be made at the intended point provided at the vacuum chamber or frame (using stainless hardware to make connection). Refer to the system General Assembly drawing for location.

⚠ CAUTION Do not use water pipes for the grounding electrode.

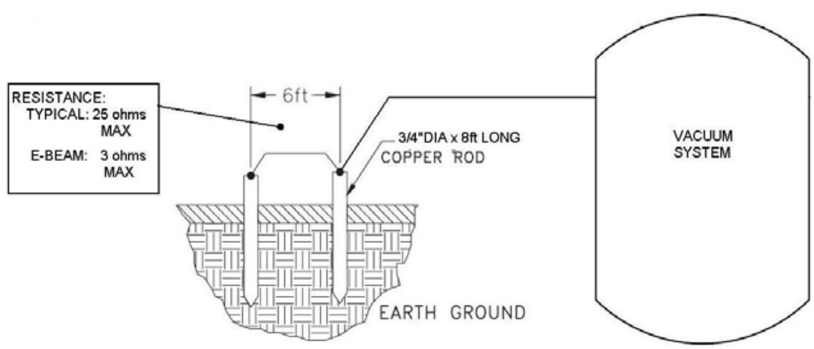


FIGURE 3
EARTH GROUND REQUIREMENTS

⚠ CAUTION Failure to connect the system to a sufficient earth ground could cause severe damage to system components and/or auxiliary electronic control equipment and will void the warranty.

GROUNDING MAINTENANCE

Resistivity should be verified using a calibrated ground resistance tester following accepted measuring methods. The grounding electrode should be checked at least once per year to assure correct resistance and that all points of connection are tight.

UTILITY CONNECTIONS

Refer to the General Assembly Schematic and Utility Requirements Document for your specific tool requirements.

ELECTRICAL

CAUTION Ensure facility power feed is off and locked out prior to installation.

Follow the applicable codes for proper wire size, power feed and grounding requirements.

The electrical requirements for your tool were calculated using the requirements of the installed components. Reference the applicable power distribution schematics for details.

Install a power cord (SO type) or use a hardwire setup (conduit with individual wires) from an appropriately sized and protected distribution panel to the power distribution unit. If separate drops are required, the General Assembly drawing should be referenced.

Verify that all instrumentation and all devices requiring line power are labeled/configured appropriately for the system line voltage (120 or 208, etc.).

It is recommended that a wall mounted power disconnect switch be mounted near the system and used as the main connection point for the incoming system power.

Depending on the configuration of your system, components such as pumps, compressor and instrument racks may be located separately from the main system. This may require interconnect cables to be run between the main system and remote item. Depending on your local, regional or national safety regulations, you may be required to provide additional protection for those interconnects, such as conduit or cable trays.

Check with your facilities manager for code specific regulations on power installation, service disconnects and interconnecting installations.

STANDARD ELECTRICAL CONNECTORS

Each KJLC Vacuum System comes with a power connection receptacle built into the system electrical rack. The mating power plug connector is shipped with the system. Below are the standard configurations for mating power plug. Power designations for each plug are listed above in the Electrical Power Connections Chart. Check with your facilities manager for code specific regulations on power installation and service disconnects and power connection wiring.

Standard System Power Configurations:

- Worldwide - 200-240 VAC, 1 phase, 50/60Hz, 30 amps
- North America – 208 VAC (+/- 10% line to line and line to neutral), 3 phase, 60Hz, 60 amps
- Europe/Asia - 380-415 VAC, 3 phase, 50Hz, 30 amps

Voltage variations outside this range may cause system alarms or erratic operation.

SYSTEM POWER CONNECTIONS

DEVICE	FREQ. (Hz)	PHASE	VOLTAGE (AC)	CURRENT (A)	SYSTEM INSERT / HOUSING (HARTING)	SUPPLIED MATING COMPONENTS (HARTING)	CUSTOMER SUPPLIED (FLYING LEADS)
Power Distribution	60	1	200-240	30	09310062601 / 09300160301	09310062701 / 09300160521 / 09000005095	3-wire
Power Distribution	50	3	380-415	30			5-wire
Power Distribution	50/60	3	208 +/- 10%	60	09380062611 / 09300160301	09380062711 / 09300160521 / 09000005097	5-wire

OPTIONAL EQUIPMENT POWER CONNECTIONS

Depending on the optional equipment purchased, some components may require a separate power drop. These items could include cryo-pump compressors, water chillers and deposition power supplies. In these cases, the system power distribution schematic and specific component manual should be referenced for requirement details.

COMMUNICATION

Analog Modem Port and/or 10/100 Ethernet Port for computer controlled systems (RJ type connector) is available. This connection is required for tool remote support and service.

COOLING WATER

Cooling water is required that is capable of providing adequate cooling to system components as identified in the utility requirements document and tool schematics.

Supplied water should have the following characteristics.

- Minimum temperature of 5° above dew point, 77°F (25°C) max
- $\leq$ 50 µm particle filtration
- pH level between 6 – 8

Typical Requirements:

DEVICE	RANGE	MAXIMUM INLET PRESSURE	MAXIMUM PRESSURE DIFFERENTIAL	MINIMUM HOSE DIAMETER
SYSTEM	2-6 GPM 7.6 - 22.8 L/MIN	70 PSI	65 PSI	0.750 INCHES
CRYO COMPRESSOR	0.5 GPM 1.9 L/MIN	70 PSI	65 PSI	0.375 INCHES

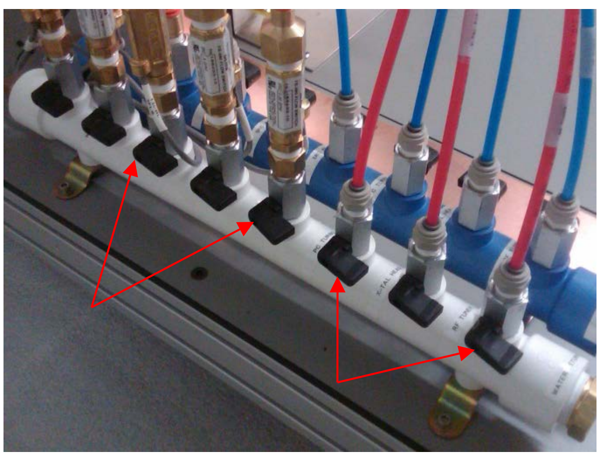
NOTE: GPM = Gallons per minute, L/min = Liters per minute, PSI = Pounds per square inch.

PRESSURE DIFFERENTIAL - This is the pressure difference between the inlet water supply and the outlet water supply. If the pressure differential between the inlet and outlet is not high enough, reduced flow through the system will result. If a reduced flow is encountered, system operation may be affected due to inadequate cooling of components or loss of flow to system interlocks.

☝ It is recommended that a main inlet and outlet water shut off valve be installed on systems that are connected to a house chiller system. If a cryo compressor is connected to the same small chiller as the KJLC system, it is required that a shut off valves are installed on the compressor inlet and outlet lines. If the system is being cooled by a larger house water system, these valves are not required.

Before installation, purge all newly constructed utility lines to remove all loose materials, such as thread compound, PTFE and tapes. Also be sure to remove any remaining burrs from the tube edges before connecting to the system.

1) Connect the supply cooling water to the BLUE water supply manifold (see photos below).



SHUT-OFF VALVES

WATER MANIFOLD CONNECTIONS

SYSTEM COOLING WATER SUPPLY/RETURN

2) Connect the water return line to the WHITE return manifold.
3) Run cooling water to the cryo compressor (if applicable).

⚠ CAUTION The system vacuum integrity should be verified prior to the flowing of cooling water. Introducing water prior to verifying vacuum integrity may cause system flooding or difficulty locating vacuum leaks in water lines. However, all customer supplied water connections (up to the system water manifolds) should be verified prior to the flowing of any water.

Typical cooling water connections:

DESCRIPTION	KJLC SYSTEM CONNECTION	CUSTOMER SUPPLIED
SYSTEM COMPONENTS	1-INCH FNPT	1-INCH MNPT
CRYO COMPRESSOR	0.5 INCH FNPT	0.5 INCH MNPT

NOTE: Connections are for Supply and Return lines.

System cooling supplies:

KJLC PART NUMBER	DESCRIPTION
PET025B+	TUBING, POLYETHYLENE, 1/4" OD, BLUE
PET025R+	TUBING, POLYETHYLENE, 1/4" OD, RED
PVCBT025	TUBING, PVC, NYLON REINFORCED, 1/4" ID, 3/32" WALL
B-10MO-1-6	FITTING, SWAGELOK CONNECTOR, BRASS, 10MM TUBE OD X 3/8” MNPT
B-15M0-1-8	FITTING, MALE CONNECTOR, BRASS, 15MMT X 1/2" MNPT
4429K424	FITTING, HEX BUSHING, BRASS, 1" MNPT TO 1/2" FNPT

Systems can be fitted with individual cooling systems. KJLC does offer water chillers as part of the system. Standard KJLC offered units are as follows. Other units are available - Consult KJLC Sales for proper size and cost.

KJLC PART NUMBER	DESCRIPTION
TT100/10T31H	CHILLER, CLOSED LOOP, 10,000 BTU, 6 GPM AT 60 PSI, AIR COOLED
TT100/15/T41	CHILLER, CLOSED LOOP, 15,000 BTU, 8 GPM AT 60 PSI, AIR COOLED
TT150/15/T41	CHILLER, CLOSED LOOP, 15,000 BTU, 8 GPM AT 60 PSI, WATER COOLED
TT10015C200S	CHILLER, CLOSED LOOP, 15,000 BTU, 15 GPM AT 60 PSI, AIR COOLED

NOTE: GPM = Gallons per minute, PSI = Pounds per square inch.

If purchased as part of the system contract, KJLC supplied chillers require the use of a glycol / water solution. The general recommendation is a 2:1 mix of water to glycol solution. Use only distilled or purified water in chillers to prevent damage to internal chiller and system components. Check with individual chiller manufacturers or the applicable service guides for further information.

KJLC CHILLER COMPONENTS

KJLC PART NUMBER	DESCRIPTION
5304K715	HOSE, RUBBER, BLACK, 3/4" NPT, 10 FT
5304K273	HOSE, RUBBER, BLACK, 3/4" NPT, 15 FT
5304K67	HOSE, RUBBER, BLACK, 3/4" NPT, 25 FT
5304K57	HOSE, RUBBER, BLACK, 1"ID, 200 PSI, 25 FT
5304K721	HOSE, RUBBER, BLACK, 1-1/2" M-F NPT, 10 FT
KJLEGG1	ETHYLENE GLYCOL HEAT TRANSFER FLUID, 1 GALLON
KJLEGG5	ETHYLENE GLYCOL HEAT TRANSFER FLUID, 5 GALLON

COMPRESSED AIR (PNEUMATICS)

Most tools and all computer controlled tools require a clean, dry compressed air supply for actuation of valves, shutters and other motion related components.

PNEUMATIC CONTROLS

Make the required connection to the bulkhead fitting or the backside of the pressure regulator located in the rear of the system. The General Assembly Schematic and utility document should be referenced.

Before installation, purge all newly constructed utility lines to remove all loose materials, such as thread compound, PTFE and tapes. Also be sure to remove any remaining burrs from the tube edges before connecting to the system.

BULKHEAD CONNECTION

PRESSURE REGULATOR

The compressed Air supplied to the system is to be Clean Dry Air (CDA). The air is to be free of dirt, moisture, and compressor lubricating oils. It is recommended that an air oil separator, as well as a desiccant filter, be installed prior to the air entering the system to help assure reliable and long lasting operation of the system pneumatic valves.

Polyethylene or Teflon tubing can be used for to supply compressed air with the following characteristics.

- 80 – 90 psi (552 – 621 kPa)
- $\leq$ 5 µm particle filtration
- Dry, non-lubricated

KJLC does not recommend the use of Nitrogen in place of compressed air. Effects of dry Nitrogen observed over time included gradual changes in some lubricants and the seals commonly used in pneumatic products. Seals have been observed to dry out and some lubricant will thicken as the dry N2 accelerates evaporation. This process may take some time, but can shorten the life of the product. The effect is more pronounced in dynamic seals then in static seals, so is more of an issue in pneumatic valve and cylinders then in fittings and flow controls.

Typical compressed air connections:

DESCRIPTION	KJLC SYSTEM CONNECTION	CUSTOMER SUPPLIED
CDA	1/4” SWAGELOK TUBING	1/4” O.D. TUBE

Compressed air supplies:

KJLC PART NUMBER	DESCRIPTION
PET025	TUBING, POLYETHYLENE, 1/4" OD, NATURAL COLOR
TT025	TUBING, TEFLON, 5/32"ID, 1/4" OD
SST-0025I	TUBING, 304L SST, RIGID, 1/4" OD, .028" WALL
SS-6MO-R-4	REDUCER, SS, 6MM TUBE X 1/4" TUBE STUB
SS-401-PC	FITTING, SWAGELOK, SS, 1/4" TUBE PORT CONNECTOR

NITROGEN GAS

All tools require a clean Nitrogen supply for chamber venting and cryo pump regeneration, if applicable.

Make the required connection to the bulkhead fitting or the backside of the pressure regulator located in the rear of the system. The General Assembly Schematic and utility document should be referenced.

Before installation, purge all newly constructed utility lines to remove all loose materials, such as thread compound, PTFE and tapes. Also be sure to remove any remaining burrs from the tube edges before connecting to the system.

BULKHEAD CONNECTION

VENT REGULATOR

REGEN REGULATOR

Teflon or stainless steel tubing can be used to supply Nitrogen with the following characteristics.

- Vent - 10 psi (69 kPa)
- Cryo Pump Regeneration - 40 psi (69 kPa)
- q< 5 µm particle filtration

Typical nitrogen connections:

DESCRIPTION	KJLC SYSTEM CONNECTION	CUSTOMER SUPPLIED
NITROGEN	1/4” SWAGELOK Tube Fitting	1/4” O.D. TUBE

Nitrogen gas supplies:

KJLC PART NUMBER	DESCRIPTION
TT025	TUBING, TEFLON, 5/32" ID, 1/4" OD
SST-0025I	TUBING, 304L SST, RIGID, 1/4" OD, .028" WALL
SST-0025CI	TUBING, 316L SST, RIGID, 1/4" OD, .035" WALL, ELECTROPOLISHED

Copper tubing is not recommended for use due to potential internal oxidation and residue that may contaminate the chamber and disrupt sensitive processes.

PROCESS GAS

Most tools require a clean process gas supply for depending on the processed be performed.

Connect the required process gas to the bulkhead fitting or Mass Flow Controller (MFC) located in the rear of the system. The General Assembly and Process Gas Schematics should be referenced.

Before installation, purge all newly constructed gas lines to remove all loose materials. Also be sure to remove any remaining burrs from the tube edges before connecting to the system.

BULKHEAD CONNECTION

MFC CONNECTION

Stainless steel, electro-polished tubing should be used to supply process gases with the following characteristics.

- 5-7 psi (35-48 kPa)
- 99.999% purity
- $\leq$ 5 µm particle filtration

☝ Sharp bends should be avoided when using electro-polished tubing. Sharp bends can introduce micro-cracks on the inside diameter of the tubing and be a potential source of contamination.

Typical process gas connections:

DESCRIPTION	KJLC SYSTEM CONNECTION	CUSTOMER SUPPLIED
MFC - VCR	1/4” MALE VCR	1/4” FEMALE VCR
MFC - SWAGELOK	SS-4WVCR6400 ADAPTER	1/4” O.D. TUBE
NEEDLE VALVE - SWAGELOK	1/4” SWAGELOK TUBE FITTING	1/4” O.D. TUBE

NOTE: Tube fitting connections should be avoided when connecting process gases whenever possible.

Process gas supplies:

KJLC PART NUMBER	DESCRIPTION
SST-0025CI	TUBING, 316L SST, RIGID, 1/4" OD, .035" WALL, ELECTROPOLISHED
SS-4WVCR6400	ADAPTER, SS, 1/4" FVCR TO 1/4"OD TUBE, SWAGELOK
4FVCR-N	NUT, FEMALE, VCR, CAJON, SS, 1/4"
4FVCR-GL	GLAND, VCR, CAJON, STAINLESS STEEL, 1/4 " TUBE SOCKET
4XVCR-GAC	GASKET, VCR, CAJON, COPPER, 1/4"

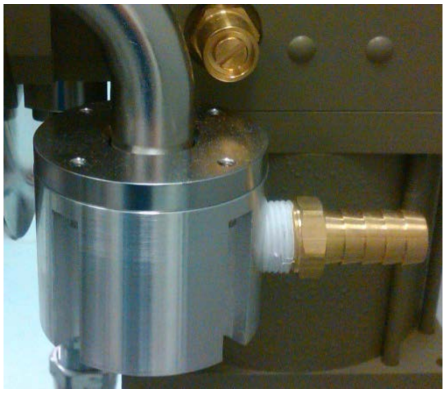
Copper tubing is not recommended for use due to potential internal oxidation and residue that may contaminate the chamber and disrupt sensitive processes.

It is recommended that each individual gas connection to the system have its own shut off valve in a location close to the inlet connection. Systems using individual bottled gasses within short distances of the system do not need shut off valves since valves are typically located on the gas bottles.

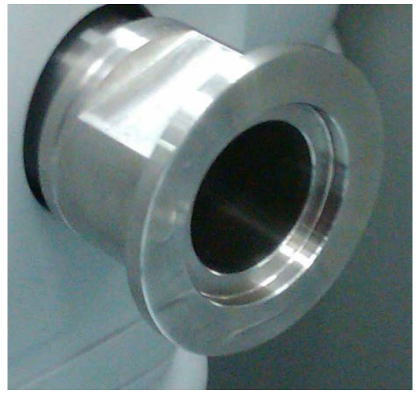
EXHAUST CONNECTIONS

Depending on the types of processes being performed and / or applicable safety regulations, some systems may need to have their exhaust port connected to an exhaust system. This prevents hazardous gases or particles from getting into the lab space. The two main connections are cryo pumps and mechanical pumps.

During the regeneration of a cryo pump, the trapped gases are expelled through the rear vent valve. KJLC installs an exhaust adapter to these valves for ease of connection. Mechanical pumps will exhaust all gases present in the chamber being evacuated.



PUMP EXHAUST



MECHANICAL PUMP EXHAUST

Typical exhaust connections:

DESCRIPTION	KJLC SYSTEM CONNECTION	CUSTOMER SUPPLIED
CRYO PUMP	QF16 OR 3/8" HOSE FITTING	QF16 OR 3/8" HOSE CONNECTION
MECH PUMP	QF16, QF25 OR QF40 (PUMP DEPENDENT)	QF16, QF25 OR QF40 (PUMP DEPENDENT)
SYSTEM	QF16 OR QF25 (PUMP DEPENDENT)	QF16 OR QF25 (PUMP DEPENDENT)

Exhaust / vent supplies:

KJLC PART NUMBER	DESCRIPTION
8080250K008	CRYO PUMP RELIEF VALVE ADAPTER KIT
8080250K031	RELIEF VALVE FILTER FOR CTI-8F
QF16-075-ARB	CENTERING RING, ALUM, QF16, BUNA O-RING
QF16-075-C	CLAMP, ALUMINUM, QF16, CAST 1/2" & 3/4"
PT075QF16-5	CLEAR REINFORCED HOSE ASSEMBLY, 3/4" ID, QF16, 5FT
PT075QF16-10	CLEAR REINFORCED HOSE ASSEMBLY, 3/4" ID, QF16, 10FT
PT075QF16-25	CLEAR REINFORCED HOSE ASSEMBLY, 3/4" ID, QF16, 25FT
QF25-100-ARB	CENTERING RING, ALUM, QF25, BUNA
QF25-100-C	CLAMP, ALUMINUM, QF25, CAST 1"
PT100QF25-5	CLEAR REINFORCED HOSE ASSEMBLY, 1" ID, QF25, 5FT
PT100QF25-10	CLEAR REINFORCED HOSE ASSEMBLY, 1" ID, QF25, 10FT
PT100QF25-25	CLEAR REINFORCED HOSE ASSEMBLY, 1" ID, QF25, 25FT
QF40-150-ARB	CENTERING RING, ALUM, QF40, BUNA
QF40-150-C	CLAMP, ALUMINUM, QF40, CAST 1-1/2"
PT150QF40-5	CLEAR REINFORCED HOSE ASSEMBLY, 1-1/2" ID, QF40, 5FT
PT150QF40-10	CLEAR REINFORCED HOSE ASSEMBLY, 1-1/2" ID, QF40, 10FT
PT150QF40-25	CLEAR REINFORCED HOSE ASSEMBLY, 1-1/2" ID, QF40, 25FT

ADDITIONAL UTILITY CONNECTIONS

The previous information listed the basic components and parts that may be needed in the installation of your new KJLC system. Various configurations may require specific connection components to complete the installation process. Please reference the system schematics and utility documentation to determine exact system requirements.

START-UP

Prior to the start-up and operation of any system equipment, the intended operator should review the individual equipment manuals and this Operation Manual.

1) Ensure that all utilities are properly installed per the previous section.
2) With all of the power distribution unit's secondary circuit breakers off, turn on the main circuit breaker. Systems with 3-phase power should determine that all phase lights on the power distribution unit are illuminated.
3) Verify that the start/stop circuit is on and that all EMO buttons are not triggered (reset by pulling out and rotating). Leave the system in a stopped state when this test is complete
4) Turn off the power switches on all instrumentation and plug strips. Start the system power and turn on the breaker(s) for the instrumentation outlet strip(s) ONLY.
5) Power up and verify (per the Power Distribution Schematic) that all devices are plugged into appropriate outlets on the power distribution unit or plug strip(s) in order to satisfy circuit breaker assignments.
6) Verify that plumbing into and out of pump is correct and that the pump has been filled with oil, if applicable.
7) Verify that the chamber motors and shutters are not obstructed and move freely.
8) Verify that all required communication and power connections to the system computer are connected and working properly.
9) Start-up the system control software (refer to the Software Operation section).
10) Verify all set points (heaters, power supplies, etc.) before starting the pump down sequence.

OPERATION OVERVIEW

Once the system has been successfully installed, the required utility connections have been made, and the start-up procedure completed, the system is ready for operation. Prior to operating the system, read through and become familiar with all instructions and with the schematics provided in the appendices.

There are three modes of system operation:

- Manual – no computer interface or automated processes are provided
- Computer Control – a computer interface is used to operate the system manually
- Recipe Driven Computer Control – a complete computer control software package allowing for process control and creating and running recipes. This is the highest level of automation available.

MANUAL OPERATION

The procedures described on the following pages are for manual operation of the system and its components.

☝ There may be sections of this manual that describe optional features that are not included in your system configuration. Please disregard these sections.

PUMPDOWN PROCEDURES

This section describes pumpdown procedures for various system configurations.

CRYOPUMP WITH LOAD LOCK CHAMBER

1) Verify all connections to the system are made. Power, water, process gas, vent gas, and vacuum connections to mechanical pump should be checked.
2) Verify that the cryo pump is cold and ready for use (<20K). If not, refer to Cryo Regeneration procedure. (Refer to the On-Board manual for On-Board cryo pump regeneration procedure.)
3) Verify that both the process chamber and the load lock chamber are at atmosphere. If not, refer to the Chamber Vent procedure.
4) Open the load lock isolation valve.
5) If operating the system for the first time, open the capacitance manometer isolation valve (if installed) and any gas isolation valves.
6) Start the system roughing pump and verify that the foreline pressure is less than 1 Torr.
7) Open the roughing valve.
8) Open load lock gate valve, if applicable. (System roughs through the load lock turbo pump.)
9) Rough the system to approximately 500 Torr as read by the process chamber convection gauge. (Refer to gauge controller manual for convection gauge operating instructions.)
10) Turn on the load lock turbo pump.
11) When the convection gauge in the process chamber is below 200 mTorr, close the load lock isolation valve (wait for it to close completely) and open the hivac gate valve to the cryo pump.
12) Wait for 10 seconds and when the pressure on the convection gauge is <1.0e-3 Torr, turn on the ion gauge. (Refer to gauge controller manual for operating instructions.)

At this point the vacuum system is under vacuum and ready for use. Refer to individual component manuals for operation of gas flow equipment and gauging equipment.

CRYOPUMP WITHOUT LOAD LOCK CHAMBER

1) Verify all connections to system are made. Power, water, process gas, vent gas, and vacuum connections to mechanical pump should be checked.
2) Verify that the cryo pump is cold and ready for use (<20K). If not, refer to the Cryo pump Regeneration procedure. (Refer to the On-Board manual for On-Board cryo pump regeneration procedure.)
3) If operating the system for the first time, open the capacitance manometer isolation valve (if installed) and any gas isolation valves.
4) Start the system roughing pump and verify that the foreline pressure is less than 1 Torr.
5) Open the roughing valve.
6) Rough the system to approximately 200 mTorr as read by the process chamber convection gauge. (Refer to gauge controller manual for convection gauge operating instructions.)
7) Close roughing valve.
8) Open the hivac gate valve to the cryo pump.
9) When the process chamber convection gauge is below 1.0e-3 mTorr turn on the ion gauge. (Refer to gauge controller manual for operating instructions.)
10) Turn off roughing pump.

At this point the vacuum system is under vacuum and ready for use. Refer to individual component manuals for operation of gas flow equipment and gauging equipment.

TURBO PUMP WITH LOAD LOCK CHAMBER

1) Verify all connections to system are made. Power, water, process gas, vent gas, and vacuum connections to mechanical pump should be checked.
2) Turn on the mechanical rough pump and wait for the foreline pressure to reach less than 1 Torr. (Refer to gauge controller manual for convection gauge operating instructions.)
3) Open the process chamber turbo backing valve and turn on the turbo pump. (Wait for the turbo to reach full speed.)
4) Verify that both the process chamber and the load lock chamber are at atmosphere. If not, refer to the Chamber Vent procedure.
5) Open the load lock isolation valve.
6) If operating the system for the first time, open the capacitance manometer isolation valve (if installed) and any gas isolation valves.
7) Close the process chamber turbo backing valve.
8) Open the roughing valve. (System roughs through load lock turbo pump.)
9) Open the load lock gate valve, if applicable.
10) Rough the system to approximately 500 Torr as read by the process chamber convection gauge. (Refer to gauge controller manual for convection gauge operating instructions.)
11) Turn on the load lock turbo pump.
12) When the convection gauge in the process chamber is below 100 mTorr, close the isolation valve (wait for it to close completely) and close the roughing valve.
13) Verify that the foreline pressure is below 50 mTorr and then open the process chamber turbo backing valve.
14) Verify that the process chamber pressure does not go above 200 mTorr and then open the hivac valve to the process chamber turbo.
15) Wait for 10 seconds and when the pressure on the process chamber convection gauge is <1.0e-3 Torr, turn on the ion gauge. (Refer to gauge controller manual for operating instructions.)
16) Open the roughing valve to the load lock turbo.

At this point the vacuum system is under vacuum and ready for use. Refer to individual component manuals for operation of gas flow equipment and gauging equipment.

TURBO PUMP WITHOUT LOAD LOCK CHAMBER

1) Verify that all connections to the system are made. Power, water, process gas, vent gas, and vacuum connection to mechanical pump should be checked.
2) If operating the system for the first time, open the capacitance manometer isolation valve (if installed) and any gas isolation valves.
3) Open the high vacuum valve. (System roughs through turbo pump.)
4) Start the system roughing pump and verify that the system pressure is decreasing.
5) Rough the system to approximately 200 mTorr as read by the process chamber convection gauge. (Refer to gauge controller manual for convection gauge operating instructions.)
6) Turn on the turbo pump. (Refer to the turbo pump manual for complete operation instructions.)
7) When the turbo pump is at speed and the process chamber convectron gauge is below 1.0e-3 Torr, turn on the ion gauge. (Refer to gauge controller manual for operating instructions.)

At this point the vacuum system is under vacuum and ready for use. (Refer to individual component manuals for operation of the gas flow equipment and gauging equipment.)

VENT PROCEDURES

This section describes the various system vent procedures.

TURBO PUMP VENT

1) Verify that all source and heater supplies are turned off.
2) Turn off the ion gauge filament.
3) Turn off all gas flow.
4) Turn off the turbo pump.
5) Close turbo backing valve.
6) Turn off the mechanical pump.
7) Open the vent valve, if applicable.
8) Wait until the system reaches atmospheric pressure. The convectron gauge can be used as an estimation, however this may have some degree of error.

At this point the vacuum system is at atmosphere. The chamber door can now be opened. (Refer to individual component manuals to make sure all equipment is in a safe mode.)

LOAD LOCK VENT

1) Turn off the ion gauge filament.
2) Turn off the turbo pump.
3) Close the roughing valve.
4) Open the turbo vent valve.
5) Wait until the system reaches atmospheric pressure.
6) Close the turbo vent valve.

At this point the vacuum system is at atmosphere. The load lock door can now be opened. Refer to manufacturers' manuals to make sure all equipment is in a safe mode.

TURBO WITHOUT LOAD LOCK VENT

1) Turn off the ion gauge filament.
2) Verify that all gas valves are closed and all source and heater supplies are off.
3) Verify that the heater is <80ºC.
4) Turn off the turbo pump.
5) Close the foreline valve.
6) Ensure the pump speed is < 80°C. If applicable, open the turbo vent valve.
7) Wait until the system reaches atmospheric pressure.
8) Close the turbo vent valve.

At this point the vacuum system is at atmosphere. The top plate can now be opened. Refer to manufacturers' manuals to make sure all equipment is in a safe mode.

TURBO AND CRYO PUMP WITH LOAD LOCK, CRYO PUMP WITHOUT LOAD LOCK VENT

1) Turn off the ion gauge filament.
2) Verify that all gas valves are closed and all source and heater supplies are off.
3) Verify that the heater is <80ºC.
4) Close the hivac valve.
5) Open the process chamber vent valve.
6) Wait until the system reaches atmospheric pressure.
7) Close the process chamber vent valve.

At this point the vacuum system is at atmosphere. The top plate can now be opened. Refer to manufacturers' manuals to make sure all equipment is in a safe mode.

PROCESS CHAMBER VENT

1) Close the hivac and roughing valves (as applicable).
2) Turn off the ion gauge.
3) Close the capacitance manometer isolation valve (if applicable).
4) Zero all process gas channels.
5) Close all process gas shut-off valves.
6) Open the nitrogen gas vent valve.
7) Wait until chamber pressure reaches 1 atmosphere (760 Torr).
8) Close the vent valve.

LOAD LOCK CHAMBER VENT

1) Close the load lock isolation valve.
2) Turn off the load lock turbo pump.
3) Wait for the turbo pump to slow to 50%.
4) Close the load lock roughing valve.
5) Open the load lock vent valve.
6) Wait until the load lock pressure reaches atmosphere.
7) Close vent valve.

CRYOPUMP REGENERATION PROCEDURE

The following section describes the cryo pump regeneration procedure.

A Cryo-Torr cryo pump periodically requires a regeneration cycle to return it to its original operating capabilities. Gasses captured from a vacuum chamber and trapped in the cryo pump through the condensation and cryo-adsorption is held primarily in an ice-like form. A regeneration cycle removes trapped gasses through a process similar to defrosting a refrigerator freezer. If the cryo pump becomes incapable of maintaining high vacuum (typically an increase in your vacuum chamber base-pressure by a factor of 10, even though the cold head and the compressor unit are operating satisfactorily), the cryo pump requires regeneration.

It is recommended that your cryo pump be regenerated on a regular schedule that coincides with system maintenance, weekend system shutdown, etc. A suitable time interval between regeneration cycles can be determined from experience.

1) Close the hivac isolation valve.
2) Shut off the cryo pump by setting the power switch on the compressor to the OFF position.
3) If the system has a cryo purge heater, immediately introduce heated dry purge gas through the vessel purge fittings at approximately 150°F (66°C) and at a flow rate of 1-2 cfm. Allow the purge gas to vent through the relief valve.
4) Halt the gas purge when the condensing arrays reach 80° F (26°C) (300K).
5) When the condensing arrays reach ambient temperature, rough the cryo pump to an initial starting pressure between 50 and 100 mTorr.
6) Perform the rate-of-rise test as follows:
7) Once the roughing cycle has roughed the cryo pump starting pressure between 50-100 mTorr, close the roughing valve.
8) Observe the rate-of-rise (ROR) over a five-minute period.

☝ The ROR should be less than 10 mTorr/minute over a five-minute period (50 mTorr total).

9) If the ROR is greater than 50 mTorr, re-purge the cryo pump, check for leaks, and repeat steps 5 and 6. If not, open the rough valve and pump to initial pressure.
10) Close the cryo pump roughing valve and start the cryo pump.
11) The cryo pump is ready for use when the second stage array reaches a temperature of 20K or lower.

PNEUMATIC VALVE PANEL OPERATION

1) Locate the valve panel in instrument rack.
2) Locate the switch that coincides with the device to be actuated (i.e. valve, shutter, etc.).
3) Actuate the switch to the desired labeled position (on/open; off/close).

CAUTION Use caution when changing the state of any valve, check that it will not affect any state of the system adversely to avoid serious equipment damage.

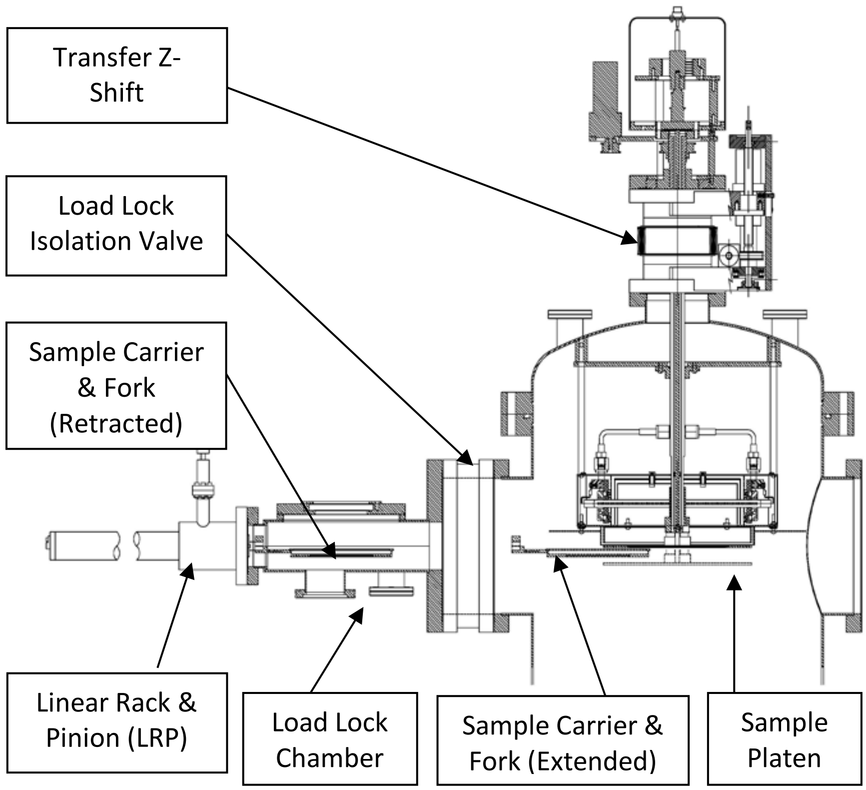
SAMPLE TRANSFER PROCEDURES

SAMPLE LOADING

1) Make sure that a sample and carrier are loaded on to the LRP end effecter (fork), and that nothing is loaded onto the platen assembly.
2) Make sure that the load lock chamber is pumped down to at least 100 mTorr.
3) Open the isolation valve between the load lock and process chambers.
4) Jog the platen rotation to accept sample transfer. (Align the two ceramic stand-offs on the platen assembly via the viewport.)
5) Open the substrate shutter (if applicable).
6) Lower the platen assembly to the bottommost position using the hand wheel on the transfer z-shift located on the chamber top plate.
7) Extend the LRP by rotating the knob on the LRP's rotary feedthrough.
8) Visually align the sample carrier with the counter bore on the sample platen using the chamber viewport.
9) When the carrier is aligned, raise the platen assembly using the transfer z-shift until the carrier is lifted from the LRP end effecter (fork). This is considered the "Transfer Position".
10) Retract the LRP completely (until it reaches the mechanical limit).
11) Raise the transfer z-shift to the uppermost position so that the platen is engaged in the heater assembly.
12) Close the load lock isolation valve between the load lock and the process chamber.

CAUTION Use caution when jogging the platen rotation while the LRP is extended to avoid serious equipment damage.
Use caution when raising and lowering the z-shift when the LRP is extended to avoid serious equipment damage.
Open the substrate shutter before lowering platen assembly.

SAMPLE UNLOADING



SAMPLE UNLOADING COMPONENTS

1) Make sure that nothing is loaded onto the LRP end effecter.
2) Make sure that the load lock chamber is pumped down to at least 100 mTorr.
3) Open the isolation valve between the load lock and process chambers.
4) Jog the platen rotation to accept sample transfer. (Align the two ceramic stand-offs on the platen assembly via the viewport.)
5) Open the substrate shutter (if applicable).
6) Lower the platen assembly to the “transfer position” using the hand wheel on the transfer z-shift located on the chamber top plate.
7) Extend the LRP by rotating the knob on the LRP’s rotary feedthrough.
8) Adjust the platen height if necessary so that the fork can be extended under the shoulder of the sample carrier.
9) Jog the LRP so that the fork is fully engaged with the carrier.
10) When the fork is aligned, lower the platen assembly using the transfer z-shift until the carrier is lifted off of the platen.
11) Retract the LRP completely (until it reaches the mechanical limit).
12) Raise the transfer z-shift to the uppermost position so that the platen is engaged in the heater assembly.

13) Close the load lock isolation valve between the load lock and the process chambers.

⚠ CAUTION Use caution when jogging the platen rotation while the LRP is extended to avoid serious equipment damage.

Z-SHIFT SETUP AND OPERATION

1) Verify the platen rotation is in a safe position. (Refer to Sample Rotation Setup and Operation procedure.)
2) Verify the substrate shutter is open.
3) Verify the LRP is in a safe position. (Refer to LRP Setup and Operation procedure.)
4) Rotate the knob/wheel on z-shift to achieve the desired position. (Z-shift is located either on the top plate or on the bottom of the chamber.)

THREE MAIN Z-SHIFT POSITIONS

- Full open – Extended to accept the wafer/carrier.
- Full closed – Retracted to engage the heater.
- Transfer – The point where the wafer carrier is engaged in the platen and lifted free from the forks.

⚠ CAUTION Use caution when moving the platen z-shift while the LRP is extended to avoid serious equipment damage. Do not rotate while the top plate of the system is open to avoid injury and/or equipment damage. Do not move the platen z-shift while the substrate shutter is closed to avoid serious equipment damage.

SAMPLE HEATING SETUP AND OPERATION

1) Verify the presence of a substrate on the platen and that the system is under vacuum.
2) The temperature will be controlled with a heater controller.
3) Refer to heater controller manual for further details on operation.

CAUTION Do not vent while heater temperature is >80°C to avoid injury or equipment damage. Use caution when removing the substrate from the chamber, it may be extremely hot.

SUBSTRATE SHUTTER SETUP AND OPERATION

The following section describes substrate shutter setup and operation.

MANUAL SUBSTRATE SHUTTER PROCEDURE

1) Verify that the shutter covers substrate. This is the closed position. (This eliminates unwanted deposition on the substrate. It also minimizes/eliminates cross deposition.)
2) If the shutter is not in the closed position, rotate the shutter feedthrough knob to close the shutter.
3) Rotate shutter feedthrough knob to open the shutter.

MANUAL PNEUMATIC SHUTTER PROCEDURE

1) Verify that the shutter covers deposition source. This is the closed position. (This eliminates unwanted deposition on the substrate. It also minimizes/eliminates cross deposition.)
2) If the shutter is not closed, rotate the shutter by either loosening the shutter actuator bracket clamp and rotating the actuator (external) or loosening the shutter blade clamp and rotating the shutter blade (internal).
3) If the shutter blade clamp is loosened, make sure to re-position the shutter height to its original offset.
4) To open/ close the shutter, actuate the switch on the valve panel. (Refer to *Valve Panel Operation* procedure.)
5) If the shutter speed control setting opens/closes the shutter too slowly/quickly, the speed can be adjusted on the shutter assembly with the speed/flow control valve.

SAMPLE BIAS SETUP AND OPERATION

☝ The z-shift must be in fully retracted position before running bias.

1) Verify the presence of a wafer in the platen and system is under vacuum.
2) Turn off the ion gauge.
3) Throttle the hivac valve.
4) Open the gas ring valve.
5) Initiate gas flow and set gas flow/chamber pressure to desired setting. This value usually falls between 1.5 and 15 mTorr. Refer to *Gas Flow Setup and Operation* procedure for further details.
6) Turn on the bias power supply. Refer to power supply manual.
7) Turn on the bias power supply output.
8) Set bias output power level.
9) When finished turn off the supply and reset the output to zero.
10) Shut off gas flow.
11) Close the gas ring valve.
12) Unthrottle the hivac valve.
13) Once chamber has achieved proper crossover, turn the ion gauge on.

⚠ CAUTION If running RF verify plasma on platen by noting a bias voltage on the matching network to avoid injury or equipment damage. Use caution when removing substrate from chamber, it may be extremely hot. Do not touch any connections while power supply is on.

GAS FLOW SETUP AND OPERATION

The following section describes system pressure control options. Refer to applicable procedure for operating instructions.

MANUAL PRESSURE CONTROL (NEEDLE VALVE)

1) If hooking up the system for the first time or changing to a new tank, proceed to step 2. If using a previously used set up go to step 6.
2) Use only clean lines to connect gas to the system. (Purge the gas lines while connecting.)
3) Pump down the system.
4) Pump out the gas supply lines. (Close the tank or wall supply valve, put the gate valve in the throttle position, open system gas valve(s), and fully open needle valves.)
5) When finished, close all system gas valves, open the tank or wall supply valve, and adjust line pressure to >5psig and<15psig.
6) Verify that the system is under high vacuum.
7) Verify that required gas is hooked to the system.
8) Put the high vacuum valve in the throttle position.
9) Open the gas inlet valve and the appropriate gas channel valve(s) and set the gas flow/chamber pressure to the desired setting. This setting usually lies between 1.5 and 15 mTorr for deposition or 100 and 400 mTorr for glow discharge.
10) When finished, close the gas inlet valve and the gas channel valve(s) and set gas flow/chamber pressure to zero.
11) Turn off throttle valve (full open).

DANGER Use appropriate safety measures for gas type(s) selected to prevent personal injury or equipment damage.

AUTO PRESSURE CONTROL (247/250)

1) If hooking up the system for the first time or changing to a new tank, proceed to step 2. If using a previously used set up go to step 6.
2) Use only clean lines to connect gas to the system. (Purge gas lines while connecting.)
3) Pump down the system.
4) Pump out gas supply lines. Close the tank or wall supply valve, throttle the gate valve, open system gas valve(s), and fully open flow valves. (Refer to 247/250 manual for proper operation.)
5) When finished, close all system gas valves, open the tank or wall supply valve, and adjust line pressure to >5psig and<15psig.
6) Verify the system is under high vacuum.
7) Turn off the ion gauge.
8) Verify proper gas is hooked to system.
9) Throttle the hivac valve.
10) Open the capacitance manometer isolation valve if applicable. (Check that the capacitance manometer reads zero.)
11) Open the gas inlet valve and the appropriate gas channel valve(s) and set gas flow/chamber pressure to the desired setting. This setting usually lies between 1.5 and 15 mTorr for deposition or 100 and 400 mTorr for glow discharge. (Refer to 247/250 manual for proper operation.)
12) When finished, close the gas inlet valve and the gas channel valve(s) and set gas flow/chamber pressure to zero.
13) Unthrottle the hivac valve.
14) Turn on the ion gauge.

CAUTION Do not unthrottle or open the hivac valve while the system pressure is above 200 mTorr to prevent equipment damage.

DANGER Use appropriate safety measures for gas type(s) selected to prevent personal injury or equipment damage.

AUTO PRESSURE CONTROL (647)

1) If hooking up the system for the first time or changing to a new tank, proceed to step 2. If using a previously used set up go to step 6.
2) Use only clean lines to connect gas to the system. (Purge gas lines while connecting.)
3) Pump down the system.
4) Pump out gas supply lines. Close the tank or wall supply valve, throttle the gate valve, open system gas valve(s), and fully open flow valves. (Refer to 647 manual for proper operation.)
5) When finished, close all system gas valves, open the tank or wall supply valve, and adjust line pressure to >5psig and<15psig.
6) Verify the system is under high vacuum.
7) Turn off the ion gauge.
8) Verify that proper gas is hooked to system.
9) Throttle the hivac valve.
10) Open the capacitance manometer isolation valve if applicable. (Check that the capacitance manometer reads zero.)
11) Open the gas inlet valve and the appropriate gas channel valve(s) and set gas flow/chamber pressure to the desired setting. This setting usually lies between 1.5 and 15 mTorr for deposition or 100 and 400 mTorr for glow discharge. (Refer to 647 manual for proper operation.)
12) When finished, close the gas inlet valve and the gas channel valve(s) and set gas flow/chamber pressure to zero.
13) Unthrottle the hivac valve.
14) Turn on the ion gauge.

CAUTION Do not unthrottle or open the hivac valve while the system pressure is above 200 mTorr to prevent equipment damage.

DANGER Use appropriate safety measures for gas type(s) selected to prevent personal injury or equipment damage.

SPUTTER SOURCE SETUP AND OPERATION

All TORUS® source designs are based on a patented, modified Penning Discharge Principle which incorporates powerful, permanent magnets and specific pole pieces to configure the sources' magnetic field just above the plane of the target. The result is a combination of film uniformity, deposition rate, target utilization, operation at lower vacuum chamber pressures, and efficient power usage.

With a TORUS® source, movement of the secondary electrons emitted during sputtering are confined by an electrical field and a strong magnetic field; the TORUS® captures electrons released near the target, concentrates them, and employs them to develop higher sputtering power. Resultant films are uniform, homogeneous and small grained; they have high density (low void area) with high specularity (reflectance), and are free of radiation damage and broken bonds.

SAFETY

⚠ DANGER

- A proper earth ground connection is required to avoid electrical shock and fire hazards.
- Great care must be taken to ensure the following:
  - ALL sources of high voltage are isolated prior to connecting/disconnecting equipment.
  - ALL high frequency sources are isolated prior to handling any equipment connections.
- Lack of proper coolant flow to the source can be potentially harmful to the user and will damage the sputtering source.

Visually inspect equipment daily for water leaks and equipment condition.

ELECTRICITY

The TORUS® source operates with high voltage DC, pulsed DC and RF industrial power supplies. Be sure all devices exposed to operating personnel are electrically connected, grounded, and protected properly. Before turning on the electrical power to the source, check to ensure that the anode and the cathode of the TORUS® source are isolated and the chamber, the body of the electrical connector and the anode (Dark Space Shield and Body) are grounded.

SETUP

Over time the shutter open/close speed may need adjusted.

1) Close the shutter speed adjustment valves (clockwise – see Figure 1).
2) Toggle the shutter to open (the shutter should not open yet).
3) Check which airline has pressure on it and slowly adjust the other speed valve counter-clockwise until the shutter opens.
4) Toggle the shutter to close (the shutter should not close yet).
5) Slowly adjust the other speed control valve counter-clockwise until the shutter closes.
6) Recheck the shutter open and close and adjust the speed valves so that the shutter operates smoothly.

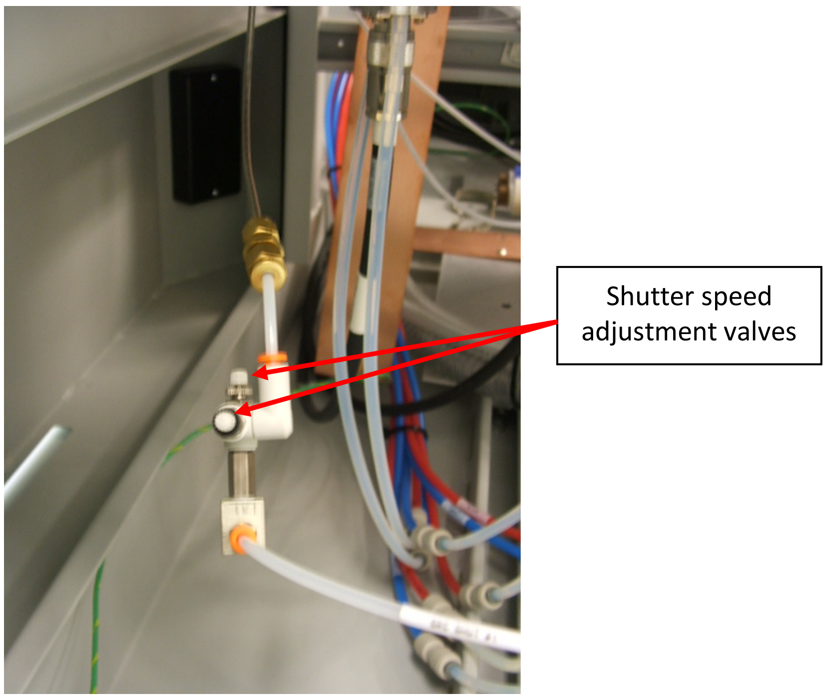


FIGURE 1

SYSTEM EQUIPMENT REQUIREMENTS

Typical sputtering systems will have the following interlocks:

- Water Flow Sensors For Each Sputter Source
- Vacuum Switch

When the water supply and return valves are open, the water flow switch should be satisfied, resulting in the flow switch changing from gray to green.

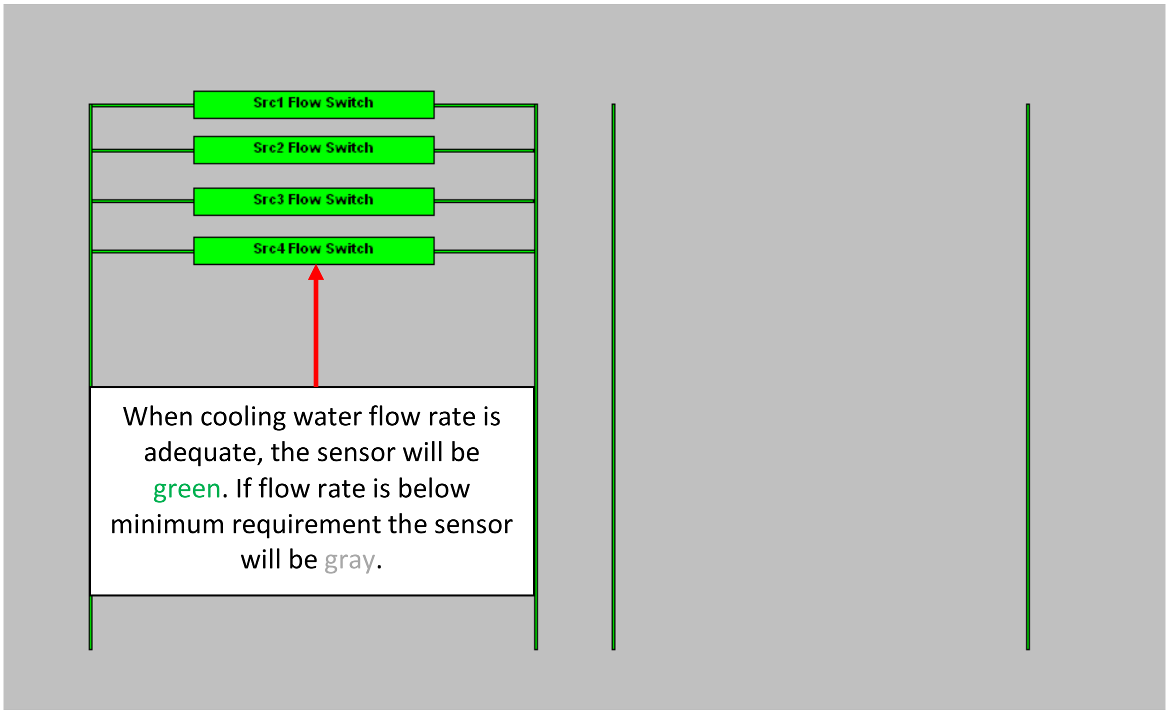


FIGURE 2
WATER FLOW SENSORS (FLOW SWITCH)

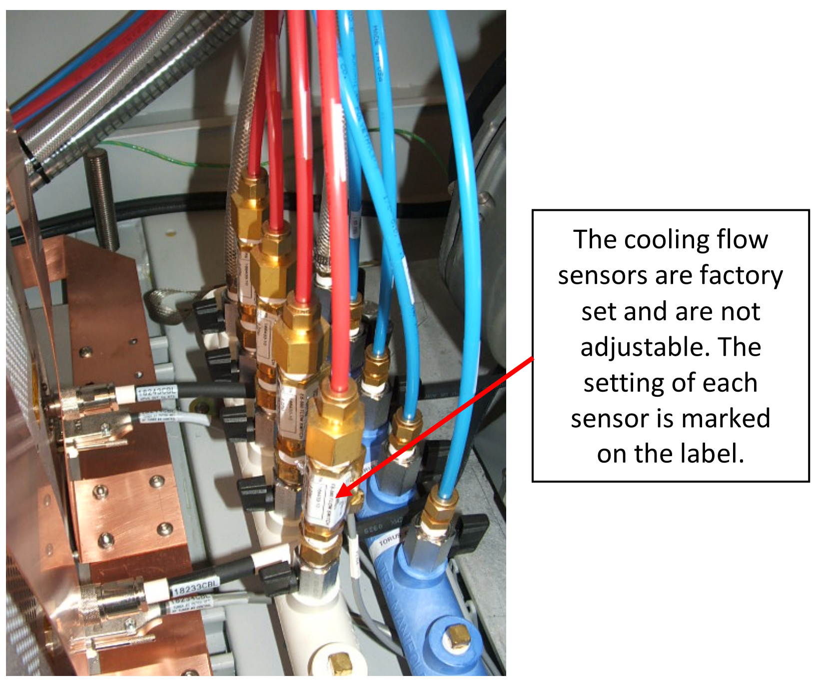


FIGURE 3

The water flow sensors are located on the cooling water return manifold.

MANUAL OPERATION THROUGH CWARE

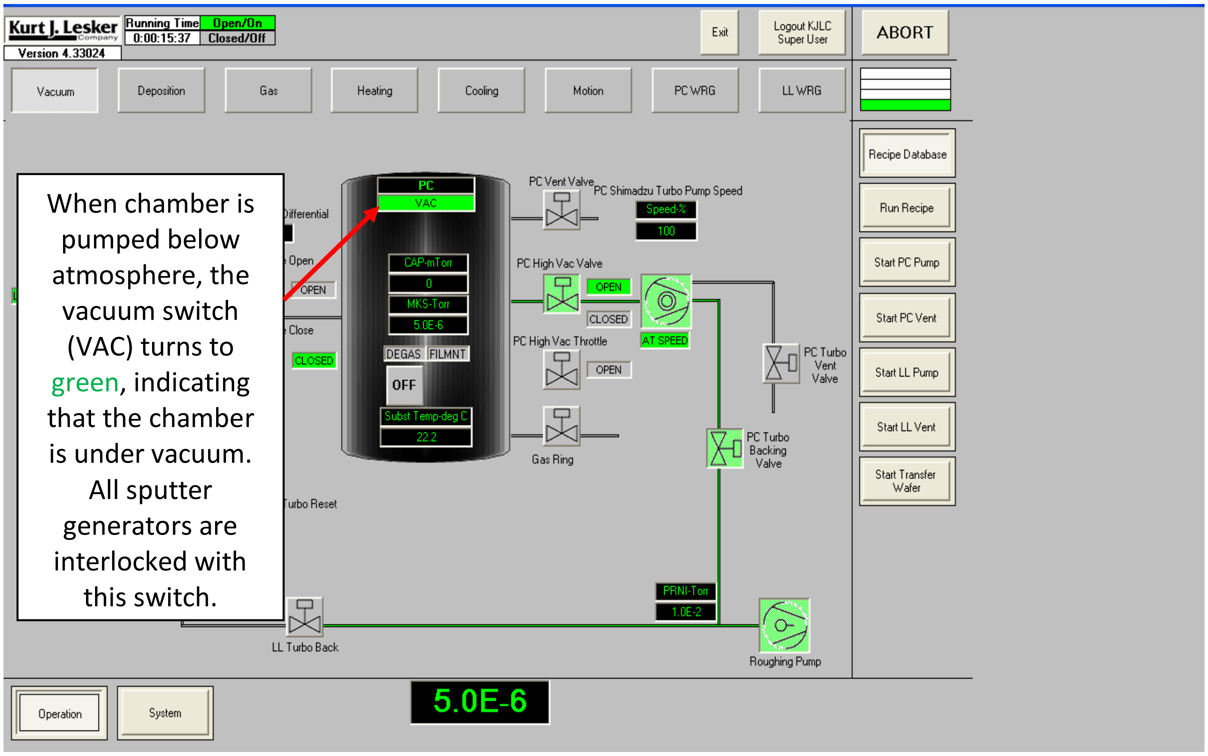


FIGURE 4

DC SPUTTERING

3-POSITION HIGH VACUUM VALVE SYSTEM

1) Pump down the vacuum chamber to high vacuum. The choice of base pressures is the decision of the user and determined by acceptable impurity levels.
2) Select the Vacuum screen. Set high vacuum valve to throttle position (see Figure 3).
3) Select the Gas screen. Open source gas valve or gas injection valve (depending on system configuration – see Figure 6).
4) Set MFC1 mode to 4.
5) Set Capman pressure set point to 5 (mTorr).
6) Wait for chamber pressure to stabilize.

> ☝ Most target materials can be sputtered with an Argon pressure of 1 to 15 millitorr, but some materials will require a higher pressure.

7) Select the Deposition screen. Turn on DC power supply output (See Figure 5).
8) Set power supply ramp rate (typically 10-20 watts per second).
9) Set power supply output set point to desired power.

10) If the voltage reads zero even though the power supply indicates current, the source or cable is short-circuited. Switch off the power supply and take the proper corrective connecting measures (See Troubleshooting section in KJLC TORUS® manual). Once the short is repaired, repeat steps 2-9. A voltage reading of 600-1000 volts with no current could indicate several problems. Turn off the power supply and follow the procedures outlined in the Troubleshooting section of the KJLC TORUS® manual.

VARIABLE SPEED TURBO PUMP SYSTEM - NO HIGH VACUUM VALVE

1) Pump down the vacuum chamber to high vacuum. The choice of base pressures is left to the user and determined by acceptable impurity levels.
2) Select the Vacuum screen. Set turbo pump speed to 50% (see Figure 4).
3) Select the Gas screen. Open source gas valve or gas injection valve (depending on system configuration - see Figure 6).
4) Set MFC1 mode to 4.
5) Set Capman pressure set point to 5 (mTorr).
6) Wait for turbo speed to slow and pressure to stabilize (this will take several minutes).
7) Select the Deposition screen. Turn on DC power supply output (see Figure 5).
8) Set power supply ramp rate (typically 10-20 watts per second).
9) Set power supply output set point to desired power.
10) If the voltage reads zero even though the power supply indicates current, the source or cable is short-circuited. Switch off the power supply and take the proper corrective connecting measures (see Troubleshooting section in KJLC TORUS® manual). Once the short is repaired, repeat steps 2-9. A voltage reading of 600-1000 volts with no current could indicate several problems. Turn off the power supply and follow the procedures outlined in the Troubleshooting section of the KJLC TORUS® manual.

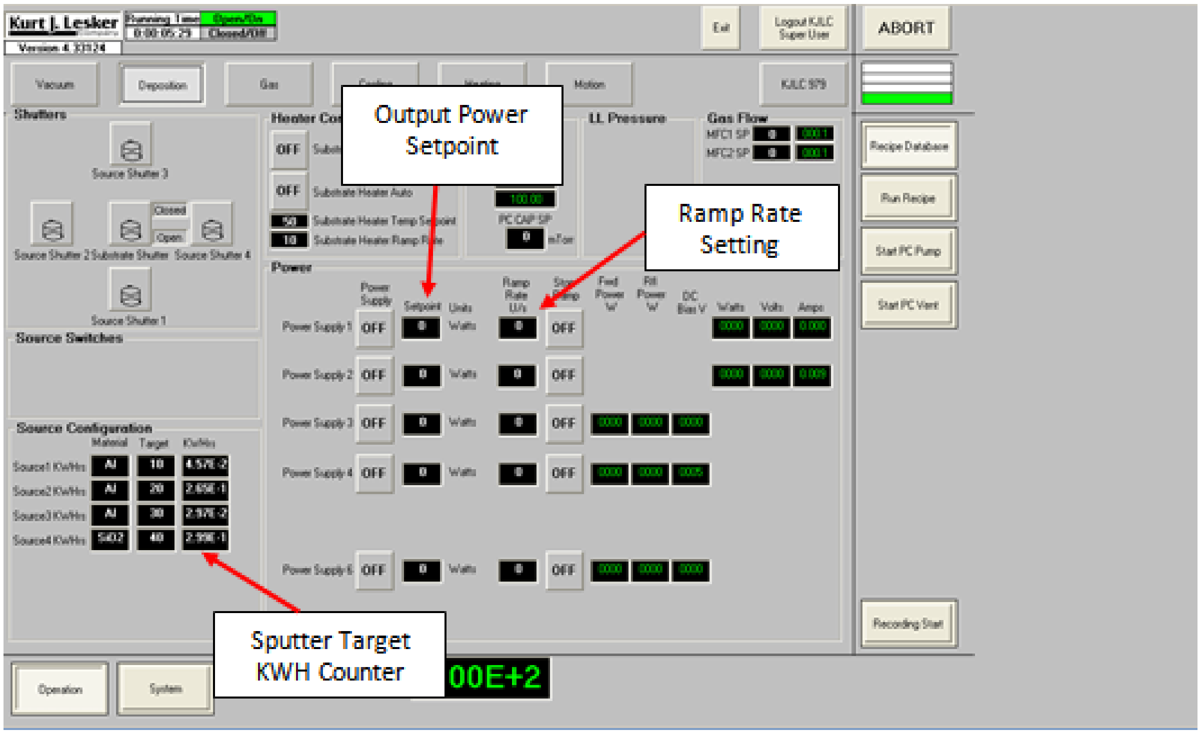

Kurt J. Lesker
ABORT
Shutters
Source Switches
Source Configuration
Power
Output Power Setpoint
Ramp Rate Setting
Sputter Target KWH Counter

FIGURE 5

DC SPUTTERED PROCESS EXAMPLE

frmRecipeItems

Seq	Type	Equipment	EquipmentItem	EquipmentItemOperation	Equipment/Test Value	GRST
1	-	Recipe	Set Abort Recipe	Abort Process		
2	-	Gauge	MKS979 WRG Pressure	Check Value <= n.nn	.000005	AT
3	-	Valve	PC High Vac Throttle	Turn_On/Open/ Opening		
4	-	Valve	PC High Vac Throttle Opened	Check_On/Open/ Opening		AT
5	-	MFC	MFC1 Mode	Set Value = n.nn	4	
6	-	Valve	Gas Injection	Turn_On/Open/ Opening		
7	-	Gauge	Capman Pressure SP	Set Value = n.nn	5	
8	-	Gauge	Capman Pressure	Check Pressure > n.nn	4.5	AT
9	-	Motors	Platen Motor Jog Velocity SP	Set Value = n.nn	20	
10	-	Motors	Platen Motor Go Continuous +	Turn_On/Open/ Opening		
11	-	Motors	Platen Motor Velocity	Check Value > n.nn	19.9	AT
12	-	Power Supply	Power Supply 2	Turn_On/Open/ Opening		
13	-	Power Supply	Power Supply2 Ramp Rate	Set Value = n.nn	10	
14	-	Power Supply	Power Supply2 Output Setpoint	Set Value = n.nn	200	
15	-	Power Supply	Power Supply2 Output Power	Check Value > n.nn	190	AT
16	-	Gauge	Capman Pressure SP	Set Value = n.nn	2.5	
17	-	Gauge	Capman Pressure	Check Pressure <= n.nn	2.7	AT
18	-	Recipe	Dwell	N Seconds (n or HH:MM:SS)	60	
19	-	Shutter	Source Shutter 2	Turn_On/Open/ Opening		
20	-	Shutter	Substrate Shutter	Turn_On/Open/ Opening		
21	-	Recipe	Dwell	N Seconds (n or HH:MM:SS)	2000	
22	-	Shutter	Substrate Shutter	Turn_Off/Closed/		

frmRecipeItems						
Seq	Type	Equipment	EquipmentItem	EquipmentItemOperation	Equipment/Test Value	GRST
				Closing		
23	-	Shutter	Source Shutter 2	Turn_Off/Closed/ Closing		
24	-	Power Supply	Power Supply2 Ramp Rate	Set Value = n.nn	10	
25	-	Power Supply	Power Supply2 Output Setpoint	Set Value = n.nn	0	
26	-	Power Supply	Power Supply2 Output Power	Check Value <= n.nn	5	AT
27	-	Power Supply	Power Supply 2	Turn_Off/Closed/ Closing		
28	-	Motors	Platen Motor Go Continuous +	Turn_Off/Closed/ Closing		
29	-	Gauge	Capman Pressure SP	Set Value = n.nn	0	
30	-	Recipe	Dwell	4 Seconds		
31	-	MFC	MFC1 Mode	Set Value = n.nn	0	
32	-	Valve	Gas Injection	Turn_Off/Closed/ Closing		
33	-	Valve	PC High Vac Throttle	Turn_Off/Closed/ Closing		
34	-	Valve	PC High Vac Valve Opened	Check_On/Open/ Opening		AT

Step 1: Always the first step in a recipe, sets which Abort Recipe should be run in the event a check step that has an AT (Abort on Time) fails.

Step 2: Waiting for a desired base pressure before deposition will begin. In this case 5x10-6 Torr.

Steps 3-4: Sets high vacuum valve to throttle position.

Steps 5-8: Set-up process gas to a pressure required to strike a plasma.

Steps 9-11: Start-up substrate rotation.

Steps 12-15: Start running sputter source.

Steps 16-17: Reduce gas pressure to required process setting (if necessary).

Steps 18-23: Pre-sputter and film deposition.

Steps 24-27: Shut down sputter source power supply.

Steps 28-32: Stop substrate rotation and turn off process gas.

Steps 33-34: Set High vacuum valve throttle off.

RF SPUTTERING

1) Pump down the vacuum chamber to high vacuum. The choice of base pressures is the decision of the user and determined by acceptable impurity levels.
2) Select the Vacuum screen. Set high vacuum valve to throttle position (see Figure 4).
3) Select the Gas screen. Open source gas valve or gas injection valve (depending on system configuration - see Figure 6).
4) Set MFC1 mode to 4.
5) Set Capman pressure set point to 10 (mTorr).
6) Wait for chamber pressure to stabilize.
7) Select the Deposition screen. Turn on RF power supply output - see Figure 5).
8) Set power supply ramp rate (typically 10-20 watts per second).
9) Set power supply forward power set point to desired power.
10) Check for the presence of a plasma; if there is no plasma, raise the pressure to 50mTorr of argon in the process chamber. If still no plasma, briefly go to “manual” tuning on the matching network and return to “auto” tuning. If there still is no plasma, briefly open the source shutter. Another method is to fire up another source in the chamber (if available) which will help ignite the plasma.

☝If the sputtering source is being powered through a cable connected from the matching network, monitor the temperature of this cable and the connectors for excessive heating. Excessive heating can be caused by low impedance at the sputtering source. This results in high current loads through this power transmission cable. Please contact a Kurt J. Lesker Company Applications Engineer for further discussion if cable temperatures exceed 80°C.

11) When a plasma has been established, reduce the gas pressure to the required setting.

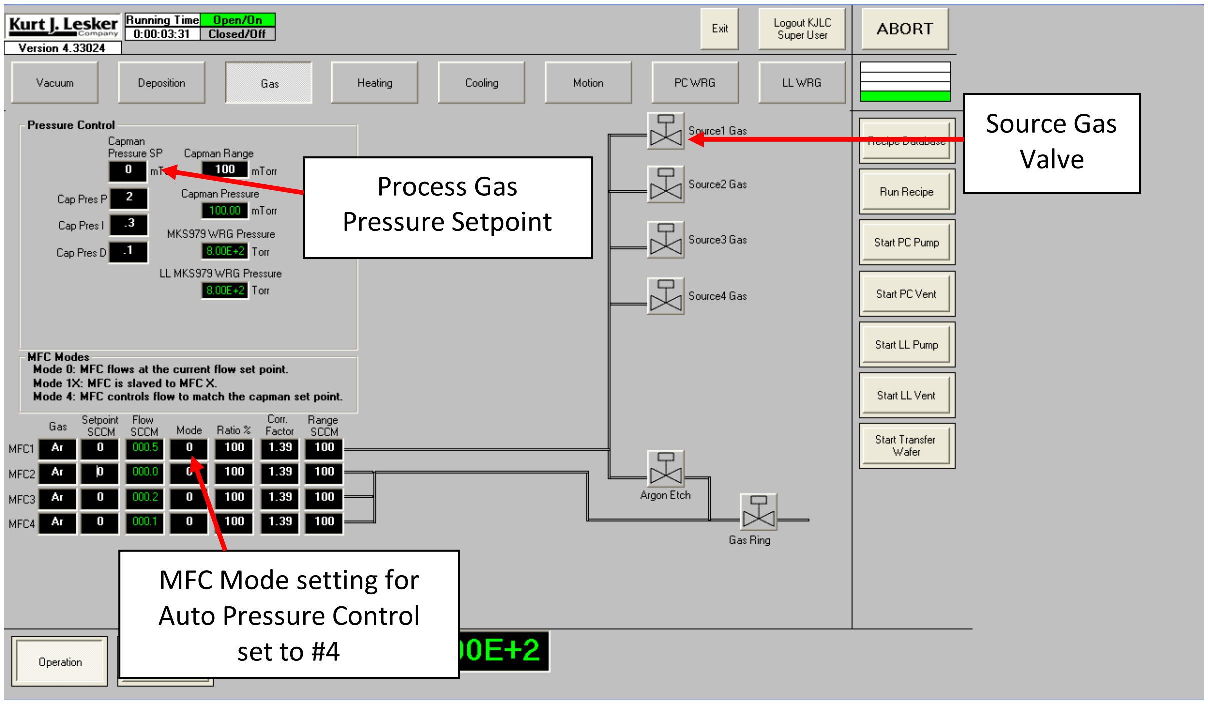

Source Gas Valve
Process Gas Pressure Setpoint
MFC Mode setting for Auto Pressure Control set to #4
Pressure Control
MFC Modes
Mode 0: MFC flows at the current flow set point.
Mode 1X: MFC is slaved to MFC X.
Mode 4: MFC controls flow to match the capman set point.
ABORT
Vacuum
Deposition
Gas
Heating
Cooling
Motion
PC WRG
LL WRG
Run Recipe
Start PC Pump
Start PC Vent
Start LL Pump
Start LL Vent
Start Transfer Wafer
Operation

FIGURE 6

RF SPUTTERED PROCESS EXAMPLE

frmRecipeItems						
Seq	Type	Equipment	EquipmentItem	EquipmentItemOperation	Equipment/Test Value	GRST
1	-	Recipe	Set Abort Recipe	Abort Process		
2	-	Valve	PC High Vac Throttle	Turn_On/Open/ Opening		
3	-	Valve	PC High Vac Throttle Opened	Check_On/Open/ Opening		AT
4	-	MFC	MFC1 Mode	Set Value = n.nn	4	
5	-	Valve	Gas Injection	Turn_On/Open/ Opening		
6	-	Gauge	Capman Pressure SP	Set Value = n.nn	12	
7	-	Gauge	Capman Pressure	Check Pressure > n.nn	11.5	AT
8	-	Motors	Platen Motor Jog Velocity SP	Set Value = n.nn	20	
9	-	Motors	Platen Motor Go Continuous +	Turn_On/Open/ Opening		
10	-	Motors	Platen Motor Velocity	Check Value > n.nn	19	AT
11	-	Power Supply	Power Supply 3	Turn_On/Open/ Opening		
12	-	Power Supply	Power Supply3 Output Setpoint	Set Value = n.nn	100	R
13	-	Shutter	Source Shutter 3	Turn_On/Open/ Opening		
14	-	Power Supply	Power Supply3 DC Bias	Check Value > n.nn	50	AT
15	-	Recipe	Dwell	1 Second		
16	-	Shutter	Source Shutter 3	Turn_Off/Closed/ Closing		
17	-	Gauge	Capman Pressure SP	Set Value = n.nn	2.5	
18	-	Gauge	Capman Pressure	Check Pressure <= n.nn	3	AT
19	-	Recipe	Dwell	N Seconds (n or HH:MM:SS)	10	
20	-	Shutter	Source Shutter 3	Turn_On/Open/ Opening		
21	-	Recipe	Dwell	N Seconds (n or HH:MM:SS)	2000	

frmRecipeItems						
Seq	Type	Equipment	EquipmentItem	EquipmentItemOperation	Equipment/Test Value	GRST
22	-	Shutter	Source Shutter 3	Turn_Off/Closed/Closing		
23	-	Power Supply	Power Supply3 Output Setpoint	Set Value = n.nn	0	R
24	-	Power Supply	Power Supply3 Fwd Power	Check Value <= n.nn	5	GT
25	-	Power Supply	Power Supply 3	Turn_Off/Closed/Closing		
26	-	Motors	Platen Motor Go Continuous +	Turn_Off/Closed/Closing		
27	-	Recipe	Dwell	N Seconds (n or HH:MM:SS)	5	
28	-	Gauge	Capman Pressure SP	Set Value = n.nn	0	
29	-	Recipe	Dwell	5 Seconds		
30	-	MFC	MFC1 Mode	Set Value = n.nn	0	
31	-	Valve	Gas Injection	Turn_Off/Closed/Closing		
32	-	Valve	PC High Vac Throttle	Turn_Off/Closed/Closing		
33	-	Valve	PC High Vac Valve Opened	Check_On/Open/Opening		AT

☝ The above example is an RF sputter deposition. The main differences to a DC sputter recipe are:

- The gas pressure will normally need to be higher when igniting the plasma.
- When checking for the presence of a plasma, check for a voltage greater than 50 (see step 14).

☝Before working on any sputter source ensure that all electrical power is removed from the power supply/generator.

TARGET CHANGING

Installing/changing targets:

1) Turn off sputter source power supply. Turn off power supply main distribution panel circuit breaker.
2) Switch to the deposition screen, open the source shutter.
3) It may sometimes be necessary to remove the shutter blade to make target removal/install easier.
4) Loosen the 3 screws supporting the dark space shield and remove the shield (see Figure 7).
5) For a 2" source, loosen the 4 screws of the target hold-down ring (see Figure 8). For a 3 or 4" source, remove the 4 screws and remove the ring.
6) When removing a target of magnetic material, carefully slide the target to one side and pick it up (do not attempt to pry magnetic targets from the cooling well. This may result in permanent damage to the cooling well).
7) Place a new target on to the source, ensuring all parts are perfectly clean. If installing a magnetic target, take extra care that fingers or parts of a glove do not get pinched between target and source as the magnets are very powerful.
8) Tighten the hold-down ring screws evenly (do not over-tighten screws).
9) The dark space shield of the TORUS® source has three machined slots, which ensure .080" dark space on top of the 1/8", 3/16", and 1/4" targets. Loosen the three #8 screws and reposition the dark space shield to the correct slot when changing the target (do not over-tighten the 3 screws).
10) After installing a target, check shutter operation and clearance between the shutter and sputter source.

Refer to the KJLC TORUS® manual for complete detailed instructions regarding target change.

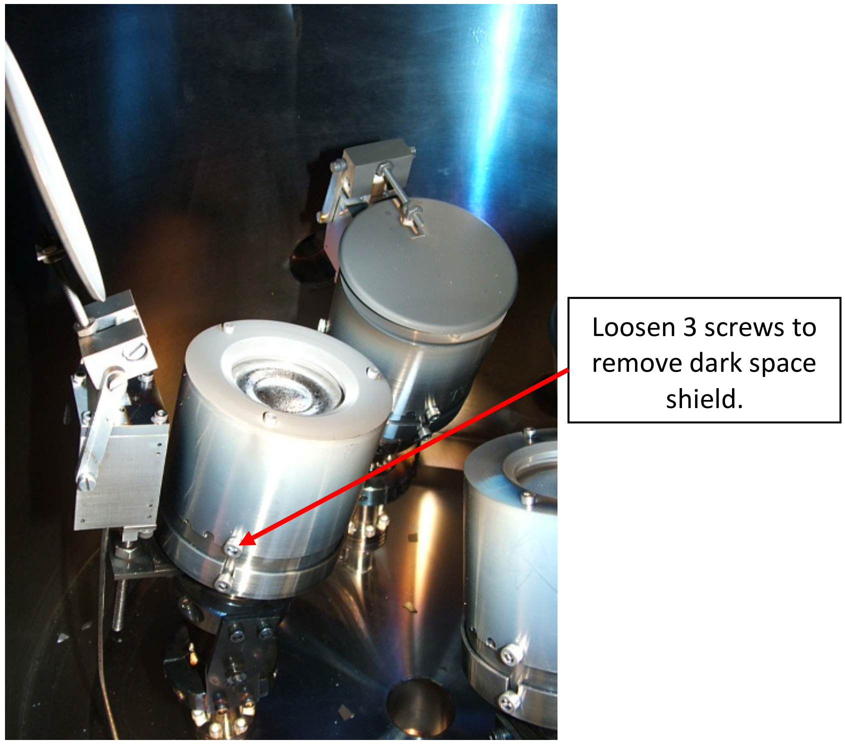


FIGURE 7

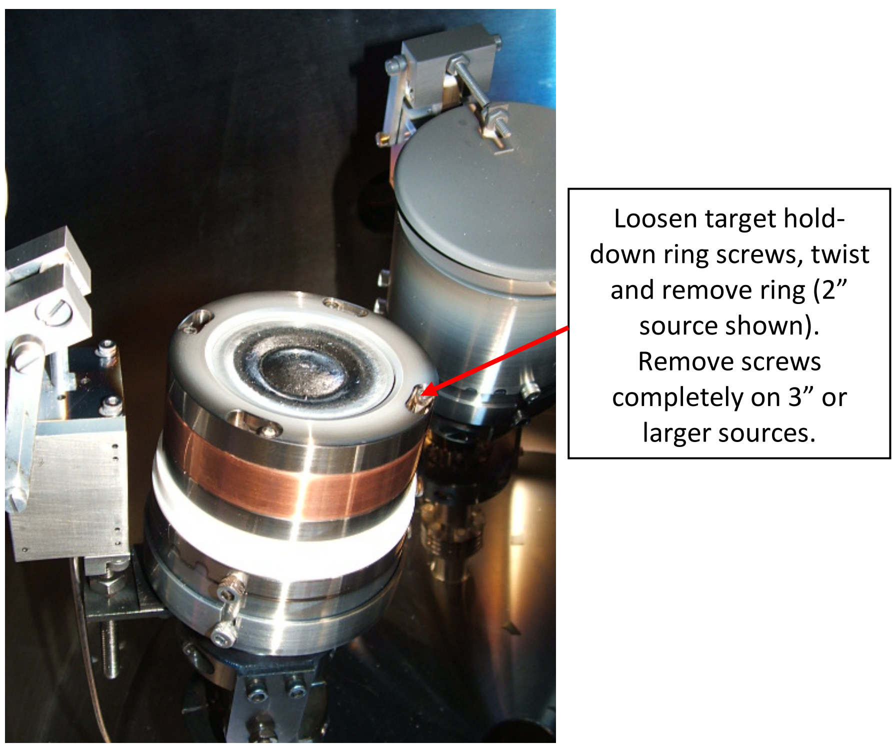


FIGURE 8

CLEANING AND MAINTENANCE

A sputter source will require cleaning after a period of time due to material build-up. If left too long, flaking can occur, resulting in arcing and shorts.

1) Turn off sputter source power supply.
2) Turn off power supply main distribution panel circuit breaker.
3) Switch to the deposition screen; open the source shutter.
4) Loosen the 3 screws supporting the dark space shield and remove the shield.
5) Remove the screws of the target hold-down ring and remove the ring.
6) Clean the dark space shield and hold-down ring (The best method for removing deposited material is with bead blasting).

E-BEAM SOURCE SETUP AND OPERATION

The electron-beam (e-beam) source high deposition rates and large evaporant capacity make it convenient for production-scale coating machines. Solid evaporants such as powder, granules, lumps, or shaped plugs are placed in the source's copper hearth or in a hearth-liner. A high electron flux generated by a hot filament placed below the source is extracted and electrostatically and magnetically bent/focused on the top of the evaporant. The electron beam's energy raises the evaporant's surface temperature. Often the beam is rastered to increase the evaporation area. Since the evaporation area is surrounded by a cooler (often solid) evaporant, unlike other thermal sources, the e-beam source's vapor plume is largely uncontaminated by crucible material.

Production scale e-beam sources are usually single pocket (one hearth). Multipocket sources (4 or 6 hearths) are available for R & D applications. A cover plate obscures the pockets "not-in-use" to prevent vapor cross-talk. Multipocket sources are particularly convenient when depositing multilayer films on a single substrate.

Evaporants often "spit" and must be heated in a series of ramp/soak steps in order to reach evaporation temperature. The melt presents a high-temperature source that thermally radiates the substrate.

SAFETY

DANGER DO NOT operate or service the E-Beam source or power supply before reading and understanding the E-Beam operation manuals.

DANGER After power has been disconnected, wait for at least 3 minutes before starting work on the power supply to allow the capacitors to discharge themselves. Also use the grounding rod to discharge the capacitors and high voltage feed thru before coming in contact with them.

FIGURE 1

1) Visually inspect equipment daily for water leaks and equipment condition.
2) Remove excess deposition from around the crucible and gun.

Excessive flaking around the crucible or heavy coatings of deposition material on top of the e-gun, can cause the gun to arc, affect the beam or operate improperly.

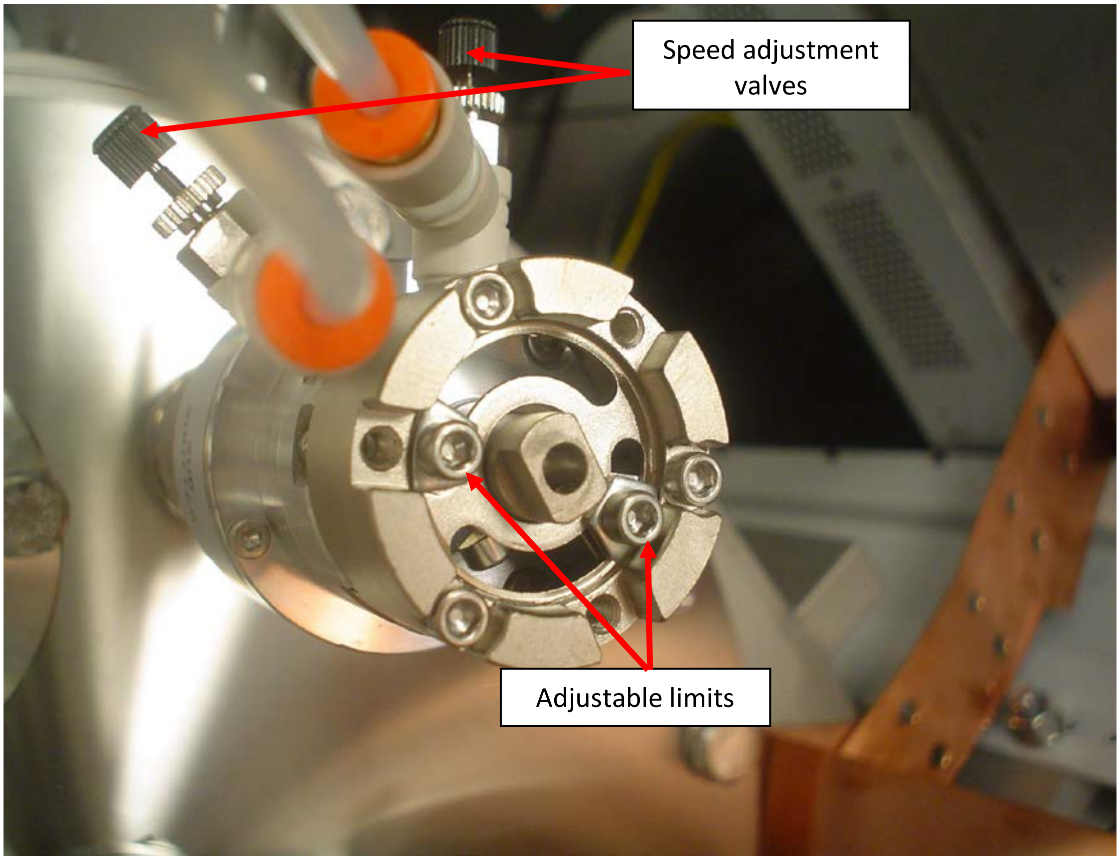
SETUP

The shutter limits or speed of open/close may need to be adjusted over time.

SHUTTER SPEED ADJUSTMENT

1) Start by closing the speed adjustment valves (clockwise). See Fig below.
2) Toggle the shutter to open (the shutter should not open yet).
3) Check which airline has pressure on it and adjust the other speed valve counter-clockwise slowly until the shutter opens.
4) Toggle the shutter to close (the shutter should not close yet).
5) Adjust the other speed control valve counter-clockwise slowly until the shutter closes.
6) Recheck the shutter open and close and adjust the speed valves so that the shutter operates smoothly.

SHUTTER LIMIT ADJUSTMENT



E-BEAM SHUTTER

Use the two adjustable limits shown above to set the open and closed position of the shutter.

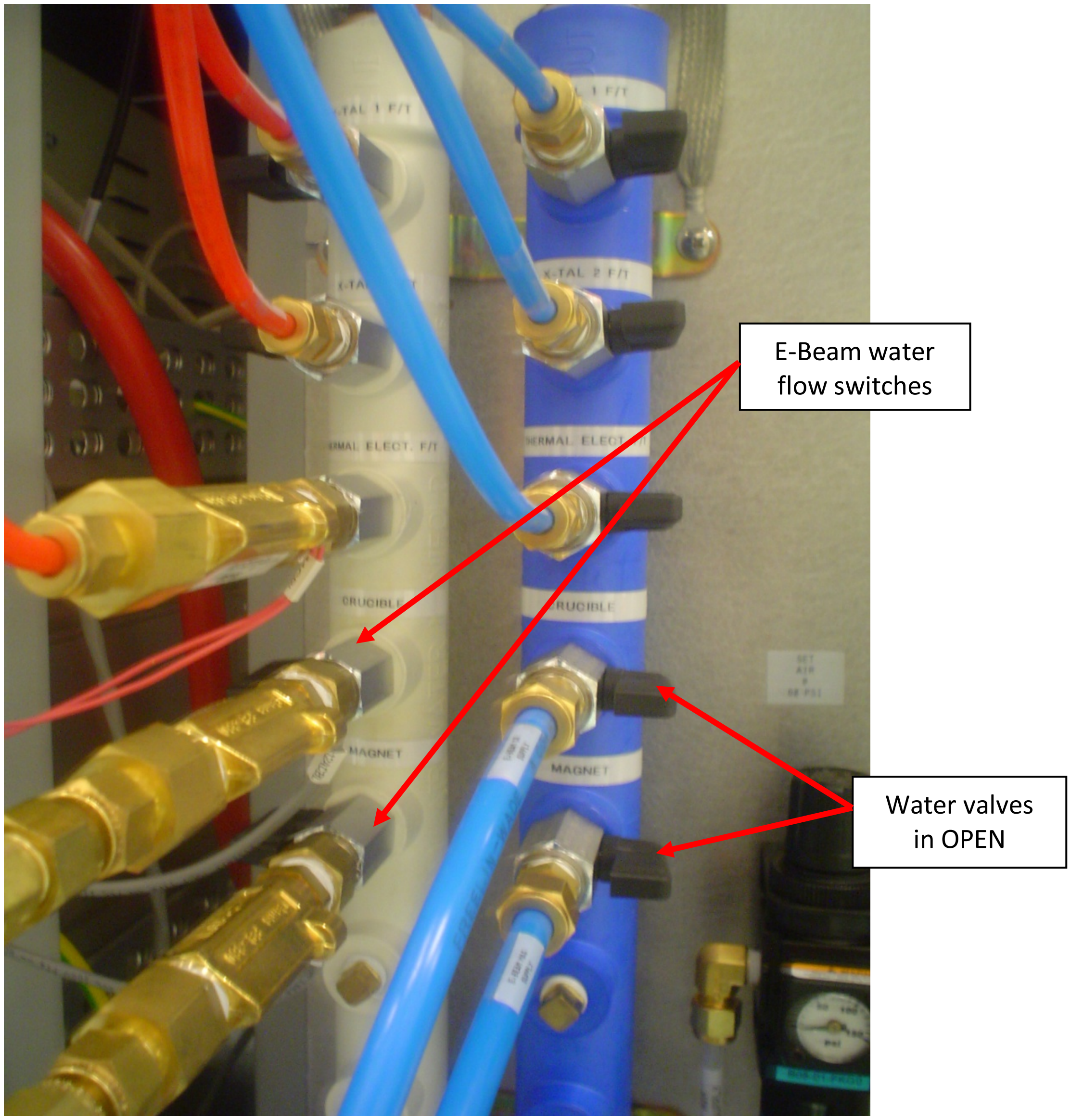
SYSTEM EQUIPMENT REQUIREMENTS

Each E-Beam system needs the following interlocks to be satisfied in order to work:

- Water flow sensors
- Vacuum monitor
- External E-Beam cover switches: Drawer door, power F/T cover switch and power cable cover interlocks to be closed

WATER FLOW SENSORS

Located on the water return line of the system's water manifold.



WATER MANIFOLD

Depending on the type of E-Beam system installed there may be 1 water flow switch or two flow switches in series, as shown above. One flow switch is for the magnet cooling; the second switch is for the crucible cooling.

☝ The valve needs to be in the OPEN position (on both supply/return manifolds) for the switch to register flow. The flow switch is normally closed.

When the water supply and return valves are open, the water flow switch should be satisfied. To ensure, the flow switch on the CWare Cooling screen will change from gray to green when satisfied.

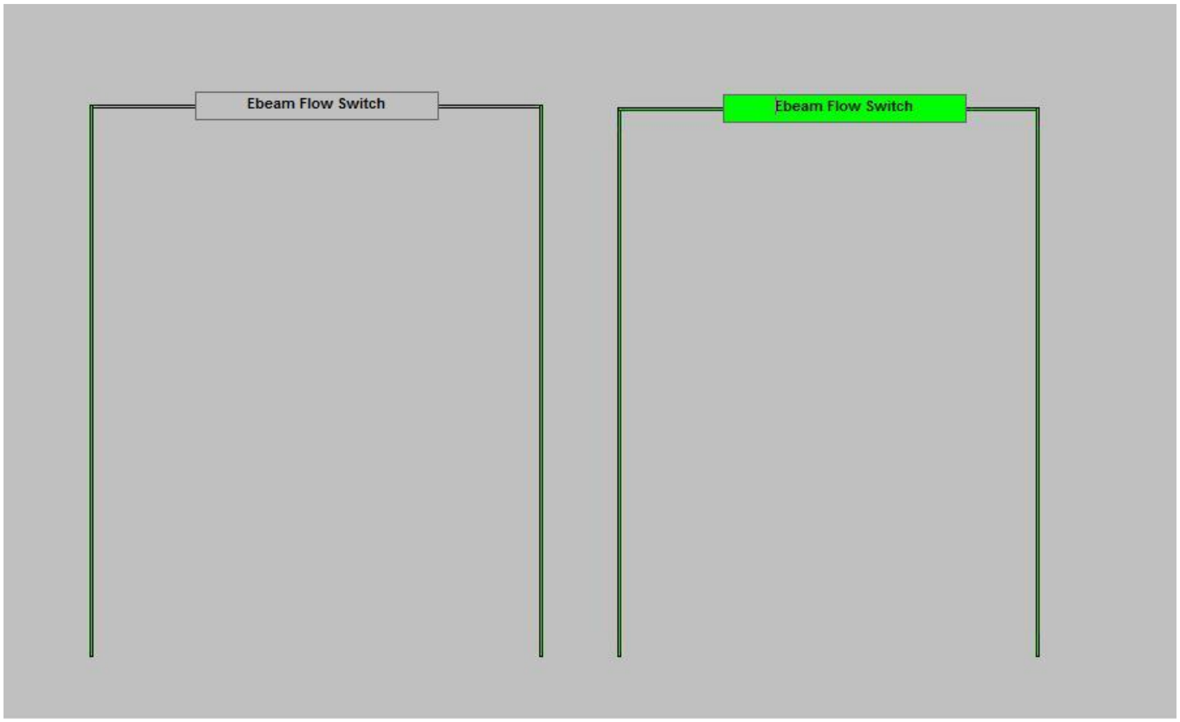


FIGURE 2

If the water supply and return valves are fully open and the flow switch is not shown as made on CWare, check that the water pressure and flow rate meet specifications. If the utilities are within spec, call the KJLC Service Department for assistance.

VACUUM MONITOR

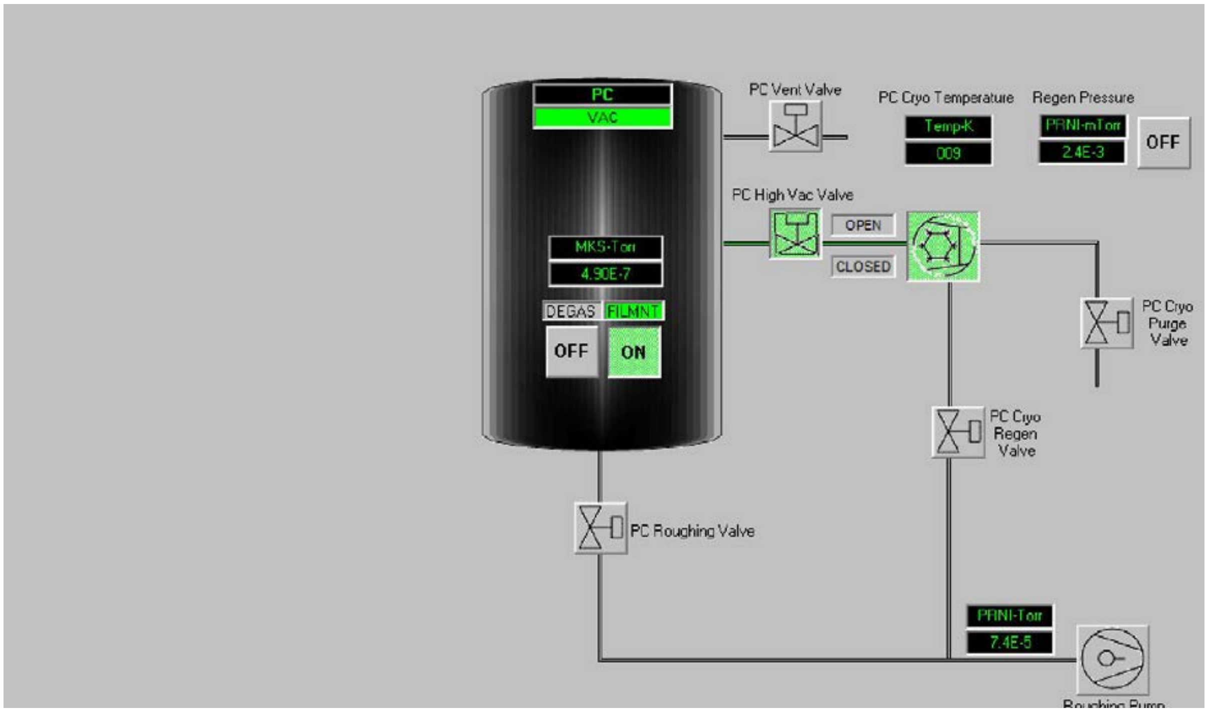


FIGURE 3

E-Beam systems are hard-wire interlocked to the VAC switch. When the system is roughed below ATM, the VAC (Vacuum Switch) turns green and indicates PC is under vacuum. The KJLC software interlock for minimum operation pressure is 5x10-4Torr; although the recommended optimum pressure is 4 x 10-5 Torr or better.

EXTERNAL COVER SWITCHES

Depending on the type of E-Beam installed in the system, there are external cover switches that will need to be made. Please refer to the manufacturer's user manual for specific location of these switches. There are two types of external switches for two common models, the 265 and KL-6.

- Telemark cover switches
- KL-6 cover switches

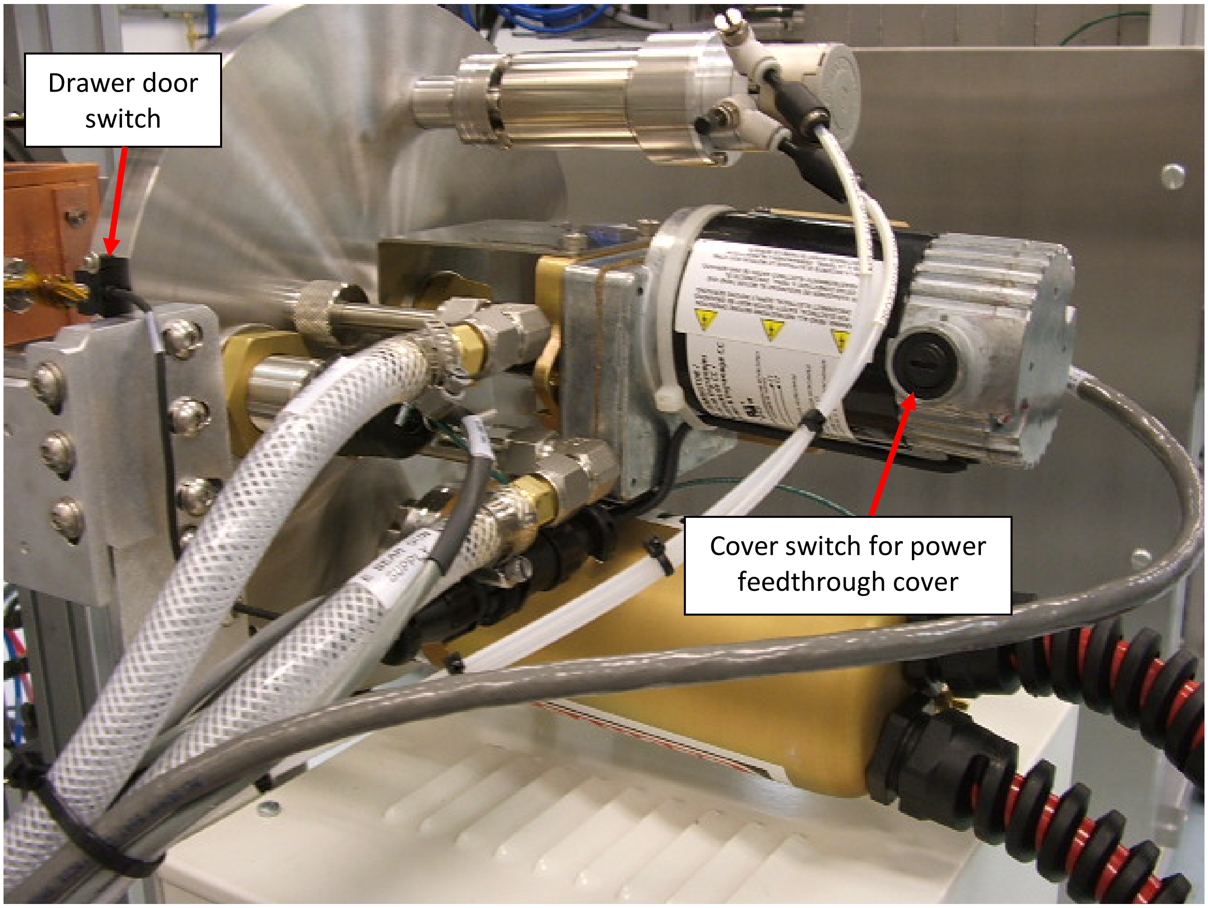


FIGURE 4

The 265 control panel LED will indicate if the cover switch is not made. When the Drawer door is made, CWare will display EB Door Closed (Figure 5).

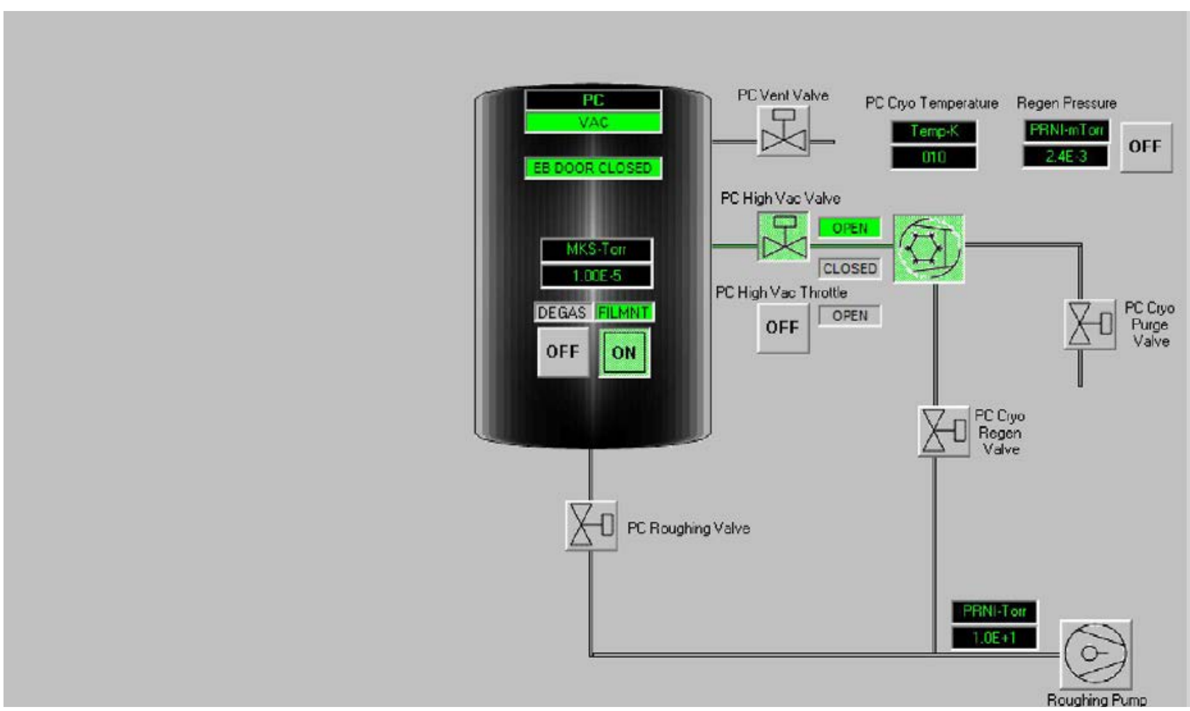
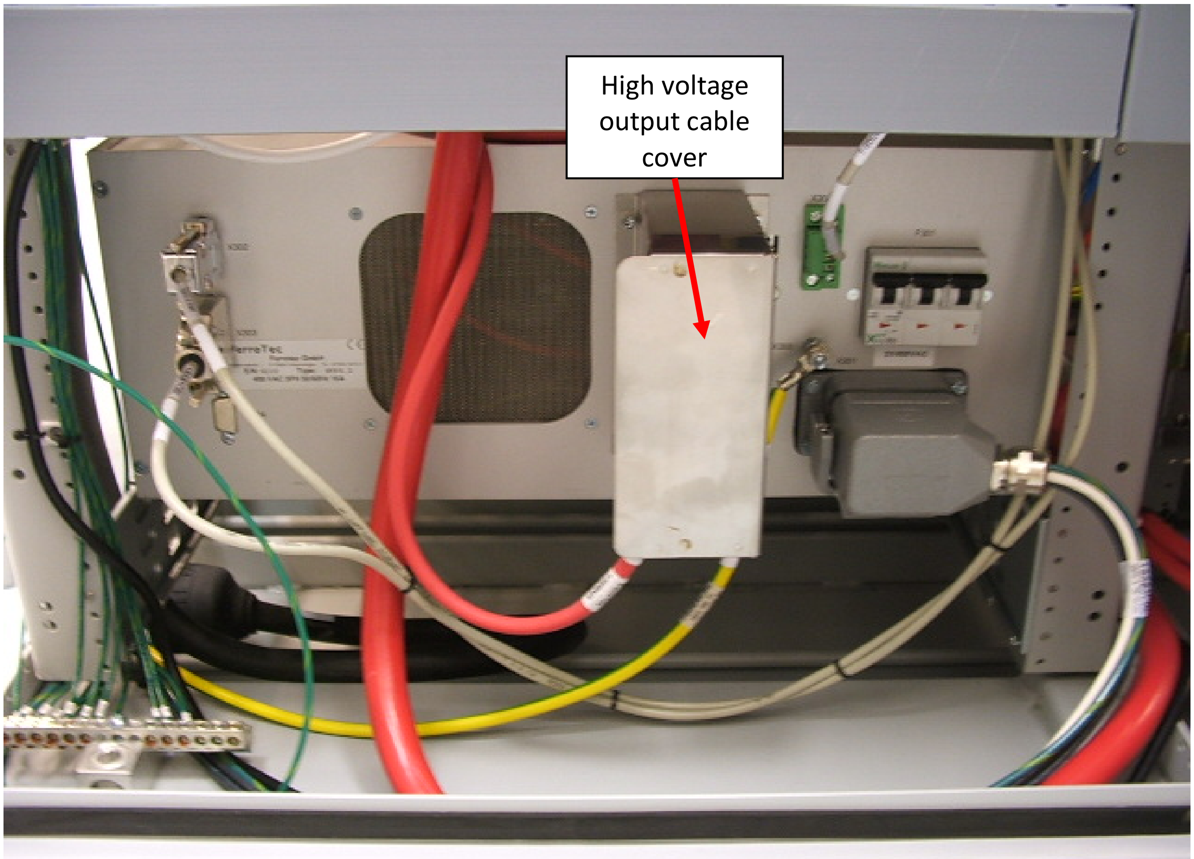


FIGURE 5



KL-6 COVER SWITCHES

OPERATION

Manual running of E-Beam through CWare

> ☝ On initial start-up of a system, follow the Initial Start-Up given in E-Beam Operator Manual, E-Beam Evaporator section, pages 39-42.

Before running E-Beam:

- Do not change High Voltage (HV) during process. If HV is changed, E-Beam limits will need to be reset as done in initial start-up. Failure to reset limits will result in Beam operating outside of crucible and could result in damage of equipment. The high voltage output cable cover must be in place correctly to make the cover switch before the High Voltage can be turned on. If not, the Interlock LED on the front panel will not turn on.
- It is recommended that a crucible not be filled with material by more than 2mm above the crucible edge to prevent Pocket Jamming Error. At least one-third of the crucible volume should remain filled during the process.
- When process starts, user should ensure the E-Beam is centered inside the crucible.
- System must be in Automatic/Remote mode.

KL-6 EXAMPLE

Following is a general example of how to manually run the KL-6 E-Beam through CWare. For this example, the E-Beam system has 4 pockets. Pocket 1 has a carbon crucible loaded with Titanium pellets.

1) Select Crucible 1 by pressing Cru Pos1 button. When Crucible is in position the feedback will turn green (Figure 1).

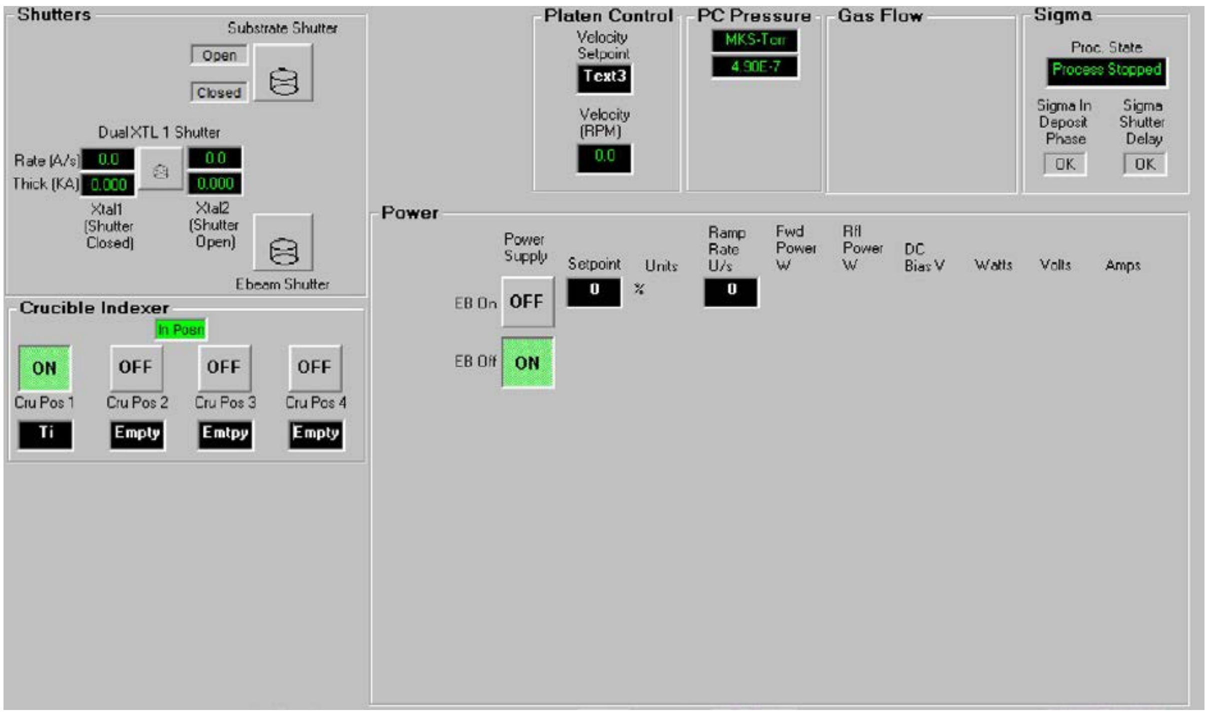


FIGURE 1

2) Open Sigma SQS242-Monitor software; this will be used to record deposition rate (Start> Programs> Sigma Instruments>SQS242-Monitor) OR with Sigma SQS242-CoDep running read rate by pull down (View>Sensor Readings).

Do not run both SQS242-CoDep and SQS242-Monitor programs at the same time.

3) Press the EB Off button and then press the EB On button. Note that the EB HV feedback will appear green; HV is now turned on.

EB On cannot be active unless power setpoint is 0% (Figure 2).

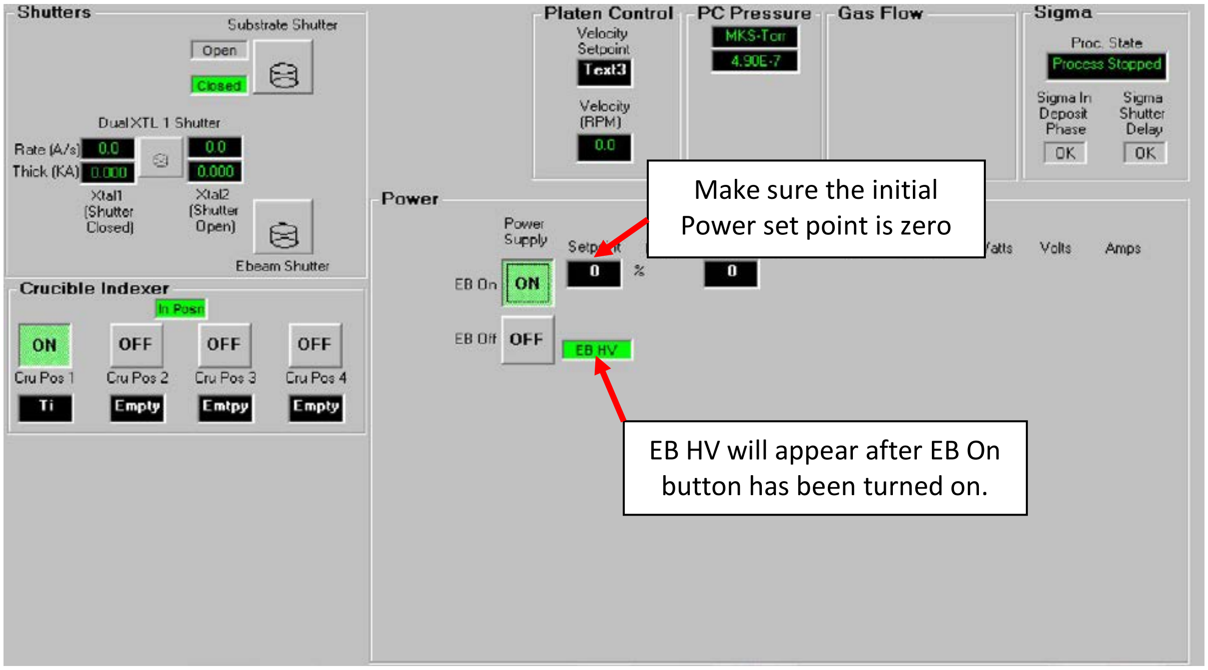


FIGURE 2

EB Power Setpoint is in percentage. The max amperage for the KL-6 is generally set to 500mA; therefore, 10% setpoint power is 50mA.

4) Increment the power setpoint (Emission Current) slowly, making sure the beam is centered in the pocket. Once the material has started its melt, open the E-Beam shutter by turning the E-beam shutter button on. Once the material has started to Melt, adjust the Setpoint to obtain the required rate of evaporation.

5) Once user has finished deposition, begin ramp down of power. Ramp down power setpoint by inputting a ramp value as seen in Figure 3. Next, the user will input 0 in the setpoint box.

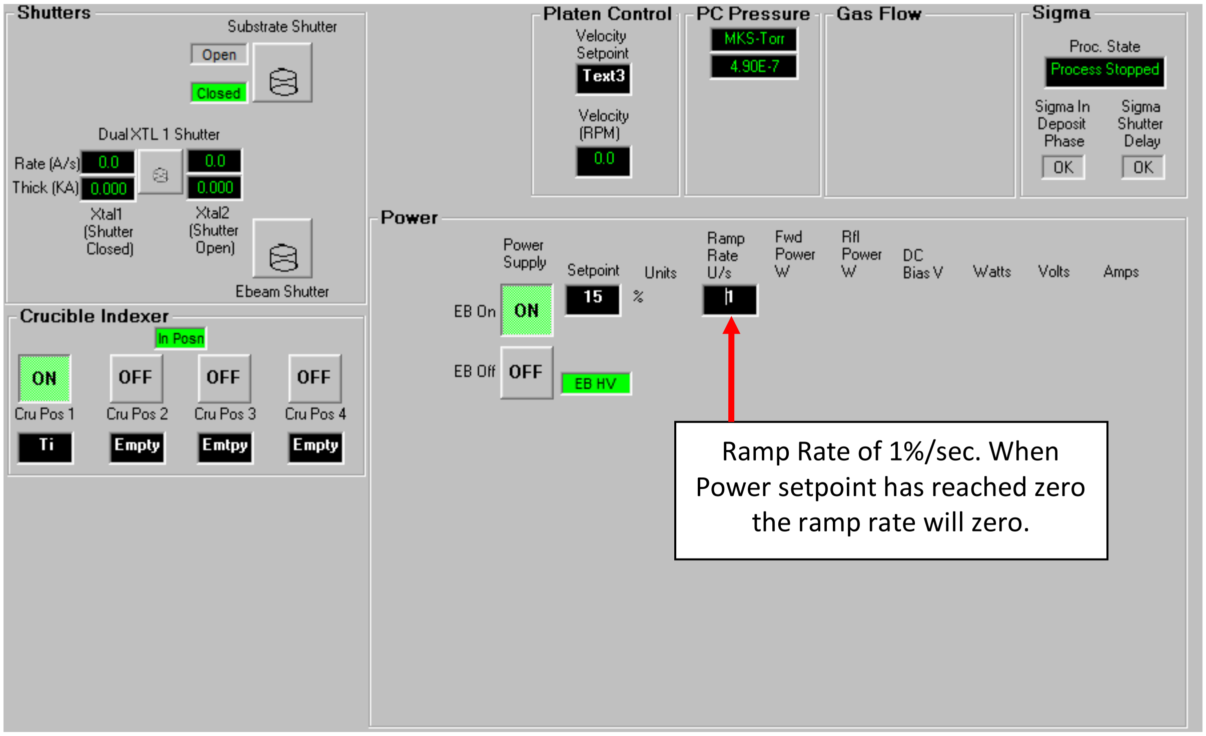


FIGURE 3

6) When ramp down to setpoint has completed, press EB Off button.

7) Press EB Off button. **NOTE:** Only when you press EB Off does the EB HV turn off.

RECIPE CONTROLLED DEPOSITION EXAMPLE WITH SIGMA (KL-6 E-BEAM)

Seq	Type	Equipment	EquipmentItem	EquipmentItemOperation	Test Value	GRST
1	-	Recipe	Set Abort Recipe	Abort Process		
2	-	Gauge	MKS979 WRG Pressure	Check Value <= n.nn	.000005	AT
3	-	Supply	Cru Pos 2	Turn_Off/Closed/Closing		
4	-	Supply	Cru Pos 3	Turn_Off/Closed/Closing		
5	-	Supply	Cru Pos 4	Turn_Off/Closed/Closing		
6	-	Supply	Cru Pos 1	Turn_On/Open/Opening		
7	-	Recipe	Dwell	HH:MM:SS)	15	
8	-	Supply	Crucible In Position	Check_On/Open/Opening		AT
9	-	Motors	SP	Set Value = n.nn	20	
10	-	Motors	Platen Motor On	Turn_On/Open/Opening		
11	-	Motors	Continuous +	Turn_On/Open/Opening		
12	-	Supply	Setpoint	Set Value = n.nn	0	
13	-	Supply	EB Off	Turn_Off/Closed/Closing		
14	-	Supply	EB On	Turn_On/Open/Opening		
15	-	Sigma	Mapping 1	Set Value = n.nn	16	
16	-	Sigma	Mapping 1	Set Value = n.nn	14	
17	-	Sigma	Mapping 2	Set Value = n.nn	16	
18	-	Sigma	Sigma Launch 242	Turn_On/Open/Opening		
19	-	Recipe	Dwell	5 Seconds		
20	-	Sigma	Sigma Control Request	Set Value = n.nn	0	
21	-	Recipe	Dwell	3 Seconds		
22	-	Sigma	Sigma Control Request	Set Value = n.nn	Titanium	
23	-	Recipe	Dwell	3 Seconds		
24	-	Sigma	Sigma Stop Process	Turn_Off/Closed/Closing		
25	-	Recipe	Dwell	2 Seconds		
26	-	Sigma	Sigma Start Process	Turn_On/Open/Opening		
27	-	Sigma	Sigma Process Stopped	Check_On/Open/Opening		AT
28	-	Supply	Setpoint	Set Value = n.nn	0	
29	-	Supply	EB On	Turn_Off/Closed/Closing		
30	-	Supply	EB Off	Turn_On/Open/Opening		
31	-	Motors	Platen Motor On	Turn_Off/Closed/Closing		
32	-	Motors	Continuous +	Turn_Off/Closed/Closing		

UNDERSTANDING THE KL-6 RECIPE

Step 1: Always the first step in a recipe; sets which Abort Recipe should be run in the event a step that has an AT (Abort on Time) fails.

Step 2: Waiting for a desired base pressure before deposition will run. In this case it is 5x10-6Torr.

Steps 3-8: Sets up Crucible for EB (3-6). Checks crucible is in position (8).

Steps 9-11: Set up substrate rotation.

Steps 12-14: Sets EB setpoint to zero and turns on EB HV.

Steps 15-27: Sets up Shutter mapping, launches Sigma program and requests that Sigma load a process (18-22).

Steps 28-30: Zero Setpoint and turn off EB HV.

Steps 31-32: Turn off motor.

265 MODEL EXAMPLE

Following is an example of how to manually run a 265 model E-Beam through CWare. In this example, the E-Beam system has 6 pockets. Pocket one has a carbon crucible loaded with Titanium pellets.

1) First Select Crucible 1 by pressing Cru Pos1 button. When Crucible is in position, Active or In Posn will turn green (Figure 1).

FIGURE 1

2) Open Sigma SQS242-Monitor software; this will be used to record deposition rate (Start> Programs> Sigma Instruments>SQS242-Monitor) OR with Sigma SQS242-CoDep running read rate by pull down (View>Sensor Readings).

Do not run both SQS242-CoDep and SQS242-Monitor programs at the same time.

3) Press (deactivate) the EB Off and EB HV Off buttons

4) Press (activate) the EB On and EB HV On buttons (Figure 2).

FIGURE 2

EB Power Setpoint is displayed in percentage. The max amperage for the 265 model E-Beam is generally set to 750mA; therefore, 10% setpoint power is 75mA.

5) Increment the power setpoint (Emission Current) slowly, making sure the beam is centered in the pocket. Open the E-Beam shutter once material begins to melt. Adjust the power setpoint to obtain the required rate of evaporation.
6) When deposition is complete, ramp back down EB power setpoint.
7) When setpoint is zero, press EB HV On button and EB On button.
8) Press EB Off button and EB HV Off button. (**NOTE:** You must press EB HV Off to turn EB HV Off).

RECIPE CONTROLLED DEPOSITION EXAMPLE WITH SIGMA (265 MODEL E-BEAM)

t	Type	Equipment	EquipmentItem	EquipmentItemOperation	Equipment/Test Value	GRST
1	-	Recipe	Set Abort Recipe	Abort Process		
2	-	Shutter	Ebeam Shutter	Turn_Off/Closed/Closing		
3	-	Shutter	Source Shutter 1	Turn_Off/Closed/Closing		
4	-	Motors	Platen Motor On	Turn_On/Open/Opening		
5	-	Motors	Platen Motor Go Home	Turn_On/Open/Opening		
6	-	Motors	Referenced	Check_On/Open/Opening		AT
7	-	Motors	SP	Set Value = n.nn	1	
8	-	Motors	Station	Turn_On/Open/Opening		
9	-	Motors	Platen Motor Position	Check Value <= n.nn	1	AT
10	-	Motors	Planet Motor On	Turn_On/Open/Opening		
11	-	Motors	Velocity SP	Set Value = n.nn	10	
12	-	Motors	Continuous +	Turn_On/Open/Opening		
13	-	Motors	Planet Motor Moving	Check_On/Open/Opening		AT
14	-	Supply	Cru Pos 2	Turn_Off/Closed/Closing		
15	-	Supply	Cru Pos 3	Turn_Off/Closed/Closing		
16	-	Supply	Cru Pos 4	Turn_Off/Closed/Closing		
17	-	Supply	Cru Pos 5	Turn_Off/Closed/Closing		
18	-	Supply	Cru Pos 6	Turn_Off/Closed/Closing		
19	-	Supply	Cru Pos 1	Turn_On/Open/Opening		
20	-	Supply	Crucible In Position 1	Check_On/Open/Opening		AT
21	-	Supply	Setpoint	Set Value = n.nn	0	
22	-	Supply	EB HV Off	Turn_Off/Closed/Closing		
23	-	Supply	EB HV On	Turn_On/Open/Opening		
24	-	Supply	EB Off	Turn_Off/Closed/Closing		
25	-	Supply	EB On	Turn_On/Open/Opening		
26	-	Sigma	Mapping 1	Set Value = n.nn	16	
27	-	Sigma	Mapping 1	Set Value = n.nn	1	
28	-	Sigma	Sigma Control Request	Set Value = n.nn	Titanium test	
29	-	Sigma	Sigma Process Name	Check Value <= n.nn	Titanium test	AT
30	-	Sigma	Sigma Load Process	Turn_On/Open/Opening		
31	-	Sigma	Sigma Start Process	Turn_On/Open/Opening		
32	-	Sigma	Sigma In Process	Check_On/Open/Opening		AT
33	-	Sigma	Sigma In Process	Check_Off/Closed/Closing		GT
34	-	Supply	Rate	Set Value = n.nn	100	
35	-	Supply	Setpoint	Set Value = n.nn	0	
36	-	Supply	EB On	Turn_Off/Closed/Closing		
37	-	Supply	EB Off	Turn_On/Open/Opening		
38	-	Supply	EB HV On	Turn_Off/Closed/Closing		
39	-	Supply	EB HV Off	Turn_On/Open/Opening		
40	-	Motors	Continuous +	Turn_Off/Closed/Closing		
41	-	Motors	Planet Motor On	Turn_Off/Closed/Closing		

UNDERSTANDING THE 265 MODEL RECIPE

Step 1: Always the first step in a recipe, sets which Abort Recipe should be run in the event a step that has an AT (Abort on Time) fails.

Steps 2-3: Close both shutters. To ensure that no deposition reaches the substrate before material, conditioned and required rate obtained.

Steps 4-13: Sets Platen and Planet position. Sets angle of substrate and rotation.

Steps 14-25: Turns off all other crucibles. Step 19 turns on Crucible 1, which is the pocket needed for this deposition (14-19). Checks Crucible is in Position (20). Sets Setpoint to zero (21). Turns on EB HV (22-25).

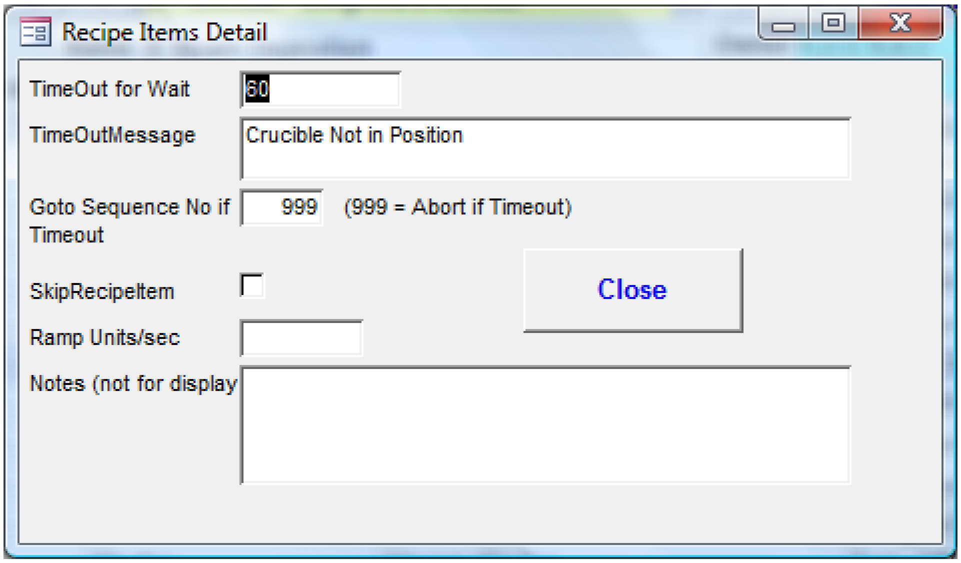
Steps 26-33: Steps 26-27 set up the Sigma shutter mapping. Steps 28-30 request Sigma to load a process named Titanium Test and verifies if the correct process has been loaded. Steps 31-33 run process called Titanium Test. (Note: For the Go To Step (33) the time needs to be set longer than it takes for the sigma process file to finish).

Steps 34-39: Zero Setpoint then turn off EB HV and EB.

Steps 40-41: Turns off motors.

ABORT IF TIMEOUT AND GOTO SETUP

When creating a recipe you can set an Abort if Timeout or Goto from the GRST column. This can be created by clicking inside the cell on the GRST column of the step you want to add the Abort if TimeOut (AT) or GoTo (GT). The following box will appear:



TimeOut for Wait: User can limit the number of seconds the recipe will check at this step.

TimeOutMessage: User information message.

Goto Sequence No if Timeout: This is the step number the recipe will go to next when TimeOut for Wait hits zero. If the user inputs 999 the abort recipe last set (usually set at step 1) will run when TimeOut for Wait hits zero.

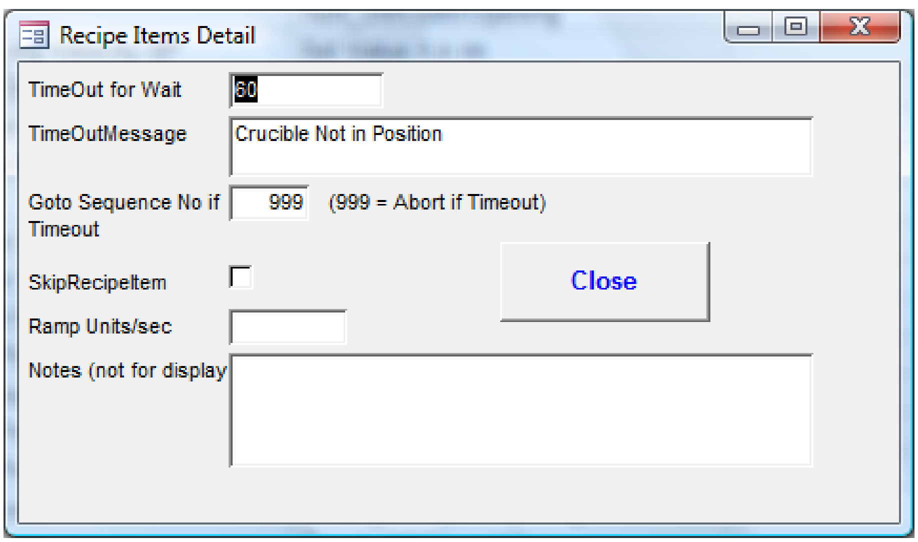
SkipRecipeItem: If checked, the step will be ignored when recipe is running.

Ramp Units/sec: Not used

Notes (not for display): Not used.

ABORT IF TIMEOUT EXAMPLE

SEQ	Equipment	EquipmentItem	EquipmentItemOperation	Equipment Test Value	GRST
1	Recipe	Set Abort Recipe	Abort Process		
2	Power Supply	Cru Pos 2	Turn_Off/Closed/Closing		
3	Power Supply	Cru Pos 3	Turn_Off/Closed/Closing		
4	Power Supply	Cru Pos 4	Turn_Off/Closed/Closing		
5	Power Supply	Cru Pos 1	Turn_On/Open/Opening		
6	Inputs	Crucible In Position	Check_On/Open/Opening		AT



ABORT IF TIMEOUT SET-UP

Step 1: Set the Abort recipe, Abort Process.

Steps 2-4: Turn off crucible positions 2, 3 and 4.

Step 5: Turn on crucible position 1.

Step 6: Check step. Recipe will verify that Crucible In Position is on for 60 sec. If Crucible In Position signal fails to be on when checked (feedback that says pocket is in position) then it will run the Abort Process Recipe as 999 is inputted in GotoSequence.

MATERIAL REPLENISHING

⚠ DANGER DO NOT operate or service the E-Beam before reading and understanding the E-Beam operation manual. Failure to comply may result in danger to user, damage of equipment and void the warranty.

1) Follow the E-Beam shutdown procedure as outlined in the manufacturer's operation manual.
2) Vent the vacuum chamber.
3) Ground all high voltage F/T with the discharge rod.
4) Replenish crucible. Crucible should generally not be filled with material by more than 2mm above the crucible edge. At least one-third of the crucible volume should remain filled during the process.

CLEANING AND MAINTENANCE

⚠ DANGER DO NOT operate or service the E-Beam before reading and understanding the E-Beam operation manual. Failure to comply may result in danger to user, damage of equipment and void the warranty.

1) Follow the E-Beam shutdown procedure as outlined in the manufacturer's operation manual.
2) See manufacturer's operation manual for general maintenance of individual components.

GLOSSARY

ABBREVIATION	DESCRIPTION
EB	Electron Beam
Cru Pos	Crucible Position
HV	High Voltage
EB HV	E-Beam High Voltage
F/T	Feedthrough

LTE/HTE FURNACE OPERATION

DANGER DO NOT operate the LTE/HTE Furnace before reading and understanding all pertinent component manuals.

1) Inspect all electrical connections between the LTE/HTE Furnace power supply and LTE/HTE Furnace source and all in-vacuum electrical and vacuum connections to the LTE/HTE Furnace source.
2) Place a loaded crucible into the pocket of the source, and ensure that the cover is installed properly into the source base. Ensure that the loaded crucible is centralized in the source cover.

DANGER Some low temperature evaporation materials are known carcinogens. Refer to all MSDS sheets for safe handling and appropriate breathing equipment and ventilation.

3) Check to see that LTE/HTE Furnace source is positioned correctly to deposit on the substrate.
4) Evacuate chamber to < 5.0e-06 Torr.

☝ Although the LTE/HTE Furnace will work under any high vacuum condition, it is recommended to start at a pressure of < 5.0e-06 Torr.

5) Precondition the material in the crucible by raising the temperature of the source to a temperature or power level just below the appearance of rate on the deposition monitor.
6) Let source stabilize at precondition temperature for at least 5 minutes.
7) Heat source to desired deposition rate by raising the temperature or power level on the supply.
8) Open the substrate / source shutter and 0 the thickness monitor.

☝ Refer to film thickness control / monitor's operating manual for detailed instructions.

9) When the desired thickness is achieved on the monitor, close the shutter and reduce heat in the source.
10) Allow source to cool prior to venting system.

DANGER Use caution when removing the substrate from the chamber, it may be hot.

THERMAL SOURCE SETUP AND OPERATION

EVAPORATION is the process whereby atoms or molecules in a liquid state (or solid state if the substance sublimes) gain sufficient energy to enter the gaseous state. The thermal motion of a molecule must be sufficient to overcome the surface tension of the liquid in order for it to evaporate; that is, its kinetic energy must exceed the work function of cohesion at the surface. Evaporation therefore proceeds more quickly at higher temperature and in liquids with lower surface tension.

SAFETY

⚠ DANGER DO NOT operate or service the Thermal Source(s) before reading and understanding the operation manual.

1) Visually inspect equipment daily for water leaks, equipment condition.
2) Thermal equipment operates with a low voltage, high current power supply. Make certain that proper LOTO procedures are followed prior to servicing.

⚠ DANGER Use caution when removing the substrate from the chamber, it may be hot.

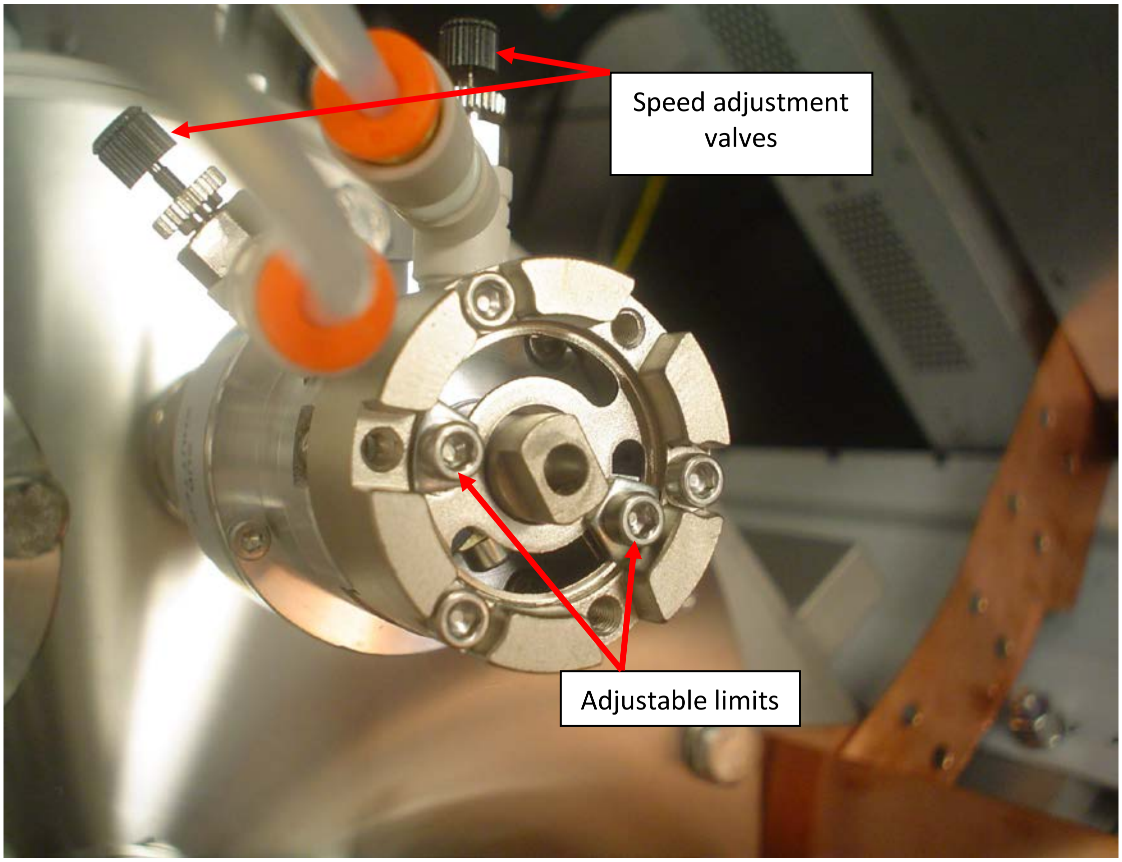
SETUP

Over time you may need to adjust the shutter limits or speed of open/close.

SHUTTER SPEED ADJUSTMENT

1) Start by closing the speed adjustment valves (clockwise). See Fig below.
2) Now toggle the shutter to open. (The shutter should not open yet)
3) Check which airline has pressure on it and adjust the other speed valve counter-clockwise slowly until the shutter opens.
4) Now toggle the shutter to close. (The shutter should not close yet)
5) Adjust the other speed control valve counter-clockwise slowly until the shutter closes.
6) Recheck the shutter open and close and adjust the speed valves so that the shutter operates smoothly.

SHUTTER LIMIT ADJUSTMENT



Using these two adjustable limits shown above, you can set the shuttered position (closed) and open position.

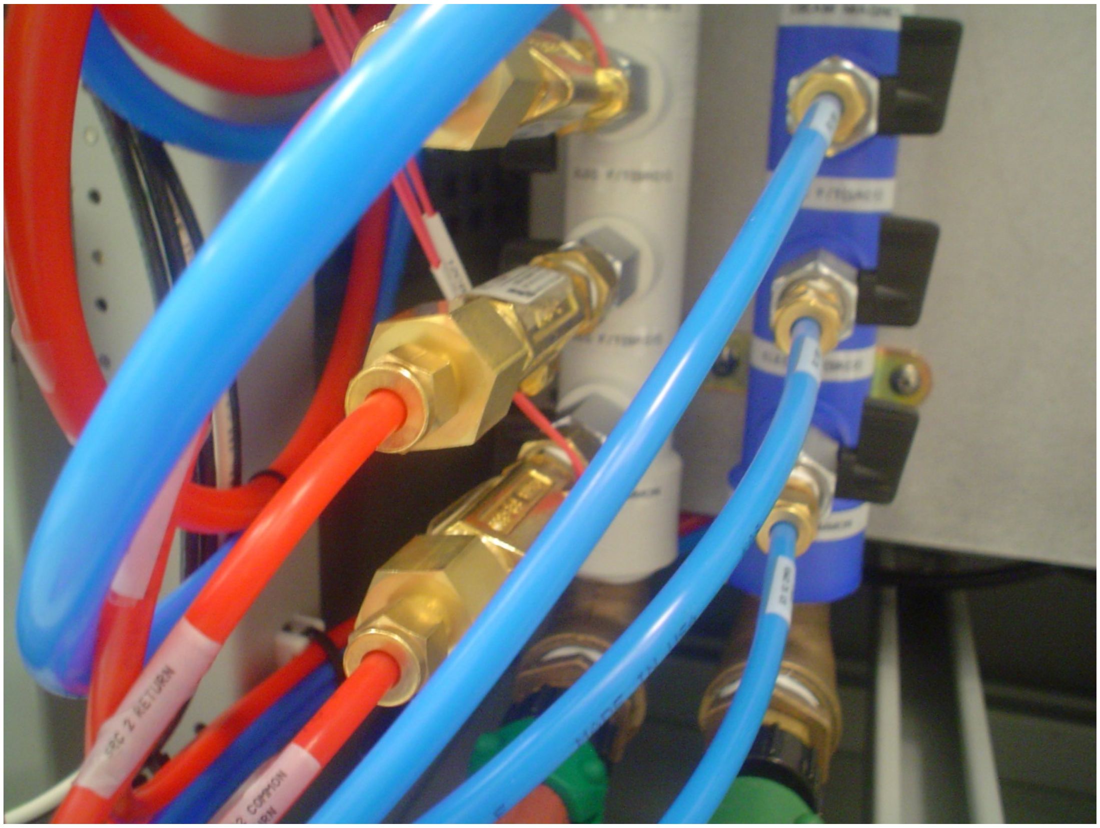
SYSTEM EQUIPMENT REQUIREMENTS

Each Thermal Source(s) system needs the below interlocks to be satisfied in order to work.

- Water Flow Sensors (if equipped)
- Vacuum monitor
- System Pressure requirements

WATER FLOW SENSORS

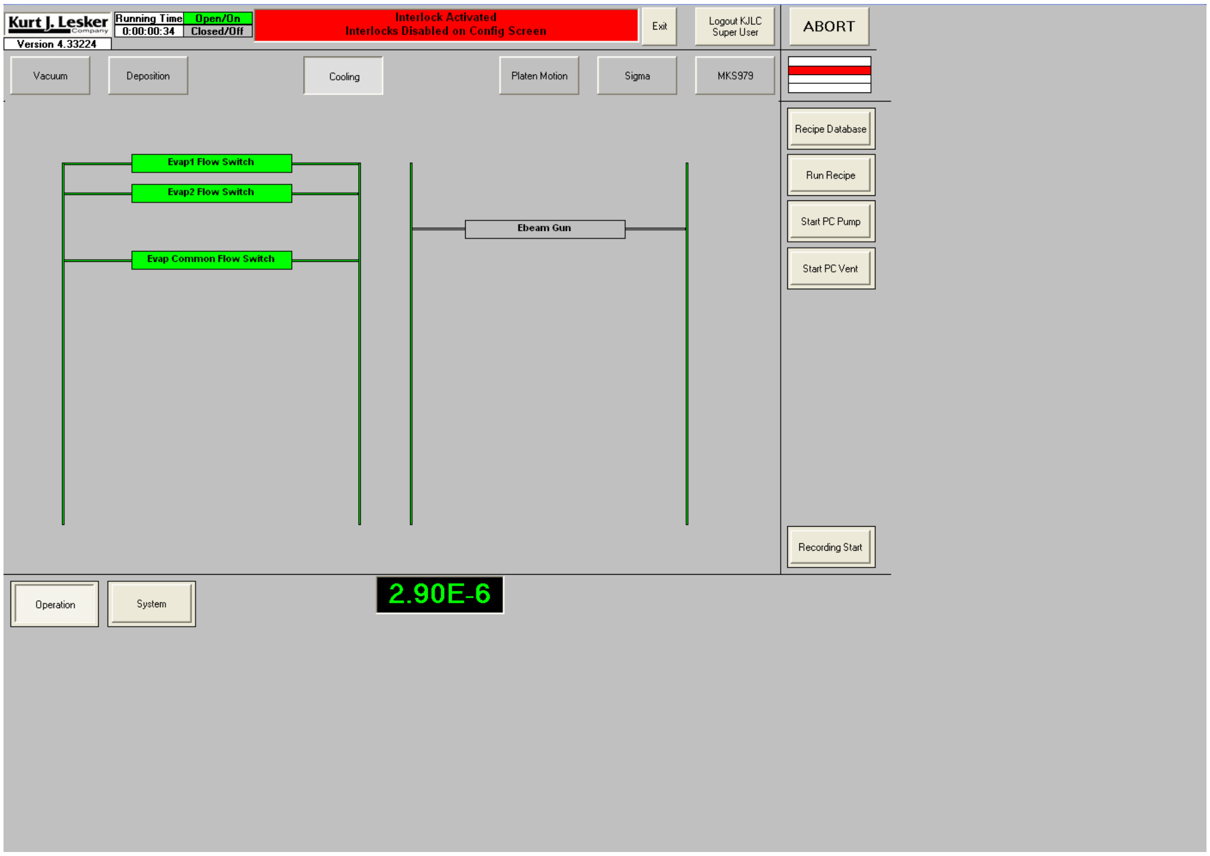
Usually located on the water return line of the system water manifold (see picture below).



WATER FLOW SENSORS

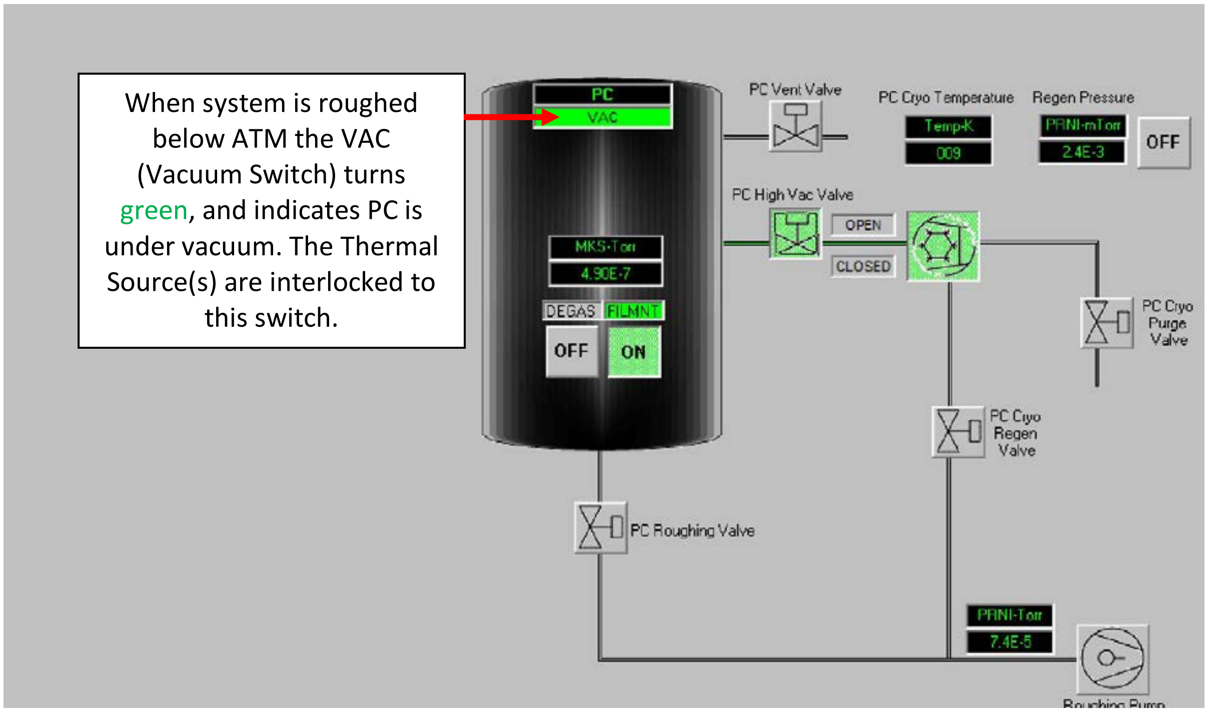
Depending on the number of Thermal Source(s) the system has, it may or may not be equipped with water flow switches. If equipped, there may be more than one water flow switch installed along with a common flow switch. When the water supply and return valves are open, the water flow switches should be satisfied. This can be confirmed by checking the cooling screen in Cware. The flow switch will change from gray to green when satisfied.

☝ The Evap1 Flow Switch, Evap 2 Flow Switch and Evap Common Flow Switch icons are illuminated or green, indicating the flow switches are made.



WATER FLOW COOLING SWITCH

If the water supply and return valves are fully open and the flow switch is not shown as made on Cware (illuminated green), then check that the utilities water pressure and flow rate meets spec. If the utilities are within spec then call KJLC Service Dept.



VACUUM MONITOR

PRESSURE REQUIREMENTS

Thermal Source systems are hard-wire interlocked to the VAC switch. The KJLC software interlock for minimum operation pressure is 5x10-3Torr, although the recommended optimum pressure is 5x10-5Torr or better.

OPERATION

MANUAL OPERATION

☝ Before running Thermal Source manually thru Cware software:

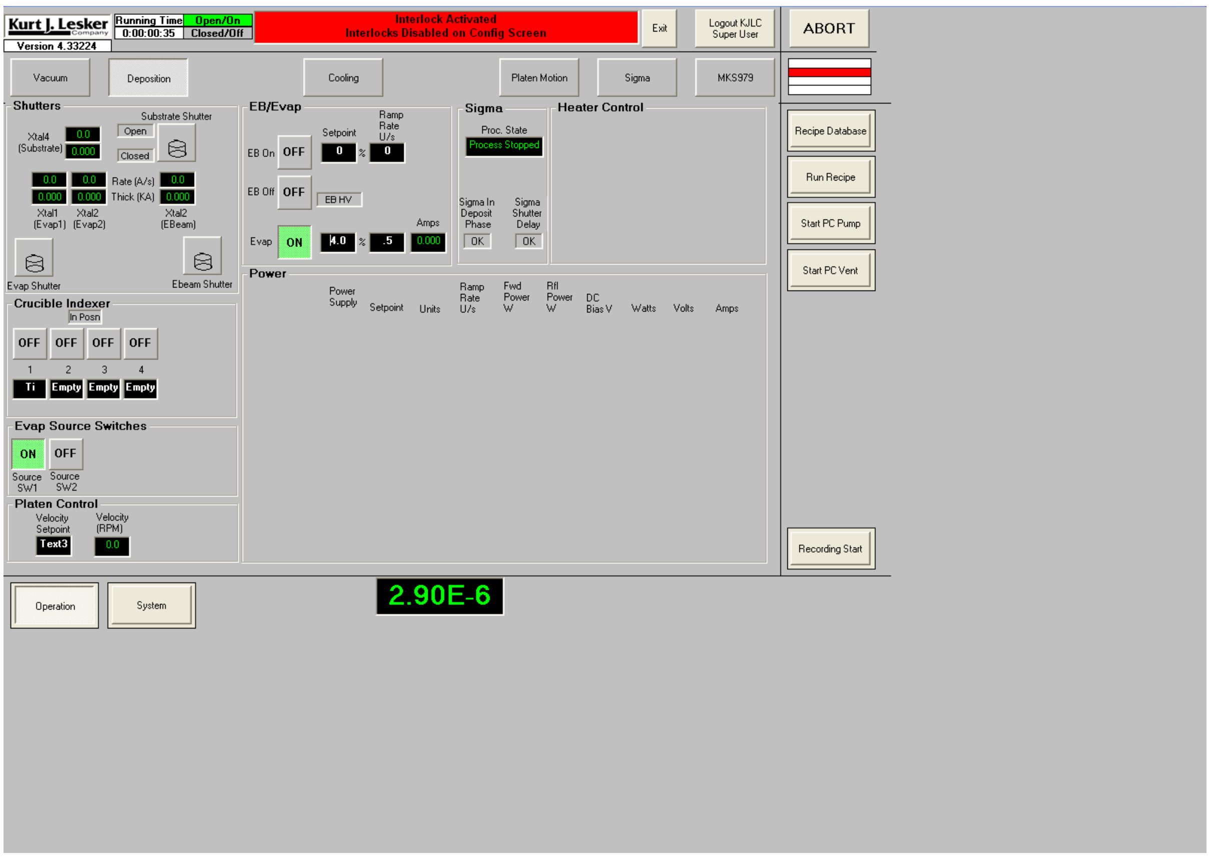
- Make certain that thermal boats, crucible heaters, wire basket filaments, etc., are securely fastened to thermal feed through with associated hardware before proceeding.
- Make certain that the thermal boats/crucible heaters, wire basket filaments, etc., are not shorted against any deposition shielding or chamber wall before proceeding.
- If using a crucible heater, make certain that the "ends" or open heat shield surrounding the crucible are not shorted. This most likely occurs when affixing the heater to the feed through post when tightening the socket head cap screw.
- Do not change Thermal Source switch position during process. This action is protected by interlocks to prevent such occurrences.
- Make certain the deposition system is at an acceptable vacuum level before attempting deposition for best results.

The following example demonstrates the procedure to manually run the Thermal Source through Cware:

1) With the "Evap" button "Off" or not depressed, change the Evap Set Point value and Ramp Rate U/s value to "0", if not already in that state.
2) Select which source you would like to run (either Source SW1 or Source SW2) by depressing the appropriate button. This button will turn green when "On" or energized.
3) Depress the Evap button to energize the power supply. This button will turn green when "On" or energized.
4) Once energized, the operator can increase power in two manners (with and without a ramp rate):
   a) Ramp Rate Operation: The operator must enter a value from (0~100) in the Ramp Rate U/s text box. This box interprets the value entered in "Units per Second". After performing this function, the operator then will enter a value from (0~100) into the % Power text box. This value is interpreted as 0 to 100 % available power. This order of steps will increase the output power to the thermal sources utilizing the ramp rate entered until the maximum % power has been reached. Once this maximum has been reached, the Ramp Rate text box will revert to a "0". To reduce power utilizing the ramp rate, perform the function in the same order. Enter a Ramp Rate value first, then a % power.

☝ If the % Power is entered first, then the Ramp Rate, the software will ignore the Ramp Rate and proceed directly to the % Power entered.

b) No Ramp Rate Operation: The operator can enter a value (0~100) in the % Power text box. Performing this function will allow the output Power to immediately increase to the percentage of Power entered **without** a Ramp Rate.



The picture above depicts Source SW1 energized, the Evap Power supply energized via the "On" button, a ramp rate of .5U/s entered, and the Setpoint box ramping up.

RECIPE CONTROLLED OPERATION

RECIPE CONTROLLED DEPOSITION WITHOUT SIGMA

frmRecipeItems						
Seq	Type	Equipment	EquipmentItem	EquipmentItemOperation	Equipment/Test Value	GRST
1	-	Recipe	Set Abort Recipe	Abort Default		
2	-	Gauge	MKS979 WRG Pressure	Check Value <= n.nn	.00005	AT
3	-	Source	Source SW2	Turn_Off/Closed/Closing		
4	-	Source	Source SW1	Turn_On/Open/Opening		
5	-	Shutter	Evap Shutter	Turn_Off/Closed/Closing		
6	-	Shutter	Substrate Shutter	Turn_Off/Closed/Closing		
7	-	Motors	Platen Motor Jog Velocity SP	Set Value = n.nn	20	
8	-	Motors	Platen Motor On	Turn_On/Open/Opening		
9	-	Motors	Platen Motor Go Continuous +	Turn_On/Open/Opening		
10	-	Power Supply	Power Supply1 Ramp Rate	Set Value = n.nn	0	
11	-	Power Supply	Power Supply1 Output Setpoint	Set Value = n.nn	0	
12	-	Power Supply	Power Supply 1	Turn_On/Open/Opening		
13	-	Power Supply	Power Supply1 Ramp Rate	Set Value = n.nn	.5	
14	-	Power Supply	Power Supply1 Output Setpoint	Set Value = n.nn	20	
15	-	Recipe	Dwell	N Seconds (n or HH:MM:SS)	60	
16	-	Power Supply	Power Supply1 Output Setpoint	Check Value > n.nn	19.5	AT
17	-	Recipe	Dwell	N Seconds (n or HH:MM:SS)	30	
18	-	Shutter	Evap Shutter	Turn_On/Open/Opening		
19	-	Shutter	Substrate Shutter	Turn_On/Open/Opening		
20	-	Recipe	Dwell	N Seconds (n or HH:MM:SS)	60	
21	-	Shutter	Substrate	Turn_Off/Closed/Closing		

frmRecipeItems						
Seq	Type	Equipment	EquipmentItem	EquipmentItemOperation	Equipment/Test Value	GRST
			Shutter			
22	-	Shutter	Evap Shutter	Turn_Off/Closed/Closing		
23	-	Power Supply	Power Supply1 Ramp Rate	Set Value = n.nn	.5	
24	-	Power Supply	Power Supply1 Output Setpoint	Set Value = n.nn	0	
25	-	Recipe	Dwell	N Seconds (n or HH:MM:SS)	60	
26	-	Power Supply	Power Supply1 Output Setpoint	Check Value <= n.nn	1	AT
27	-	Power Supply	Power Supply 1	Turn_Off/Closed/Closing		
28	-	Motors	Platen Motor Go Continuous +	Turn_Off/Closed/Closing		

UNDERSTANDING THE CWARE RECIPE

Step 1: Always the first step in a recipe, sets which Abort Recipe should be run in the event a check step that has an AT (Abort on Time) fails.

Step 2: Waiting for a desired base pressure before deposition will run. In this case 5x10-5Torr.

Steps 3-6: Sets up appropriate source switch, closes system shutters.

Steps 7-9: Set up substrate rotation.

Steps 10-12: Zero's the Ramp Rate text box and the % Setpoint text box, turns "On" Power Supply.

Steps 13-14: Sets Ramp Rate text box to .5U/s, and enters a value of 20% in the Setpoint text box.

Steps 15-16: Sets a dwell time of 60 seconds and checks that the % Setpoint is > (greater than) 19.5 after the dwell time has elapsed.

Steps 17-19: Additional 30 second Dwell time for material temp to equilibrate and turn "On" or activation of both Evap and Substrate shutters.

Steps 20-22: Deposition dwell for 60 seconds followed by closing of the Substrate and Evap shutter.

Steps 23-24: Sets Ramp Rate text box to .5 U/s, and enters a value of 0% in the Setpoint text box.

Steps 25-26: Sets a dwell time of 60 seconds and checks that the % Setpoint is <= (less than or equal to) 1 after the dwell time has elapsed.

Step 27: Turns "Off" the Power Supply.

Step 28: Turn "Off" motor Go Continuous +.

RECIPE CONTROLLED DEPOSITION WITH SIGMA

frmRecipeItems

Seq	Type	Equipment	EquipmentItem	EquipmentItemOperation	Equipment/Test Value	GRST
1	-	Recipe	Set Abort Recipe	Abort Default		
2	-	Gauge	MKS979 WRG Pressure	Check Value <= n.nn	.00005	AT
3	-	Source	Source SW2	Turn_Off/Closed/Closing		
4	-	Source	Source SW1	Turn_On/Open/Opening		
5	-	Shutter	Evap Shutter	Turn_Off/Closed/Closing		
6	-	Shutter	Substrate Shutter	Turn_Off/Closed/Closing		
7	-	Motors	Platen Motor Jog Velocity SP	Set Value = n.nn	20	
8	-	Motors	Platen Motor On	Turn_On/Open/Opening		
9	-	Motors	Platen Motor Go Continuous +	Turn_On/Open/Opening		
10	-	Power Supply	Power Supply1 Ramp Rate	Set Value = n.nn	0	
11	-	Power Supply	Power Supply1 Output Setpoint	Set Value = n.nn	0	
12	-	Power Supply	Power Supply 1	Turn_On/Open/Opening		
13	-	Sigma	Sigma Launch 242	Turn_On/Open/Opening		
14	-	Sigma	Sigma Shutter Delay Mapping 1	Set Value = n.nn	17	
15	-	Sigma	Sigma Shutter Deposit Mapping 1	Set Value = n.nn	14	
16	-	Sigma	Sigma Control Request	Set Value = n.nn	Ag EVAP 4KW	
17	-	Sigma	Sigma Stop Process	Turn_Off/Closed/Closing		
18	-	Recipe	Dwell	3 Seconds		
19	-	Sigma	Sigma Load Process	Turn_On/Open/Opening		
20	-	Sigma	Sigma Start Process	Turn_On/Open/Opening		
21	-	Sigma	Sigma In Process	Check_On/Open/Opening		AT
22	-	Sigma	Sigma In Process	Check_Off/Closed/Closing		AT
23	-	Power Supply	Power Supply1 Ramp Rate	Set Value = n.nn	0	
24	-	Power Supply	Power Supply1 Output Setpoint	Set Value = n.nn	0	
25	-	Power Supply	Power Supply 1	Turn_Off/Closed/Closing		
26	-	Motors	Platen Motor Go Continuous +	Turn_Off/Closed/Closing		

UNDERSTANDING THE SIGMA CONTROLLED CWARE RECIPE

Step 1: Always the first step in a recipe, sets which Abort Recipe should be run in the event a check step that has an AT (Abort on Time) fails.

Step 2: Waiting for a desired base pressure before deposition will run. In this case 5x10-5Torr.

Steps 3-6: Sets up appropriate source switch and closes system shutters.

Steps 7-9: Sets up substrate rotation.

Steps 10-12: Zeroes the Ramp Rate text box and the % Setpoint text box; turns “On” Power Supply.

Steps 13-15: Launches (turns on) Sigma control via KJLC software, and sets both the shutter delay and shutter deposit mapping to the correct values. (This ensures that the correct shutters are actuated via Sigma control).

Step 16: Sets the value (Sigma Control request) to the appropriate program from Sigma for which to would like to run. **<u>NOTE:</u> This name (Ag EVAP 4KW for example) must match the process in Sigma exactly!**

Steps 17-18: Turns the Stop Process signal “Off” and then dwells for 3 seconds.

Steps 19-20: Loads the Sigma Control request for which to run and Starts the Sigma Process.

Step 21: Checks that the Sigma Process is running or “In Process”

Step 22: Checks that the Sigma Process has ‘Stopped”

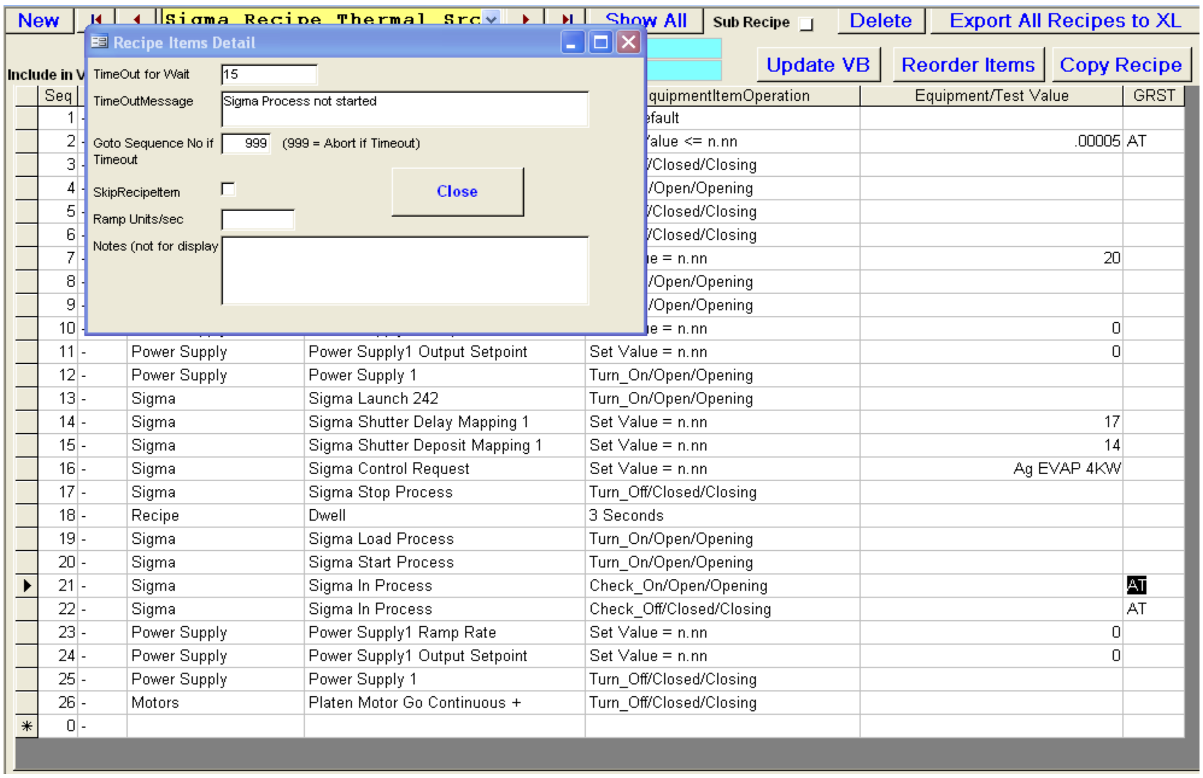
Steps 23-24: Sets Ramp Rate text box to 0 U/s, and enters a value of 0% in the Setpoint text box.

Step 25: Turns “Off” the Power Supply.

Step 26: Turn “Off” motor Go Continuous +.

ABORT IF TIMEOUT AND GOTO SETUP

When creating a recipe, the Abort if Timeout or Goto from the GRST column can be set. Click inside the cell on the GRST column of the step you want to add the Abort if TimeOut (AT) or Goto (GT). The following box will appear:



ABORT IF TIMEOUT

- Recipe Step 21 is used for this example. The “Recipe Items Detail “box is explained below.
- This Abort step allows 15 seconds to elapse before aborting (TimeOut for Wait).
- If the “Sigma In Process” step has not initiated after 15 seconds, the “Abort Recipe” will run and the message written in the “TimeOutMessage” box will be displayed (Sigma Process not Started).
- Inputting the value of “999” in the “Goto Sequence No. if Timeout” textbox will run the Abort Recipe.

MATERIAL REPLENISHING

1) Allow the thermal source (boat/crucible/wire filament/etc.) to adequately cool prior to venting the Chamber.
2) Make certain the thermal source is "Off" or de-energized and that both the "Ramp Rate U/s and % Setpoint boxes have "0" values entered.
3) Vent the Vacuum Chamber to atmosphere.
4) Turn off the associated circuit breaker for the thermal source.
5) Replenish the thermal source with applicable material.

CLEANING AND MAINTENANCE

1) Allow the thermal source (boat/crucible/wire filament/etc.) to adequately cool prior to venting the Chamber.
2) Make certain the thermal source is "Off" or de-energized and that both the "Ramp Rate U/s and % Setpoint boxes have "0" values entered.
3) Turn off the associated circuit breaker for the thermal source.
4) Use "Scotchbrite" brand or equivalent to remove deposition from thermal source feedthrough points.
5) Sandblast deposition shields and shutters to remove condensate.
6) Adequately clean "sandblasted" materials (shutters/deposition shields) with IPA and lint free wipes prior to reinsertion in vacuum chamber.
7) Use vented hardware on thermal feed thru posts if replacements are needed.

KAUFMAN & ROBINSON ION BEAM SOURCE OPERATION

This procedure details the operation of Kaufman & Robinson Ion Beam (KRI) sources in conjunction with KJLC CWare software. The following are examples of operating modes and are for reference only. The KRI manual should be used as a reference for specific process details.

There are two modes of operation for the discharge:

- Constant Current Mode: Allows for small variations in the discharge voltage while maintaining a constant current and is recommended when operating at 120V and below.
- Constant Voltage Mode: Will allow for small variations in discharge current while maintaining a constant voltage and is recommended when operating at 120V and above.

ION GUN POWER SUPPLY

CONSTANT CURRENT MODE

The operating condition selected for this demonstration is with a 2.5A, 120 V, discharge, which is Constant Current Mode operation. These conditions are based on a vacuum pump speed of 800 liters per second. Operating parameters for other pump speeds and gases can be found in the Ion Source Manual. Note that the operating range of the ion source may be limited by the vacuum facility pump speed or other process that take place while the ion source is running.

1) From the GUI Gas screen, turn on the “Ion Source Gas Valve”
2) Turn “On” the KRI Auto Controller via rocker switch manually.
3) Turn “On” the KRI Filament Controller via rocker switch manually.
4) Turn “On” the KRI Discharge Controller via rocker switch manually.
5) Place the KRI Auto Controller in “Local” Mode
6) Place the KRI Filament Controller in “Local” Mode
7) Place the KRI Discharge Controller in “Local” Mode
8) From the KRI Auto Controller, change the Operating mode to “Gas Only”.
9) From the KRI Auto Controller, select “Gas 1” using the white Gas Channel Select Button.
10) From the KRI Auto Controller, turn the “Gas Adjust Knob” until 10 sccm is displayed on the SCCM display.
11) From the KRI Filament Controller, turn the “Emission Adjust Knob” until 2.7 amps is indicated in the Emission Amps display. Note that the filament emission is usually set equal to or up to 10% greater than the discharge current.
12) From the KRI Discharge Controller, use the white “Select” button to select Volts.
13) From the KRI Discharge Controller, turn the “Setpoint Adjust Knob” until the discharge voltage is at its maximum reading as indicated on the Discharge Volts display.
14) From the KRI Discharge Controller, use the white “Select” button to select Amps.
15) From the KRI Discharge Controller, turn the “Setpoint Adjust Knob” until the discharge current is set to 2.5 amps as indicated on the Discharge Amps display.
16) From the KRI Auto Controller, press the white “Enable/Standby Button” to “Enable”.
17) From the KRI Filament Controller, press the white “Enable/Standby Button” to “Enable”.
18) From the KRI Discharge Controller, press the white “Enable/Standby Button” to “Enable”.
19) From the KRI Auto Controller, adjust the gas flow using the “Gas Adjust Knob” until the discharge voltage is approximately 120 V as read from the KRI Discharge Controller.
20) Operate the ion source for at least 10 minutes to clean any contaminates from the ion source that may have been introduced while at atmosphere.

21) The discharge voltage (as read from the KRI Discharge Controller) will vary slightly during this time. Adjust the gas flow (from the KRI Auto Controller) after the 10 minutes to obtain a discharge voltage of approximately 120 V (as read from the KRI Discharge Controller).

> At this point the operating conditions can be saved as a program (on the KRI Auto Controller) to be used later in the "Manual Gas" mode. To save this program, first press the white "Program Select" button (located on the KRI Auto Controller) repeatedly until the desired program number is selected as indicated by the numbered red LED's. From the KRI Auto Controller, press and hold the white "Acquire Setpoints Button" until the red numbered LED that was selected stops flashing.

To Turn the Ion Source Off:

1) From the KRI Discharge Controller, press the white "Enable/Standby" button to "Standby".
2) From the KRI Filament Controller, press the white "Enable/Standby" button to "Standby".
3) From the KRI Auto Controller, press the white "Enable/Standby" button to "Standby".
4) Restarting the ion source in the **"Gas Only" mode** consists of enabling the KRI Auto Controller, KRI Filament Controller and KRI Discharge Controller (in that order). Slight variations in discharge voltages may be seen while the source is reaching operating temperature. The variations should be acceptable for most cleaning or ion-assist applications.

CONSTANT VOLTAGE MODE

The operating condition selected for this demonstration is with a 2.5 A, 150 V discharge which is Constant Voltage Mode operation. The following conditions are based on a vacuum pump speed of 1600 liters per second. Operating parameters for other pump speeds and gases can be found in the Ion Source Manual. Note that the operating range of the ion source may be limited by the vacuum facility pump speed or other process that take place while the ion source is running.

1) From the GUI Gas screen, turn the “Ion Source Gas Valve” on.
2) Turn the KRI Auto Controller on via rocker switch manually.
3) Turn the KRI Filament Controller on via rocker switch manually.
4) Turn the KRI Discharge Controller on via rocker switch manually.
5) Place the KRI Auto Controller in “Local” Mode.
6) Place the KRI Filament Controller in “Local” Mode.
7) Place the KRI Discharge Controller in “Local” Mode.
8) From the KRI Auto Controller, change the Operating mode to “Gas Only”.
9) From the KRI Auto Controller, select “Gas 1” using the white Gas Channel Select Button.
10) From the KRI Auto Controller, turn the “Gas Adjust Knob” until 15 sccm is displayed on the SCCM display.
11) From the KRI Filament Controller, turn the “Emission Adjust Knob” until 2.7 amps is indicated in the Emission Amps display. Note that the filament emission is usually set equal to or up to 10% greater than the discharge current.
12) From the KRI Discharge Controller, use the white “Select” button to select Volts.
13) From the KRI Discharge Controller, turn the “Setpoint Adjust Knob” until the discharge voltage is set to 150 volts as indicated on the Discharge Volts display.
14) From the KRI Discharge Controller, use the white “Select” button to select Amps.
15) From the KRI Discharge Controller, turn the “Setpoint Adjust Knob” until the discharge current is at its maximum reading as indicated on the Discharge Amps display.
16) From the KRI Auto Controller, press the white “Enable/Standby Button” to “Enable”.
17) From the KRI Filament Controller, press the white “Enable/Standby Button” to “Enable”.
18) From the KRI Discharge Controller, press the white “Enable/Standby Button” to “Enable”.
19) From the KRI Auto Controller, adjust the gas flow using the “Gas Adjust Knob” until the discharge voltage is approximately 2.5 amps as read from the KRI Discharge Controller.
20) Operate the ion source for at least 10 minutes to clean any contaminates from the ion source that may have been introduced while at atmosphere.

21) The discharge voltage (as read from the KRI Discharge Controller) will vary slightly during this time. Adjust the gas flow (from the KRI Auto Controller) after the 10 minutes to obtain a discharge voltage of approximately 2.5 amps (as read from the KRI Discharge Controller).

At this point the operating conditions can be saved as a program (on the KRI Auto Controller) to be used later in the “Manual Gas” mode.

22) To save this program, first press the white “Program Select Button” (located on the KRI Auto Controller) repeatedly until the desired program number is selected as indicated by the numbered red LED’s.

23) From the KRI Auto Controller, press and hold the white “Acquire Setpoints Button” until the red numbered LED that was selected stops flashing.

To Turn the Ion Source Off:

1) From the KRI Discharge Controller, press the white “Enable/Standby Button” to “Standby”.

2) From the KRI Filament Controller, press the white “Enable/Standby Button” to “Standby”.

3) From the KRI Auto Controller, press the white “Enable/Standby Button” to “Standby”.

4) Restarting the ion source in the **“Gas only” mode** consists of, enabling the KRI Auto Controller, KRI Filament Controller and KRI Discharge Controller in that order. Slight variations in discharge voltages may be seen while the source is reaching operating temperature. The variations should be acceptable for most cleaning or ion-assist applications.

☝ The following steps must be performed prior to running in Remote Mode.
Determine what mode of operation is compatible with system and perform these operational steps (Constant Current Mode Operation OR Constant Voltage Mode Operation) prior to running in remote mode.

MANUAL GAS MODE

1) Manual Gas mode sequentially enables the gas, filament and discharge in the same manner that these would be enabled manually if the Gas Only mode were used. There is no feedback to adjust the gas flow to maintain the constant discharge parameters.
2) From the KRI Auto Controller, select the “Manual Gas” mode using the “Operating Mode Button”. Select the program to run using the “Program Select” button. Enable the program by pressing the “Enable/Standby” button on the KRI Auto Controller. Press the “Enable/Standby” button again to stop the program and put the units into **“Standby”.**
3) All of the setpoints can be adjusted before or after the KRI Auto Controller is enabled as in the gas only mode.

☝ Operation in manual mode does not use interlocks.

4) Saving a program is the accomplished in the same manner as described above for the Gas Only operating modes.

GUI (REMOTE MODE)

OPERATION

1) Turn on the Ion Source Gas valve for the Ion Source and evacuate the line to the MFC supplied with the Ion Gun.
2) Determine that system base pressure is acceptable.
3) Turn on the KRI Auto Controller via rocker switch (manually).
4) Turn on the KRI Filament Controller via rocker switch (manually).
5) Turn on the KRI Discharge Controller via rocker switch (manually).
6) From the KRI Auto Controller, select the program that is desired to run.
7) From the KRI Auto Controller, select **“Remote”** mode.
8) From the KRI Auto Controller, change the Operating Mode to **“Manual Gas”**.
9) Turn on the **Ion Source** via the GUI Deposition screen.
10) This action will run the Program in remote mode using the Cware interlocks.

SHUTDOWN

1) Turn the Ion Source off via the GUI Deposition screen.
2) Turn the KRI Discharge Controller off via rocker switch manually.
3) Turn the KRI Filament Controller off via rocker switch manually.
4) Turn the KRI Auto Controller off via rocker switch manually.
5) Turn the Source Gas valve off for the Ion Source.

FILM THICKNESS MONITOR/CONTROLLER

Please refer to the Film Thickness Monitor/Controller manual for detailed information on operating this device. This manual can be found in the supplemental documentation binder.

☝ Operator is responsible for setting density and z-ratio based on material. Operator is also responsible for calibrating tooling factor based on characterization runs.

EMERGENCY-OFF RECOVERY

☝ Emergency Off button would have been pressed due to a hazardous condition. Before recovery of system, ensure that hazard no longer exists.

What happens when the EMO Switch is activated?

All power to the system is immediately shut off. The only component left energized is the System Power Distribution Unit (Pulizzi - Figure 1). The systems Monitor and PC will stay powered on for approximately 15 min. They are powered by the onboard Uninterruptable Power Supply (UPS). Also, if the system has a Cryo, its temperature controller will be powered by the UPS (See Figure 2).

FIGURE 1: SYSTEM POWER DISTRIBUTION UNIT (PULIZZI)

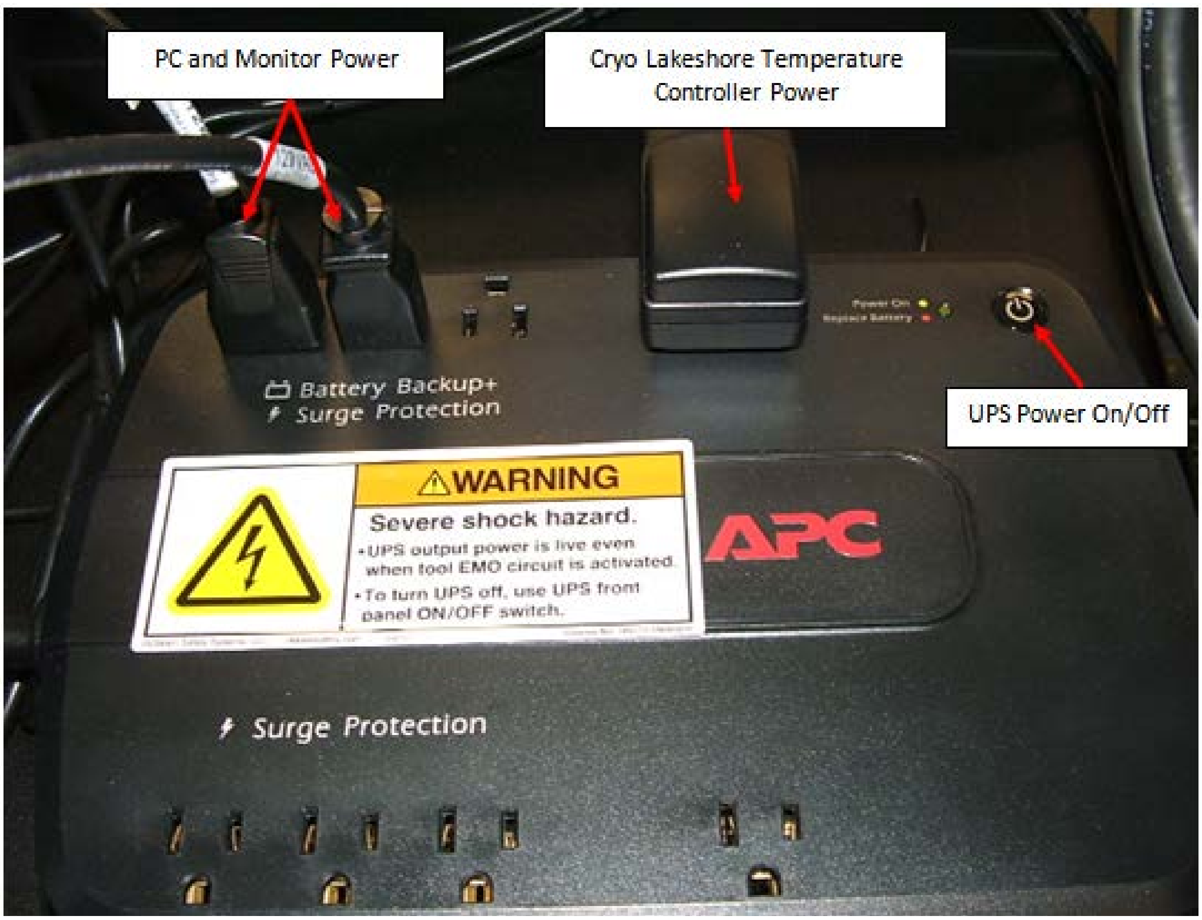


FIGURE 2: UNINTERRUPTABLE POWER SUPPLY

SYSTEMS WITH SEPARATE CONTROL RACK & FRAME

FIGURE 3

1) Reset the activated EMO switch by turning it clockwise or pulling it out.
2) Rotate switch from On position to Start position. This returns power to system components.
3) Turn on system UPS (see Figure 2).
4) Turn on system PC, let Windows boot up.
5) Once in Windows, open CWare.

SYSTEM WITH INTEGRATED CONTROL RACK & FRAME

1) Depress the EMO switch located at front of mainframe.
2) Turn on system UPS (see Figure 2). It may need to charge for a few minutes before next step.
3) Turn on system PC, let Windows boot up.
4) Once into Windows, open CWare.

RECOVERY FROM ACCIDENTAL PRESSING OF EMO

In the event of an accidental EMO, a quick recovery can be performed by:

1) Resetting the EMO that was activated. If system is a PVD or NANO, go to step 3.
2) If the system is a CMS, see Figure 3 and turn switch on Main Power Control strip to START position (Main Power Control not on PVD or NANO).
3) Wait 10 seconds and exit CWare.
4) Wait 10 seconds once CWare has closed.
5) Restart the CWare software. Failure to restart this software may result in serial devices not responding to user requests. Examples of possible problems would be values in motor text box on motion screen will disappear (See Figure 4) and cryo pump temp or Turbo speed may read zero. This occurs because they are on a serial connection. When the communication is broken, it needs to be re-established again with a CWare restart.

If the message below appears, the system EMO is still activated or power has not been restored to the Wide Range Gauge (MKS979). This message will prevent CWare from functioning until EMO has been reset and power has been restored to the device.

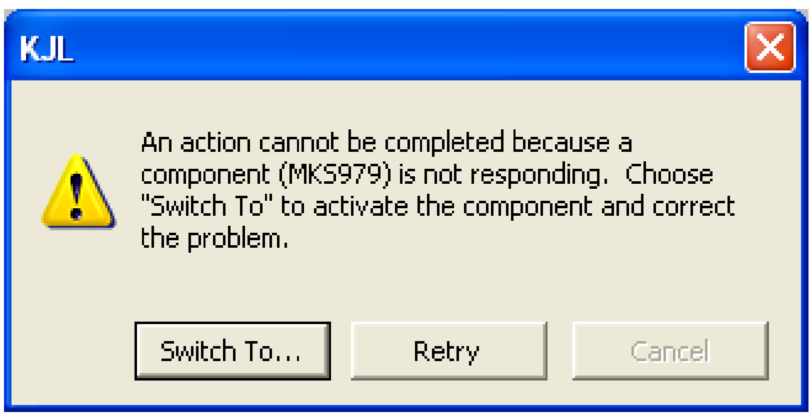
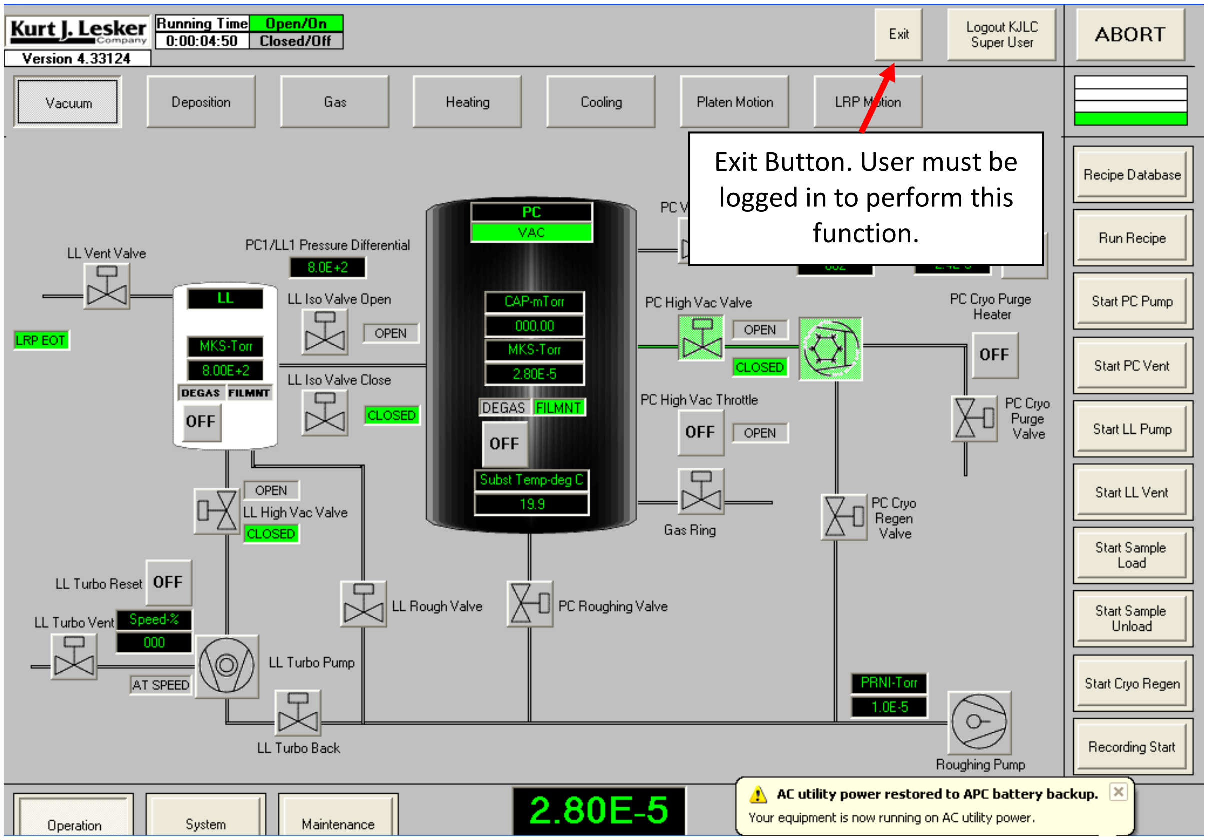
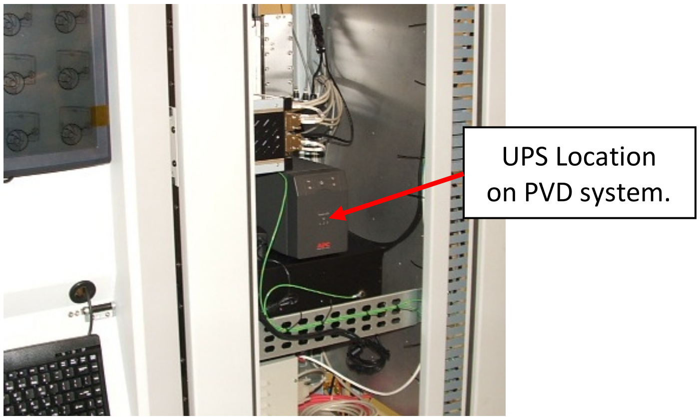


FIGURE 4

SYSTEM SHUTDOWN



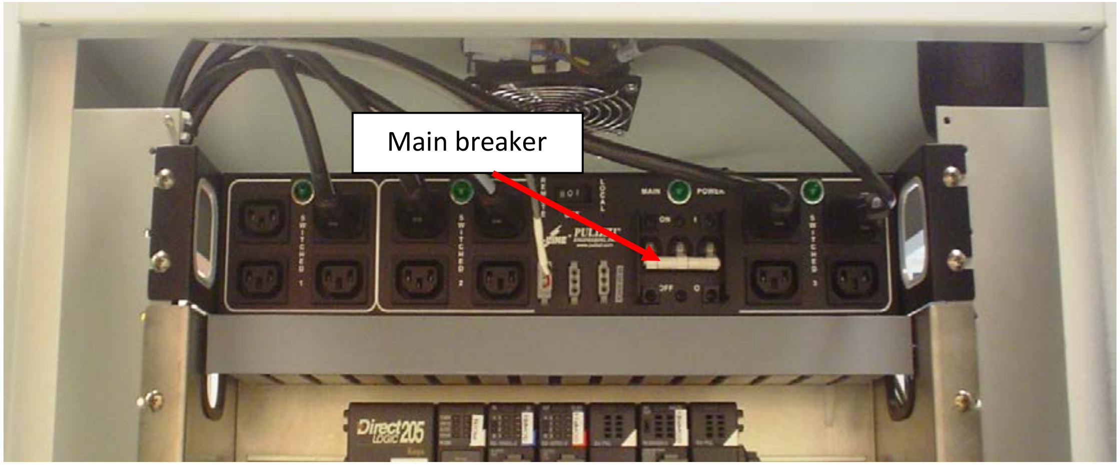
1) User press exit button in CWare. Wait for CWare software to exit.
2) Shut down Windows software.
3) Turn UPS off.



PVD SYSTEM

Turn breaker OFF at System Power Distribution Unit. Location of breaker depends on type of Power Distribution Unit installed.

3 PHASE POWER DISTRIBUTION UNIT



SINGLE PHASE POWER DISTRIBUTION UNIT

SHUT DOWN

1) Verify that all gas valves are closed, the source and heater supplies are turned off, and that the temperature is below 80°C.
2) Turn off the ion gauge filament.
3) If leaving the system under vacuum:
    a) Complete the pumpdown sequence (if the system is not already under vacuum) as described in the appropriate pumpdown procedure.
    b) Close the high vacuum valve.
    c) Turn off the turbo pump controller.
    d) When the turbo stops, close the roughing valve.
    e) Turn the mechanical pump off (if it is on).
4) If leaving the system vented:
    a) Close the hivac valve.
    b) Turn off the high vacuum pump (this initiates the AutoVent).
    c) Turn off the mechanical pump.
5) Turn off the individual branch circuit breakers on the main power distribution box (branch breakers are located behind the hinged access panel on the power distribution box).
6) Turn off the individual component power switches as required (power supplies, turbo controllers, etc.).

At this point the system is at shut down. Power can now be removed from the whole system or any of the system components. Refer to the manufacturers' manuals to make sure that all equipment is in a safe mode.

SOFTWARE OPERATION

CWARE OVERVIEW

The Kurt J. Lesker Company CWare HMI (Human Machine Interface) consists of two components:

- System Database
- Runtime Software

Together, these two components give the system operator an interface that provides capabilities such as:

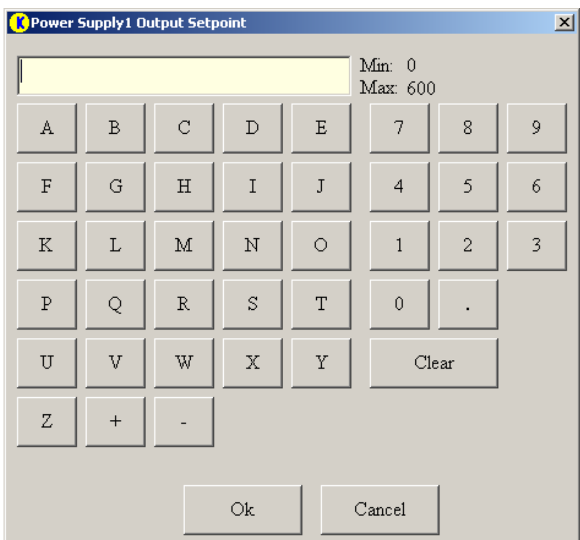
- Process automation
- Process (recipe) creation
- System status
- Manual control of the system
- Datalogging
- Alarms
- Password protection
- Interlocks
- Offline process editing

The software operates on a Windows based computer with a mouse, keyboard, and standard CRT flat screen monitor (or optional touchscreen monitor).

GENERAL GUIDELINES

CWare enables the user to run the tool manually or in an automated fashion, as well as provides system and process feedback.

- All actions and selections are done with a **single mouse click** (or single push of the finger, in the event of a touchscreen monitor). There are NO double-click actions on any Runtime screen.
- All buttons are typically **two state radio buttons** that can be either up or down. When a button is visible it indicates either the state of a request to turn on a device, the state of a sequence, or the active navigation screens. Typically, a button that is "pressed" or down indicates that the user (or a process) is requesting the respective device to turn on. A button that is not pressed or up signifies a device that is being requested to turn off.
- Devices that can be turned on or off typically have an **indicator or icon** inside their respective control buttons. While the state of the button indicates whether or not a device is requested to turn on or off, the color of the indicator or icon inside the button notifies the user of the actual state of the device. Color definitions for each button or indicator can be found in the section of the manual that corresponds to the screen on which it appears.
- All **alphanumeric fields** will appear as green text with a black background when not accessible by the logged-in user and white text when the field is accessible. The alphanumeric interface shown here will appear when an available data entry field is clicked. The maximum and minimum values for each numeric variable are displayed at the upper right within the pop-up screen while the signal name appears at the left of the title bar.



- The availability of the **Runtime Software Screens** is based upon the parameters set for the logged in user (See the *Security* Section for further details). This manual is intended to provide information regarding the operation of ALL features currently available in CWare. Not all features/screens are available on every system. Disregard the manual sections for the features/screens not included in your system configuration.
- **Tool Tip Text** is displayed for all controls and indicators on all screens. Without clicking, place the mouse cursor over the control or indicator to see the Tool Tip Text.

TERMINOLOGY AND DEFINITIONS

ACCESS FORMS - the portion of the HMI associated with the system database. These forms (or screens) are used when developing processes, recipes, and configuring the Runtime software.

ANALOG INPUTS (AI) – system Input that can have many different numerical values (positive or negative), both integer and decimal. *Analog Inputs* include motor speeds, gas flows, pressure, temperatures, power supply feedback signals, etc.

ANALOG OUTPUTS (AO) – system Output that can have many different numerical values (positive or negative), both integer and decimal. *Analog Outputs* include motor speed setpoints, gas flow setpoints, heater temperature and ramp setpoints, power supply setpoints, etc.

DISCRETE INPUT (DI) – system Input that can have only one of two values (i.e. on/off, 1/0, opened/closed). *Discrete Inputs* include vacuum switches, flow switches, gate valve positions, etc.

DISCRETE OUTPUTS (DO) – system Output that can have only one of two values (i.e. on/off, 1/0, open close). *Discrete Outputs* include valves, pumps, power supply enable signals, heater enable signals, shutter open/close signals, etc.

STRING INPUTS – Can be Discrete or Analog and are used primarily for communication with serial devices.

STRING OUTPUTS – Can be Discrete or Analog and are used primarily for communication with serial devices.

DOWNSTREAM PRESSURE CONTROL MODE – method of pressure control mode whereby effective pumping speed is varied and gas flow is held constant to achieve a desired pressure. The point of pumping is referred to as being downstream relative to the means of gas introduction.

HMI – Human Machine Interface. This refers to the computer control screens utilized by the operator to run the tool and monitor system status.

MFC – Mass Flow Controller. This refers to a device for introducing process gas at a controlled (variable) rate, typically in units of sccm (standard cubic centimeter per minute).

PID CONTROL – Proportional Integral Derivative Control. A type of control used in closed loop feedback systems. See *Operation – Gas* section for more information.

RECIPE – an automated sequence that consists of one or more steps or recipes. The steps specified in a given recipe are executed in a pre-defined (increasing numerical) order.

RUNTIME SCREENS – the portion of the *HMI* associated with the Runtime software (as opposed to the system database forms). These are the screens most often used when operating the tool.

RUNTIME SOFTWARE – the control software responsible for I/O system interface, control logic, recipe execution and a majority of the *HMI*.

STEP – the part of a recipe that sets and checks system I/O. Steps can be thought of as the building blocks for recipes.

SYSTEM ABORT – in case of a dangerous situation, when the *System Abort* button is pressed on the *HMI* (or the system is aborted as the result of a *Red Alarm* or device communications error) all processes are stopped and all *Discrete* and *Analog Outputs* are set to their default (startup) state as configured by the system database. Typically most *Discrete Outputs* are turned off and most *Analog Output* setpoints are set to zero.

SYSTEM DATABASE – a Microsoft Access database that contains recipes, user information, and system configuration details.

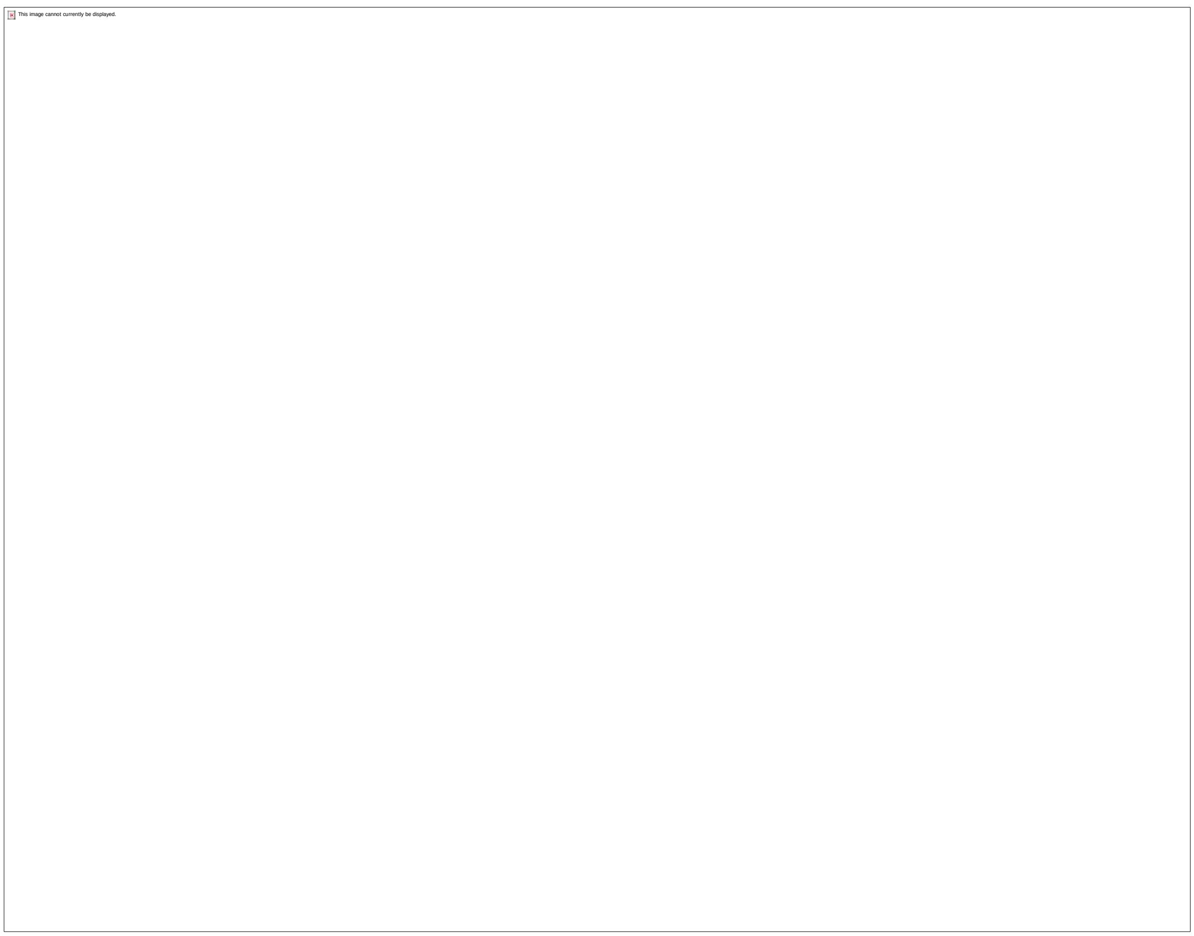
SYSTEM I/O – system *Inputs/Outputs*. *I/O* refers to the electronic hardware controls for a system. *Inputs* are typically device signals that provide system status or feedback. Examples of *Inputs* include flow switches, vacuum switches, valve positions, pressures and motor speeds. *Outputs* are typically device signals that provide system control or manipulation. Examples of *Outputs* include pumps, valves, flow setpoints and power supply setpoints.

UPSTREAM PRESSURE CONTROL MODE – method of pressure control whereby effective pumping speed is held constant (i.e. fixed position throttle valve) and gas flow is varied to achieve a desired pressure. The point of gas introduction is referred to as being “Upstream” relative to the means of pumping.

SECURITY

KJLC CWare security is managed with a user name and password approach. Ideally, one or two people should be assigned to manage the system security. The System Administrator(s) will need to assign a login name for each person that will operate the system using the computer interface. Each login name will be assigned parameters that dictate that user's access to the software. The *System Users Screen* is used to administer this information and is accessed through the *System Database*:

1) On the Operation – Vacuum Screen, click the Recipe Database button.
2) Click the Systems Users button on the topmost toolbar of the System Database Screen.
3) The following screen should appear:



ADDING A NEW USER

1) Click the New User button.
2) Choose a unique Log-in Name for the new user and type it in the User Log-in Name box. This is the field that will get captured during datalogging.
3) Complete the SurName (last name), FirstName, and Initials boxes with the person's actual name and initials.
4) Using the drop-down menu, choose which software screen should appear first when this user logs onto the system.
5) The password is chosen by the user when they log in for the first time and must consist of at least one character.
6) In the set of checkboxes labeled Recipe Database Access, choose the database screens that this user should be allowed access to.

⚠ CAUTION Access to the Interlock Screen should only be granted to the Super User level (System Administrator). No Operators or Process Engineers should be allowed access to the Interlocks Screen.

7) In the set of checkboxes labeled VB Mainform Access, choose the screens that this user should be allowed access to.

8) In the set of checkboxes labeled VB Other Access, choose the appropriate boxes:
   a) Operate if Running Recipe - allows the user to operate heaters/shutters on the runtime software screens while a recipe is running
   b) Can change ANY recipe - Can amend any recipe, even if the user does not own the recipe.
9) Also in the VB Other Access box, choose a level of security for the new user:
   - <u>Operator</u> - Can only run recipes that have been assigned to Operators.
   - <u>Process Engineer</u> - Can only run recipes that have been assigned to Process Engineers.
   - <u>Super User</u> - Can run, modify and delete any recipe. This is the highest level of security.

DELETING A USER

To delete a user, simply select that user from the *Find Existing System User* box, and then click the *Delete User* box. The deleted user's recipes and any other associated data will still be available.

MODIFYING A USER'S ACCESS

At any time, the access parameters for a user can be changed. Simply select that user from the *Find Existing System User* box, and then modify the parameters as required.

RESETTING A PASSWORD

To change the access parameters for a user, simply select that user from the *Find Existing System User* box, and then check the *Clear Password* button. The password will be re-chosen by the user when they log in the next time and must consist of at least one character.

SOFTWARE FILE STRUCTURE & MAINTENANCE

KJLC CWare consists of two components: Runtime Software and Microsoft Access database files. The .exe and supporting files are located in this folder: C:\Program Files\Lesker*Your Company Name*. The data directory in the path mentioned above is where supporting database files and the datalog.mdb file is stored. To access the datalog.mdb file double click it. Or if the software is running, open MS Access from the Start menu and browse to this file then open it.

☝ It is the responsibility of the customer to periodically backup the system software and database, as well as remove or archive the datalog information.

☝ KJLC does not recommend using CDRW discs or storing multiple backups on a single CD.

BACKING UP SYSTEM DATA

1) Stop the system software from running.
2) Launch Nero CD burning software.
3) Add the C:\Program Files\Lesker directory of data to be saved to CD.
4) Burn the disk.

RESTORING SYSTEM DATA

1) Stop the system software.
2) Copy the Lesker directory from the backup disk to C:\Program Files.
3) Right click on the restored Lesker folder and un-check the Read Only attribute box.
4) Apply this to the current folder, sub folders and files.

SOFTWARE UPGRADES

Periodically, KJLC will address performance issues with the Runtime Software or add features to the Runtime Software as well as the database. Depending on the nature of the changes, KJLC may request that the customer send KJLC a recent backup of their software to facilitate creating a software revision that may be installed by the customer. Some revisions pertaining to software performance and existing features will be available to the customer at no charge; other revisions will be available for purchase as an option.

Typically, upgrading the Runtime software involves copying a new "*Customer Name*" folder from a CD provided by KJLC to the computer's C:\ drive (refer to Soft*ware File Structure and Maintenance* section). Follow the instructions included with the revision CD for loading software upgrades

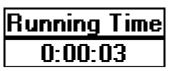
COMMON ICONS

These common icons appear throughout the Runtime software screens. Some icons appear on every screen, others only where specified.

TIME AND DATE BANNER

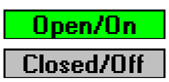
The *Time and Date Banner* appears at the top left of all runtime screens. The current Windows time and date is displayed.

RUNNING TIME INDICATOR



The *Running Time Indicator* appears at the top left of all runtime screens. The time displayed here is the elapsed time that the software has been up and running since the last shut down.

LEGEND INDICATORS

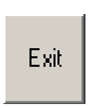


The *Legend Indicators* appear at the top left of all runtime screens. The status of a corresponding active or inactive signal is indicated here.

SOFTWARE VERSION

The *Software Version* box appears at the top left of all runtime screens. This box displays the current CWare software revision.

EXIT BUTTON



The *Exit Button* appears at the top right of all runtime screens. Pressing this button closes both the runtime engine and the system database.

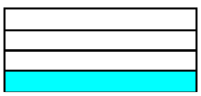
LOGIN / LOGOUT BUTTON

The *Login/Logout Button* appears at the top right of all runtime screens. This button allows the user to login or logout of the software. This icon also displays the login name and security level of the current user.

ABORT BUTTON

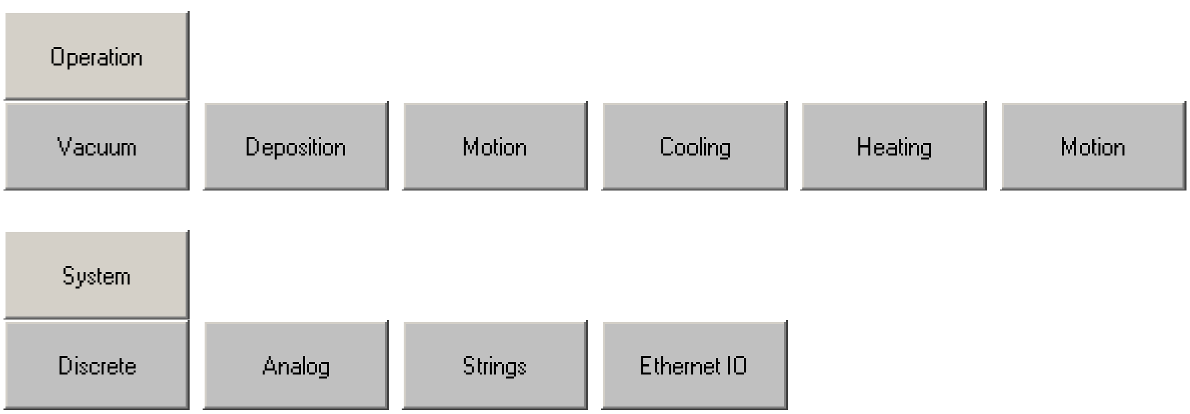
The *Abort Button* appears at the top right corner of all runtime screens. Pressing it activates an abort condition.

LIGHT TOWER



The *Light Tower* appears in the top right corner of all screens. When the topmost bar is illuminated red, a red alarm condition is present. The second bar will light yellow to indicate a yellow alarm. The third bar will light green to indicate that a recipe is running. The bottom bar will light blue to indicate a "normal" status, no alarms are present and no recipes are running.

NAVIGATION BUTTONS – RUNTIME SOFTWARE

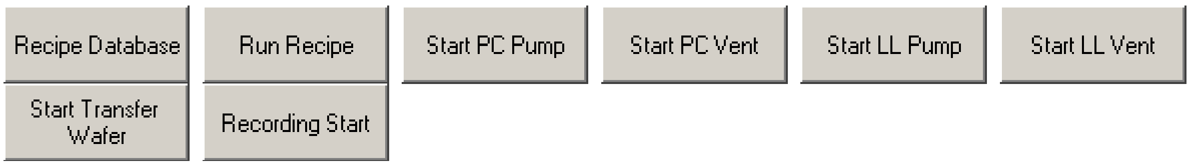


This set of *Navigation Buttons* appears on the Runtime Software screens. They are used to navigate the major screen groups. Each button opens a new screen with a different set of information or data.

NAVIGATION BUTTONS – SYSTEM DATABASE

This set of Navigation Buttons appears at the top of the System Database and is used to navigate throughout the database. Each button opens a new screen with a different set of information or data.

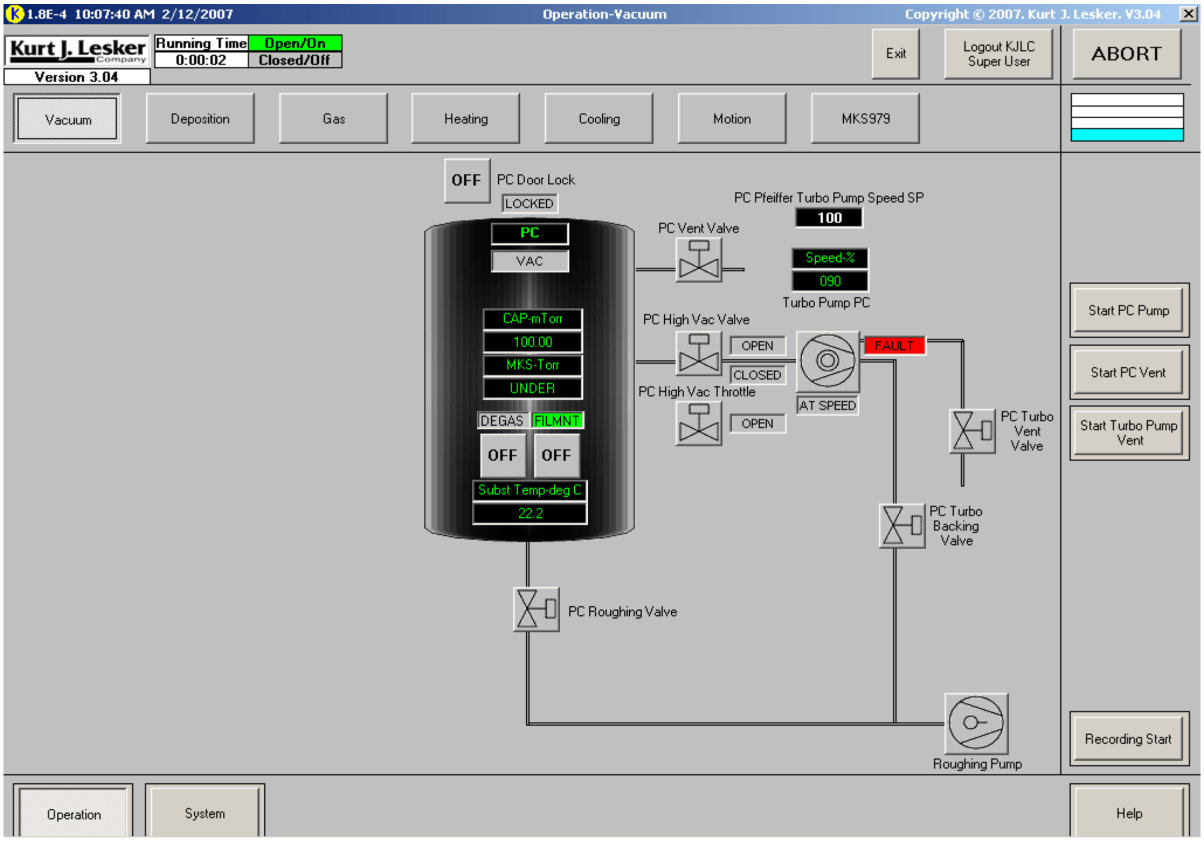
COMMAND BUTTONS



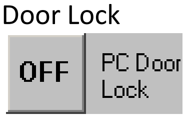
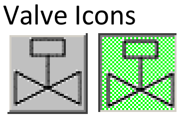
Command Buttons appear on all Runtime Software screens and are used to run pre-programmed processes as well as user-selected processes. In addition to standard *Command Buttons*, additional custom buttons are available to be configured by KJLC upon customer request. The number of custom buttons available depends upon system configuration.

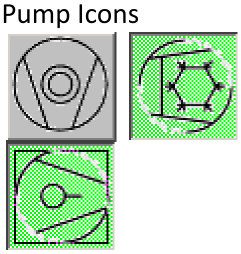
OPERATION

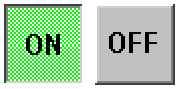
VACUUM SCREEN



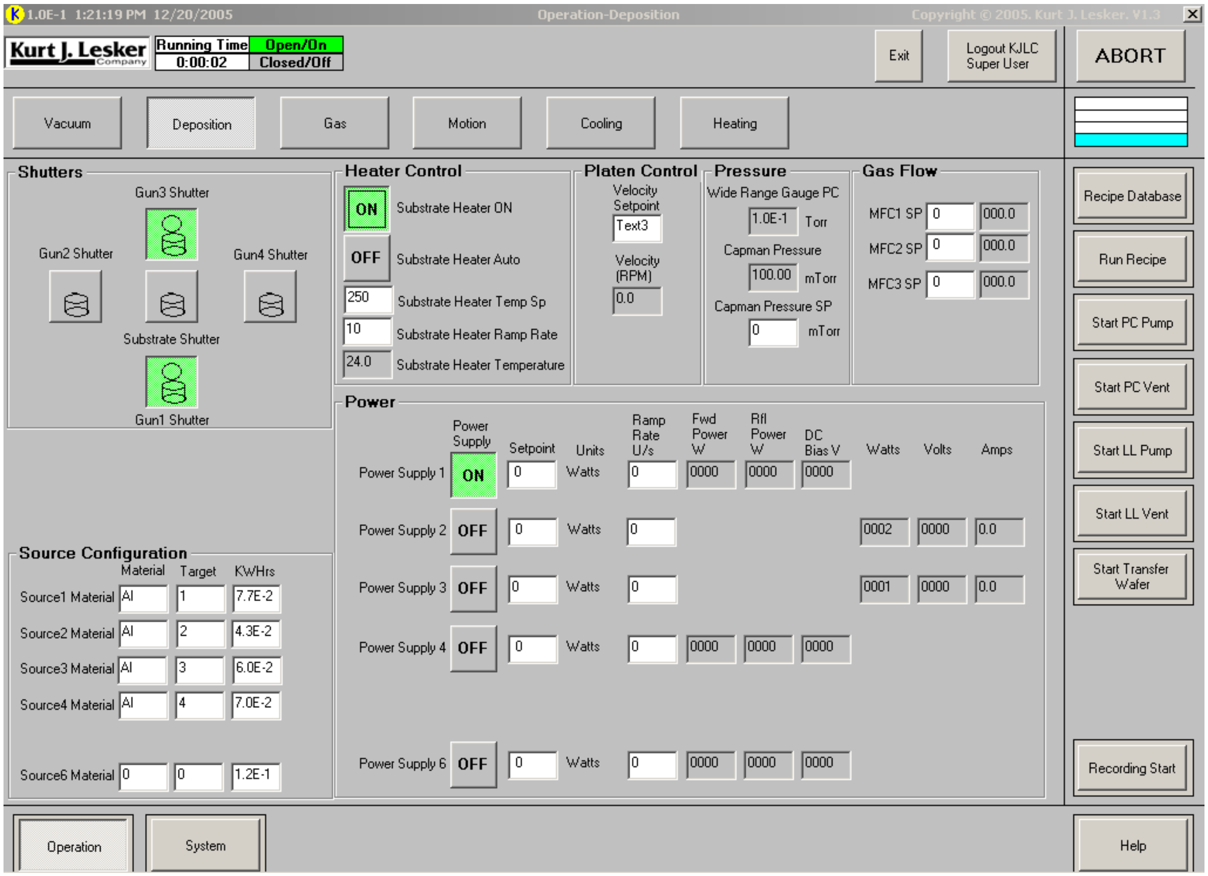
The chamber representations appear white while at atmosphere and get darker as the pressure in the chamber decreases. The Process Chamber above is at high vacuum (black), while the Load Lock chamber above is at atmosphere (white).

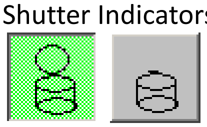
ICON OR DATA FIELD	ACTION	RESULT
Door Lock 	Click to activate	Clicking the on/off button will lock or unlock the process chamber door while the locked/unlocked icon indicates the current status.
Valve Icons 	Click to activate	Green / Pressed = open or active Gray / Unpressed = closed or inactive
Valve Indicators 	Display only	Indicates position of valves with real feedback, such as the isolation and high vacuum valves
Fault 	Display only	This icon will only appear during a fault condition

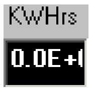
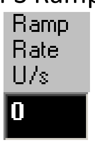
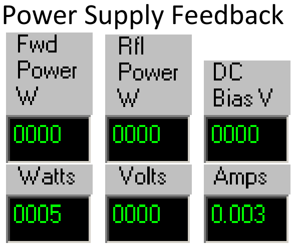
ICON OR DATA FIELD	ACTION	RESULT
Speed Speed-% 100	Display only	Indicates the current speed of the LL turbo pump
Pirani Gauge PRNI-Torr 6.1E+0	Display only	Indicates Pirani gauge pressure in Torr
Cryo Temperature Cryo-K 012	Display only	Indicates the temperature of the Cryo pump in Kelvin
Regeneration Pressure PRNI-mTorr 2.4E-3	Display only	Indicates pressure in mTorr of the Cryo pump during regeneration
Pump Icons 	Display only	On = green, animated motion, and appear pressed/down Off = gray, no animation, and appear un-pressed/up
Turbo Speed Setpoint PC Pfeiffer Turbo Pump Speed SP 100	Click to enter value	Enter the desired turbo speed in percent (valid range is 20-100%)
Process Chamber:		
Vacuum Indicator VAC	Display only	Gray = atmospheric pressure Green = some level of vacuum
Pressure WRG-Torr 7.1E-8	Display only	Indicates wide range gauge pressure in Torr
Capacitance Manometer CAP-mTorr 000.10	Display only	Indicates capacitance monometer pressure in mTorr
Temperature Substrate-deg C 22.0	Display only	Indicates process chamber temperature in degrees Celsius
Degas DEGAS	Display only	Green = Degas mode on Gray = Degas mode off
LL Chamber Pressure WRG-Torr 7.1E-8	Display only	Indicates wide range gauge pressure in Torr

ICON OR DATA FIELD	ACTION	RESULT
LRP End of Travel 	Display only	Green = LRP is fully retracted (End of Travel) Illuminates to On color if active and Off color if inactive
On/Off 	Click to activate	Turns on/off the corresponding equipment.
Filament 	Display only	Green = hot filament on Gray = hot filament off

DEPOSITION SCREEN



ICON OR DATA FIELD	ACTION	RESULT
Shutter Indicators 	Display only	Green = Open Gray = Closed
Source Switches ON OFF	Click to activate	Turns respective source switch on/off
Source Material Material Al	Click to enter current target material	Target material is displayed on the Operation – Deposition screen and recorded in process and manual datalogs
Source Power Supply Mapping Target 1	Click text to map source to a particular power supply and switch position (if applicable)	The mapped source kilowatt-hours counter will increment accordingly when the respective power supply is on and has positive output power

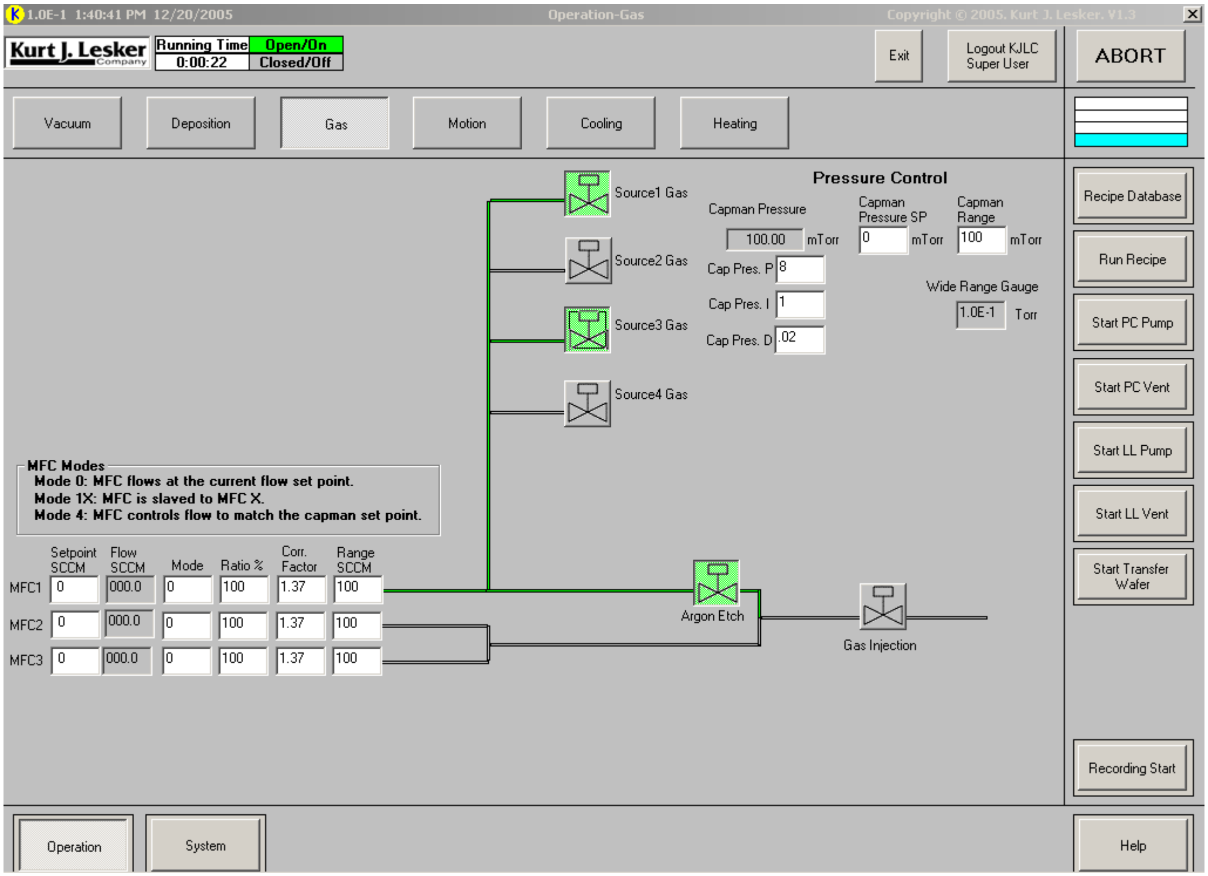
ICON OR DATA FIELD	ACTION	RESULT
Source Kilowatt Hours 	Displays current kilowatt-hours for a particular target. Click to zero or preset the kilowatt-hours counter.	The kilowatt-hours counter increments accordingly based on the output state of the corresponding power supply. The counter is set accordingly and increments from the preset value.
Power Supply On/Off 	Click to activate	Turns respective power supply on/off
PS Output Setpoint 	Click to enter value	Enter the desired power supply output setpoint in Watts (also see Ramp Rate below)
PS Ramp Rate 	Click to enter value	Enter the desired power supply ramp rate in units per second **NOTE:** Set Ramp Rate PRIOR to setting the output setpoint.
Power Supply Feedback 	Display only	Displays current power supply status

Refer to the *Operation - Heating* section for descriptions of heater control icons included on the Deposition screen.

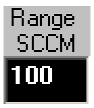
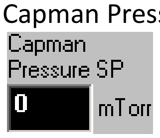
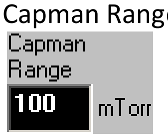
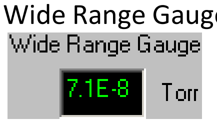
Refer to the *Operation - Gas* section for descriptions of gas and pressure control icons included on the Deposition screen.

Refer to the *Operation - Motion* section for descriptions of platen control icons included on the Deposition screen.

GAS SCREEN



ICON OR DATA FIELD	ACTION	RESULT
MFC Setpoint Setpoint SCCM 0	Click to enter value	Sets MFC flow in sccm. **NOTE:** Applies to Independent Mode only
MFC Flow Flow SCCM 000.3	Display only	Indicates gas flow from corresponding MFC
MFC Mode Mode 0	Click to enter value	Sets mode of operation for corresponding MFC. Mode 0 = Independent (Flow) Mode Mode 1X = Slave Mode (X = master) Mode 4 = Upstream Pressure Control Mode
MFC Ratio % Ratio % 0	Click to enter value	Sets MFC flow as a percent ratio of master channel (Slave Mode). Sets MFC contribution as a percent of full range (PID/Pressure Control Mode).

ICON OR DATA FIELD	ACTION	RESULT
MFC Correction Factor 	Click to enter value	Sets gas correction factor for corresponding MFC (as a function of nitrogen calibration). Refer to gas controller manual(s) or web site(s) for gas correction factor tables.
MFC Range 	Click to enter value	Sets flow range of corresponding MFC in sccm (max nitrogen flow)
Capman Pressure 	Display only	Indicates Capman pressure in mTorr
Capman Pressure Setpoint 	Click to enter value	Sets desired chamber pressure in mTorr. **NOTE:** Requires one MFC in Mode 4 and corresponding gas valve open
Capman Range 	Click to enter text	Sets the range of the capacitance manometer in mTorr. **NOTE:** Maximum value is typically 1000 mTorr.
Wide Range Gauge 	Display only	Indicates wide range gauge pressure in Torr
NOTE: DO NOT adjust PID values for pressure control loop while in Pressure Control Mode.		
Capman Pressure – Proportional Term 	Click to enter value	Sets proportional term for pressure control loop. The proportional term determines the amount of change in gas flow to compensate for the difference between desired pressure and actual pressure – the greater the proportional term, the quicker the flow will change to adjust for pressure differences (large P terms can lead to instability). This is the most critical term for tuning the pressure control loop. Typically, as the throttle position increases (greater conductance = higher effective pumping speed), the P term must be increased to achieve the desired pressure (greater change in gas flow is required to affect a pressure change).

ICON OR DATA FIELD	ACTION	RESULT
Capman Pressure – Integral Term 	Click to enter value	Sets integral term for pressure control loop. This term typically does not need to be changed from its factory default value.
Capman Pressure – Derivative Term 	Click to enter value	Sets derivative term for pressure control loop. This term typically does not need to be changed from its factory default value.

Refer to the *Operation – Vacuum* section for descriptions of heater control icons included on the Gas screen.

GAS CONTROL OVERVIEW

The software supports control of up to 4 MFCs in flow or pressure control modes. Only one MFC can be designated as the "master" for upstream pressure control, but any of the remaining MFCs can be "slaved" to the master. Any MFC can be set for independent or slave flow mode at any time. The ranges for the gas flow and pressure hardware can be changed (in appropriate maintenance levels) to accommodate modifications by the customer. Additionally, pressure control PID values can be changed manually (on the *Operation – Gas* screen) or in a recipe to accommodate various throttle valve positions.

MASTER/SLAVE OPERATION

Master/Slave relationships are ratiometric based on flow. Multiple levels of this relationship are supported so that an MFC slaved to one channel could also be master to another. The flow of a given slave channel is based on the actual flow of the corresponding master channel, not the setpoint of the master. In this way, if the master channel is not flowing correctly or is otherwise limited, the gas composition remains correct. Additionally, if a given slave flow is limited based on that MFC's range, the flow setpoint for the corresponding master is limited to maintain the desired gas ratio.

SLAVE MODE EXAMPLE

Mode 11 for MFC 2 slaves MFC 2 to MFC 1.
The flow setpoint for MFC 2 = (actual flow of MFC1) x (the ratio of MFC2).
So if MFC1 actual flow = 100 sccm and MFC 2 ratio is 50%, MFC2 flow setpoint = 50 sccm.

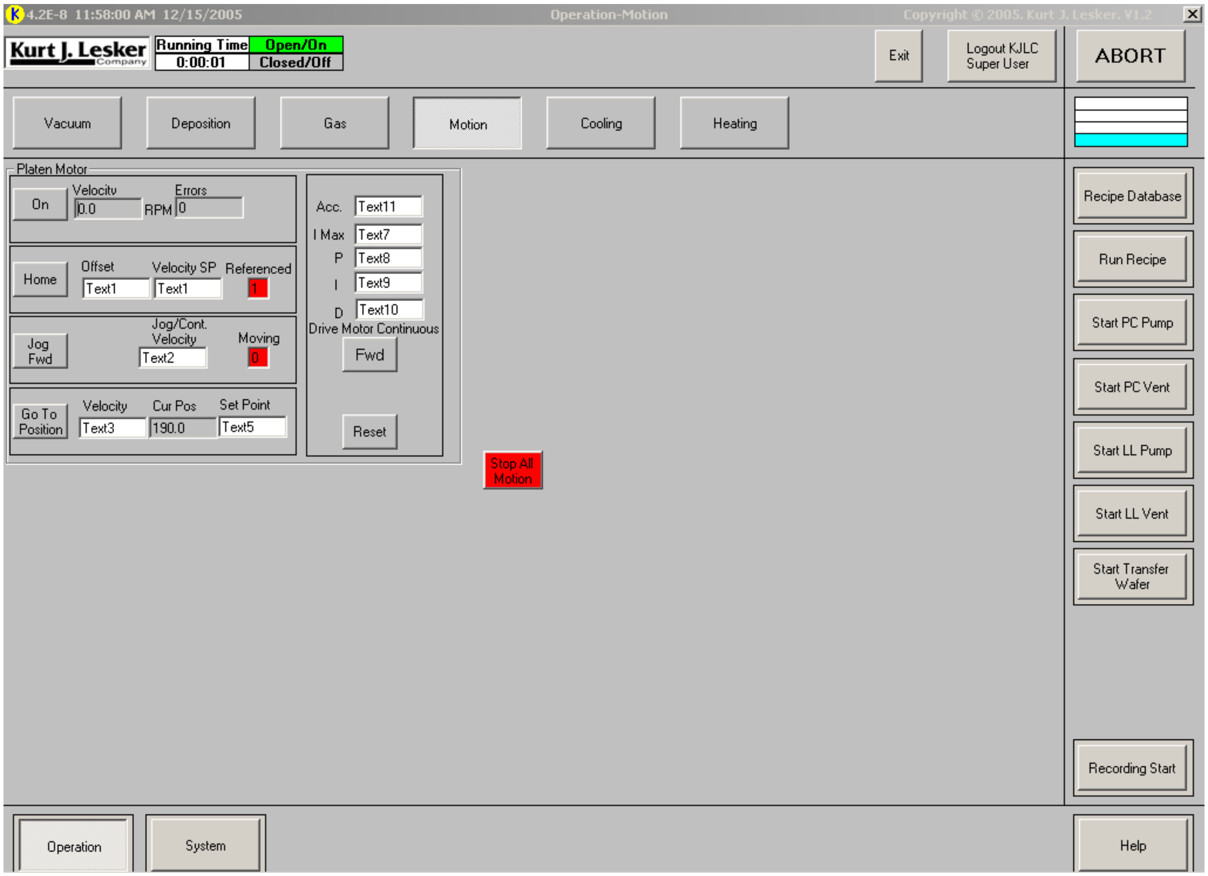
SLAVE MODE NOTES

A channel cannot be slaved to itself. If this is requested, the channel will be set to Independent Mode with a flow setpoint of zero.
A circular slave relationship is not allowed. If two channels are slaved to each other, the highest number MFC is set to Independent Mode with a flow setpoint of zero. If the setpoint for a slave channel is greater than its range, the setpoint for the slave is limited to its maximum and the corresponding setpoint for the master channel is set such that the desired gas composition is maintained.

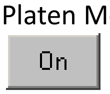
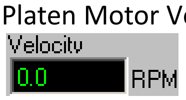
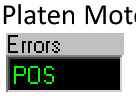
PRESSURE CONTROL

The software uses closed loop PID control to accomplish upstream pressure control. When a given MFC is assigned to pressure control mode, the software adjusts that MFC's flow rate setpoint accordingly based on the desired pressure setpoint and the actual pressure reading supplied by the capacitance manometer. If any additional channels are slaved to the pressure control channel, then their flows will also be adjusted respectively.

MOTION SCREEN



Additional icons appear on the Operation - Motion screens for systems equipped with automatic transfer. Please disregard descriptions for icons not included with your particular system configuration.

ICON OR DATA FIELD	ACTION	RESULT
Platen Motor On 	Click to activate	Click to turn the Platen motor on
Platen Motor Velocity 	Display only	Indicates the current motor velocity in RPM or IPS depending on motor
Platen Motor Errors 	Display only	Indicates if an error occurs with the platen motor
Platen Home 	Click to activate	Click to send the motor home. The button will stay pressed while the platen is homing. Once the platen is homed/referenced, the button changes to un-pressed.

ICON OR DATA FIELD	ACTION	RESULT
Platen Home Offset Offset Text1	Click to enter value	Enter the desired offset from home that you want the motor to consider its new home. When you home with an offset, the motor will go home, then move to the offset and consider this location to be 0.
Home Velocity Setpoint Velocity SP Text1	Click to enter value	Enter the desired home velocity in RPM or IPS depending on motor
Referenced Indicator Referenced	Display only	Indicates when the motor is referenced. Green / 1 = referenced Gray / 0 = not referenced
Platen Jog Forward Jog Fwd	Click to activate	Click and hold to move the motor in the forward direction. The motor will stop when the button is released.
Platen Jog Reverse Jog Rev	Click to activate	Click and hold to move the motor in the reverse direction. The motor will stop when the button is released. **NOTE:** Some motors are restricted to forward motion only. In this case, the Jog Rev button is not visible
Jog/Continuous Velocity Jog/Cont. Velocity Text2	Click to enter value	Set the jog and continuous velocity for the motor in RPM or IPS. Jog and Continuous motion share the same velocity setpoint
Moving Indicator Moving	Display only	Indicates when the motor is moving. Green / 1 = Moving Gray / 0 = Not moving
Go To Position Go To Position	Click to activate	Sends the motor to the position indicated in the position setpoint box at the velocity shown in the position velocity setpoint box. This button stays pressed until the motor reaches the position setpoint
Position Velocity Velocity 0.0 RPM	Click to enter value	Set the velocity at which the motor should move to the desired position
Currrent Position Indicator Cur Pos 206.9	Display only	Indicates the current position of the motor
Motor Position Setpoint Set Point Text5	Click to enter value	Enter the setpoint for the motor to move to when the Go To Position button is activated

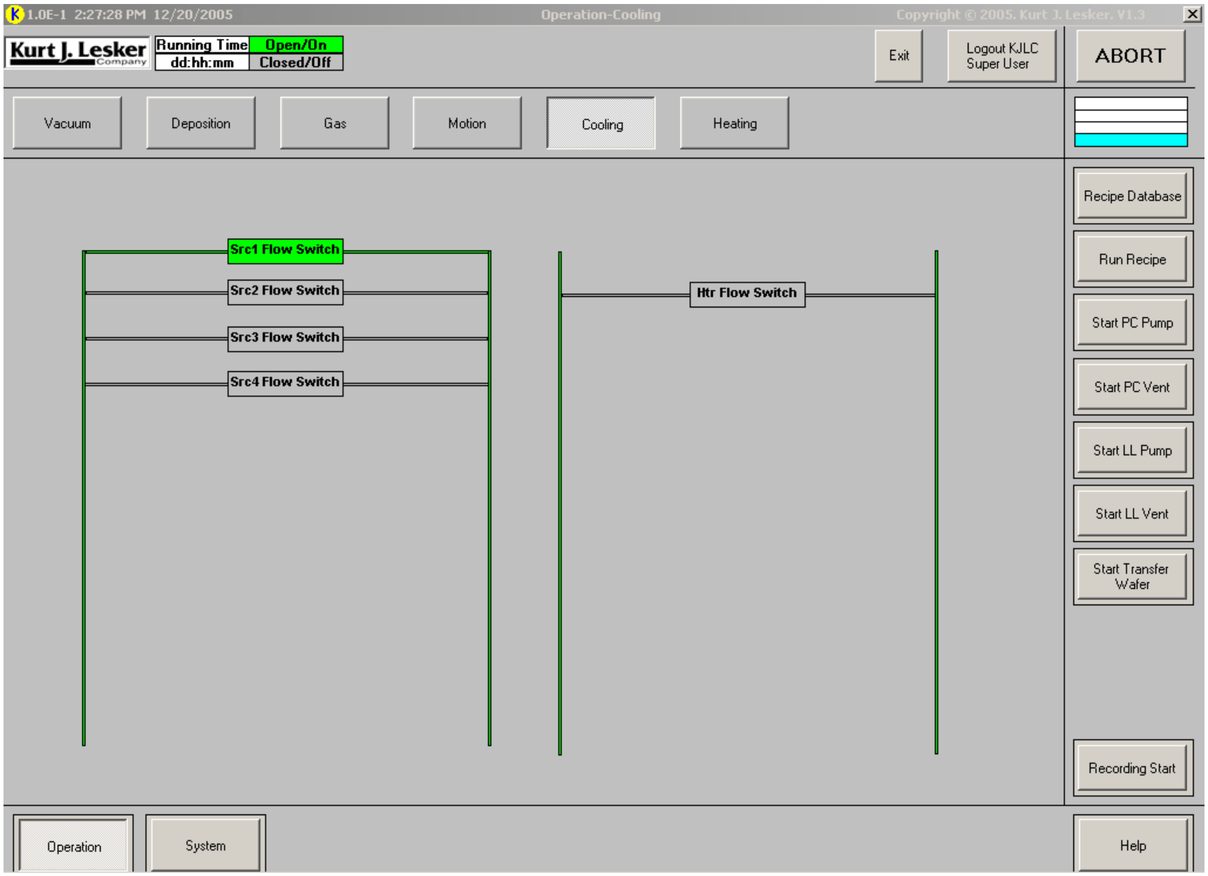
ICON OR DATA FIELD	ACTION	RESULT
Motor Forward Fwd	Click to activate	Initiates the motor to move in a forward motion at the Jog/Cont velocity. The motor will move continuously until the button is clicked again
Motor Reverse Rev	Click to activate	Initiates the motor to move in a reverse motion at the Jog/Cont velocity. The motor will move continuously until the button is clicked again
Motor Error Reset Reset	Click to activate	Resets motor error conditions
Stop Motion Button Stop All Motion	Click to activate	Click to stop all motor motion
Station Setpoints Station 1 4.2 IN	Click to enter Value	Enter the desired setpoint in inches
Go To Station Go To Station 13	Click to activate	Causes the shutter motor to go to the location specified for the given station
<u>NOTE:</u> The following icons and fields are available for adjustment, however it is highly recommended that the SMI User's Guide be read prior to adjusting these parameters. Changing motor tuning parameters can seriously degrade the performance of your motors.		
Motor Acceleration Acc. Text11	Click to enter value	Set or change the motor acceleration (Refer to the SMI User's Manual)
Maximum Motor Current I Max Text7	Click to enter value	Set the maximum motor current (Refer to the SMI User's Manual)
Motor PID Filter P Term P Text8	Click to enter value	Refer to the SMI User's Manual
Motor PID Filter I Term I Text9	Click to enter value	Refer to the SMI User's Manual
Motor PID Filter D Term D Text10	Click to enter value	Refer to the SMI User's Manual
Substrate X/ Source Y (Substrate Position Key) (See example below)	Click text to enter the desired station setpoint in degrees.	The platen will move to the desired position when the station setpoint is used in conjunction with the enable position button.

SUBSTRATE X/SOURCE Y EXAMPLE

This station setpoint is intended for systems with single or multiple platens. For example, a station setpoint of 14 on a system with one platen signifies that platen 1 (the only platen) should move to deposition source (or position) 4. A station setpoint of 25 on a system with 4 platens signifies that platen 2 should move to deposition source (or position) 5.

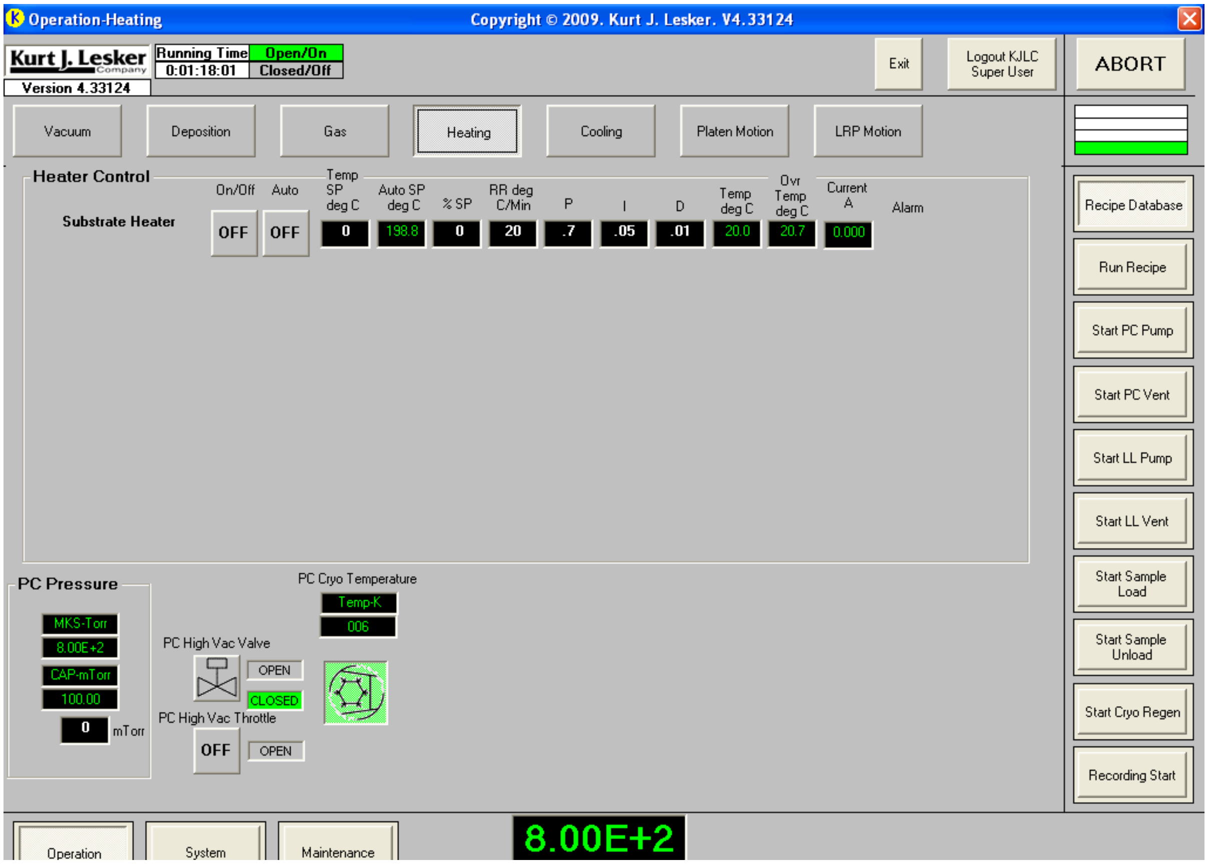
☝ Setting a new station setpoint places a value in the motor position setpoint (in inches or degrees, depending on the type of axis), but the Move to Position button must be pressed before the motor will actually move.

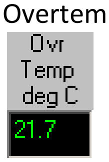
COOLING SCREEN

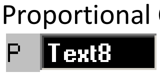


ICON OR DATA FIELD	ACTION	RESULT
Flow Switch(es) Src1 Flow Switch Src2 Flow Switch	Display only	Green = On Gray = Off

HEATING SCREEN



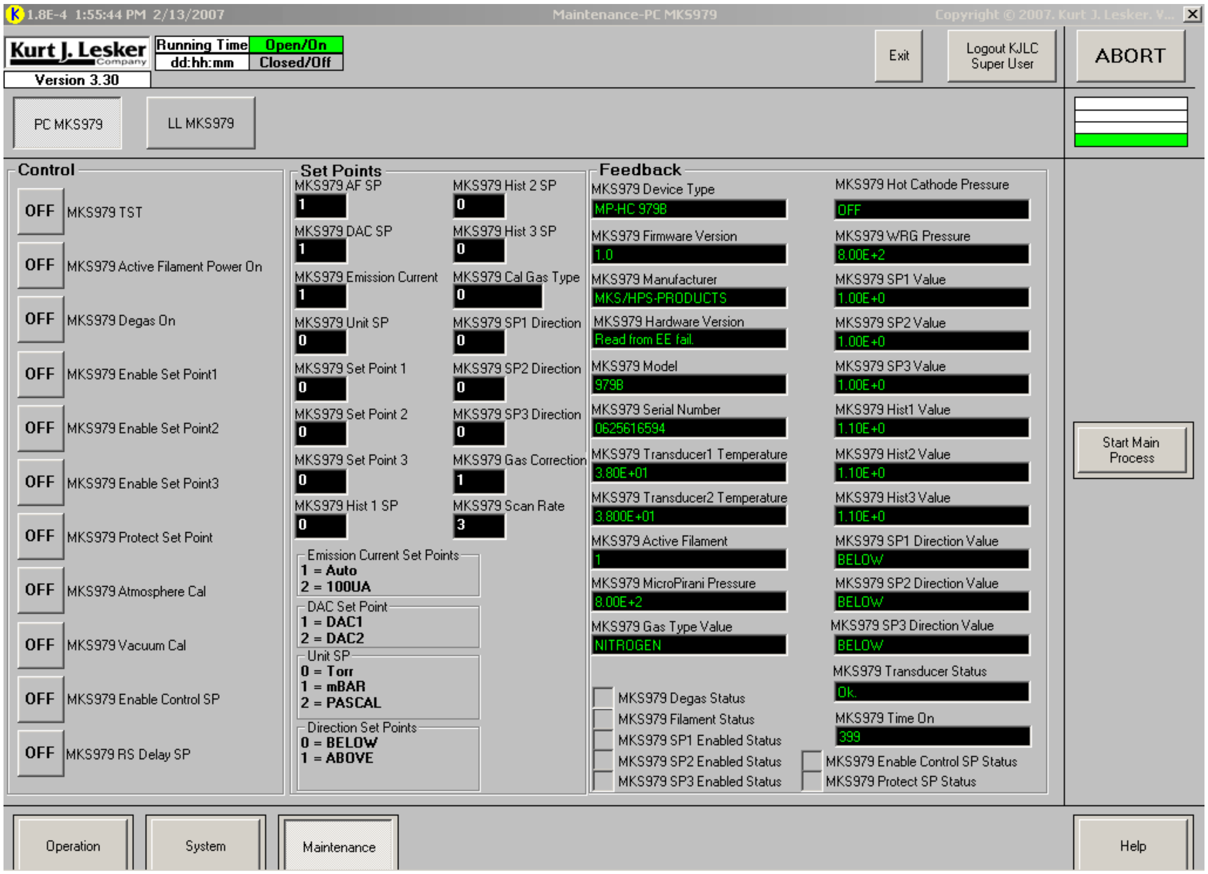
ICON OR DATA FIELD	ACTION	RESULT
Overtemperature 	Display only	This icon is only visible when the heater is over temperature
Temperature Setpoint 	Click to enter value	Enter the desired temperature setpoint
Auto Mode Setpoint 	Click to enter value	Enter the desired temperature setpoint for Auto Mode. When Auto Mode is enabled, this value is used in conjunction with the Ramp Rate box to achieve the desired temperature. **NOTE:** If a ramp rate is desired, it must be entered PRIOR to entering the desired temperature.

ICON OR DATA FIELD	ACTION	RESULT
Heater Setpoint 	Click to enter value	Enter the desired heater output as a percentage of full scale. When Auto Mode is disabled, the heater can be controlled by power setpoint
Ramp Rate 	Click to enter value	Enter the desired ramp rate to be used during Auto Mode in degrees C per minute. Once a ramp rate is entered followed by a new Temperature Setpoint, the heater will ramp to the desired value. **NOTE:** The ramp rate starting point is the CURRENT Temperature Setpoint, NOT the current actual temperature. To avoid delays in achieving the desired ramp temperature, be sure to set the Temperature Setpoint close to the actual temperature, then set the desired ramp parameters, and finally the target temperature.
Over Temperature Indicator 	Display only	Monitors for an over temperature condition.
Temperature Indicator 	Display only	When Auto Mode is enabled, this field displays the current temperature control setpoint. If a ramp rate has been specified, this field displays the temperature setpoint as it ramps up rather than the final target temperature.
Proportional Coefficient 	Click to enter value	Enter the Proportional coefficient for the Auto Mode temperature control loop. The control loop is immediately changed. The P term determines the change in heater output power applied to compensate for differences between actual and desired temperature. Typically, larger P terms are required for greater thermal mass. **CAUTION: Disable Auto Mode while adjusting PID parameters.**

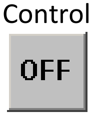
ICON OR DATA FIELD	ACTION	RESULT
Integral Coefficient I Text9	Click to enter value	Enter the Integral coefficient for the Auto Mode temperature control loop. The control loop is immediately changed. **CAUTION: This term does not typically need to be adjusted from its factory default value. Disable Auto Mode while adjusting PID parameters.**
D Request D Text10	Click to enter value	Enter the Derivative coefficient for the Auto Mode temperature control loop. The control loop is immediately changed. **CAUTION: Disable Auto Mode while adjusting PID parameters.**
Heater On Manual Button ON OFF	Click to activate	Green = Heater On Gray = Heater Off
Heater On Auto Button ON OFF	Click to activate	Green = Auto Mode Enabled Gray = Auto Mode Disabled When Auto Mode is enabled, the heater is controlled by the temperature setpoint rather than % power.

Refer to the *Operation – Heating* section for descriptions of heater control icons included on the Heating screen.

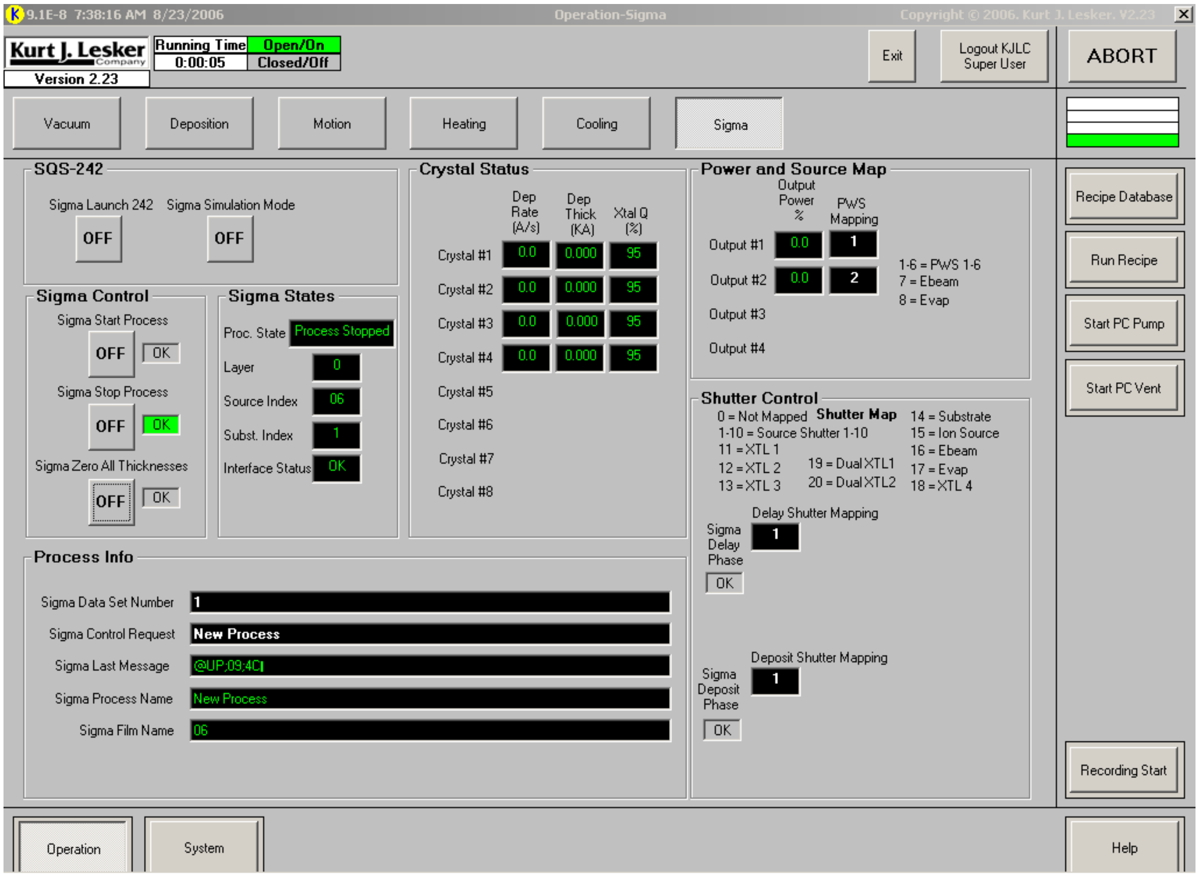
MKS979 GAUGE



This software screen provides an interface allowing the user to communicate with the MKS979 gauge. Also see the component manual for additional details.

ICON OR DATA FIELD	ACTION	RESULT
Control On/Off 	Click to activate	Turns on and off the corresponding MKS979 control
Set Points 	Click to enter text	Communicates the value entered with the MKS979 gauge
Feedback 	No action	Provides feedback as to the status of the corresponding reading from the MKS979 gauge

SIGMA SCREEN



CWare provides a basic interface for the Sigma controller. Refer to the Sigma manual for details regarding function and data set parameters.

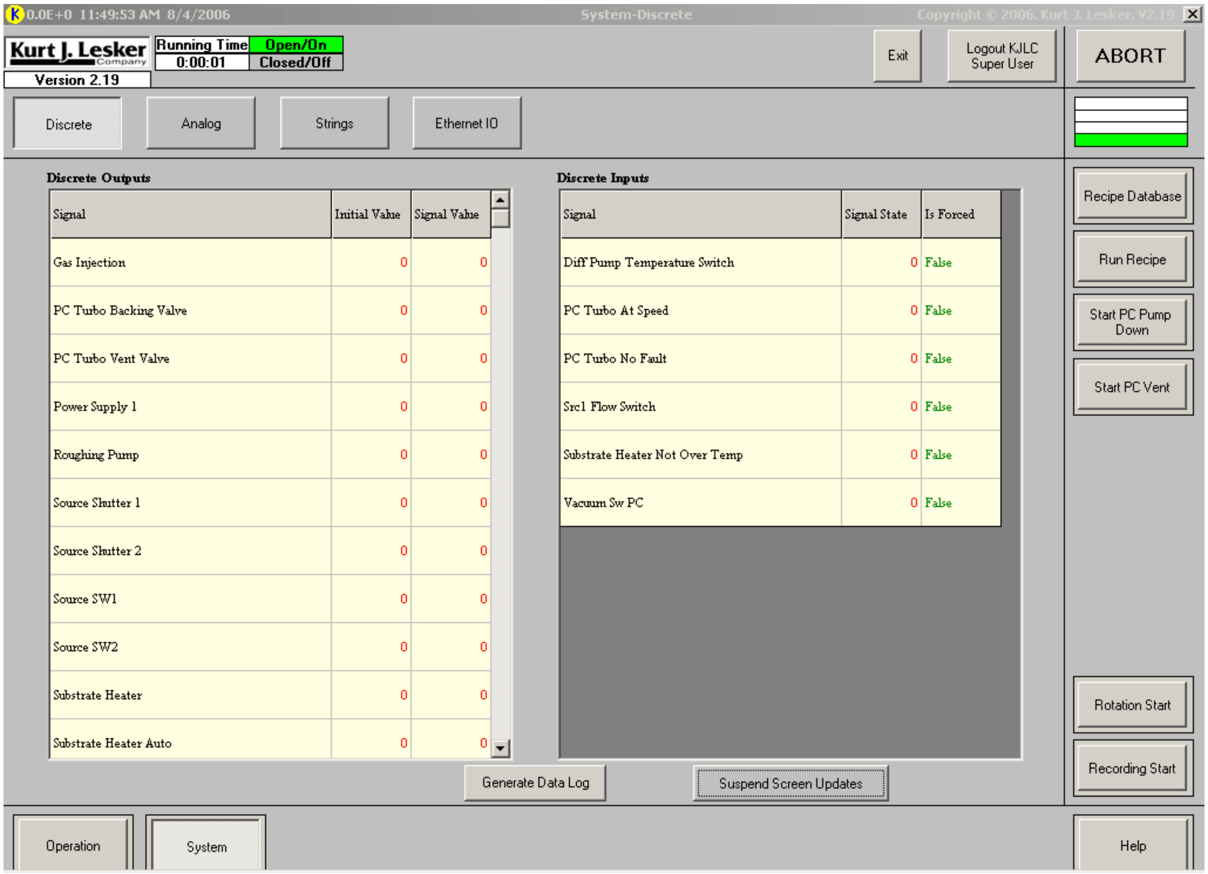
ICON OR DATA FIELD	ACTION	RESULT
Sigma Launch 242 ON OFF	Click to activate	Initiates the Sigma deposition control software.
Sigma Simulation Mode ON OFF	Click to activate	Simulates Sigma processes in the absence of Sigma hardware.
Sigma Start/Stop Process ON OFF	Click to activate	Initiates the currently loaded Sigma process.
Sigma Zero All Thicknesses ON OFF	Click to activate	Zeros the Sigma thickness.
OK Indicator OK	Display only	Lights green when Sigma acknowledges communication with CWare

ICON OR DATA FIELD	ACTION	RESULT
Power Supply Mapping PWS Mapping 1	Click to enter value	Map the power supply to the corresponding Sigma deposition source number. Example: If a "1" is entered, The Sigma process output Power setpoint will be transferred to the outpoint setpoint for KJLC deposition power supply #1.
Data Shutter Mapping Delay Shutter Mapping 1	Click to enter value	Map the desired shutter to the Sigma delay shutter control signal. Controls the opening and closing of the corresponding shutter. Shutter will open for the Shutter Delay and Deposit phases of the Sigma process only. This is typically used to map a source shutter.
Deposit Shutter Mapping Deposit Shutter Mapping 1	Click to enter value	Map the desired shutter to Sigma deposit control signal. Controls the opening and closing of the corresponding shutter. Shutter will open for the Deposit phase of the Sigma process only. This is typically used to map a substrate shutter.
Sigma Data Set Number 1	Click to enter value	Transfers the Sigma process setup associated with this number from the Recipe database to the Sigma software
Sigma Control Request New Process	Click to enter value	Loads the target process. Type the name of the process you want to run then Enter. If there is an associated process name in the Sigma software, this is the process that will run when you click on Sigma Start Process.
Sigma Last Message @UP;09;4C|	Display only	Displays the last message sent to Cware from the Sigma software.
Sigma Process Name New Process	Display only	The current process is displayed.
Sigma Film Name 06	Display only	The Sigma specific name of the current file is displayed.

Refer to the *Sigma Data Sets* section and the Sigma manual for descriptions of additional icons included on the Operation – Sigma screen.

SYSTEM

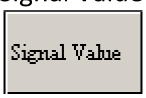
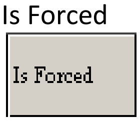
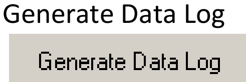
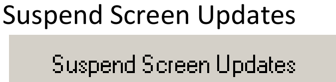
DISCRETE SCREEN



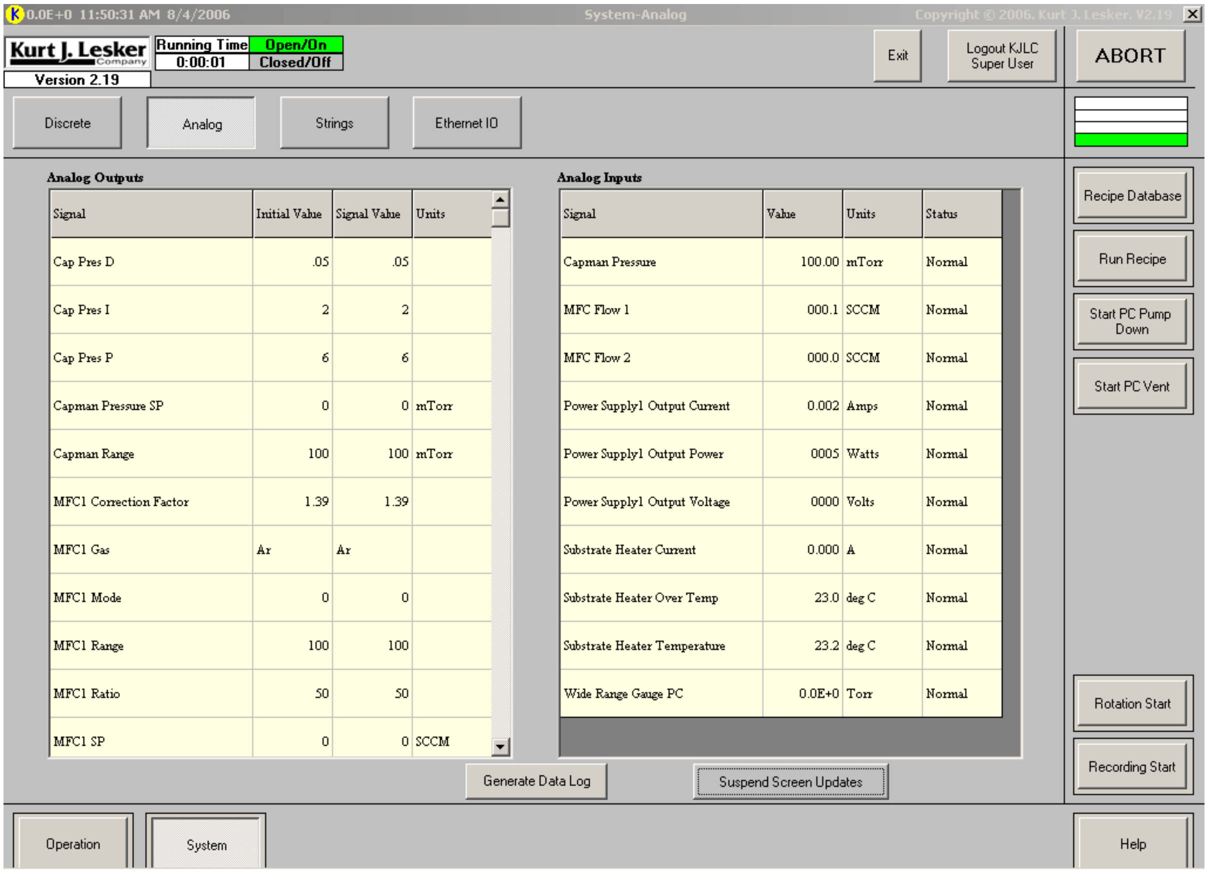
This screen is primarily used for troubleshooting and selecting datalog items. It is recommended that operators other than the system administrator do not have access to this screen. Users can be denied access to this screen based upon their login parameters – see the System Users Screen and the Security section of this manual.

CAUTION Failure to follow the proper preventative maintenance procedures could result in premature failure of the system or components.

CAUTION Forcing discrete inputs can override interlocks. When system troubleshooting is complete, you must remember to reset (un-force) signals.

ICON OR DATA FIELD	ACTION	RESULT
Signal 	Click to select or deselect	All Discrete Outputs and Inputs are listed in alphabetical order
Initial Value 	Display only	Displays the initial condition of the corresponding discrete output at system startup.
Signal Value 	Click to activate	Displays the actual current state of the corresponding discrete output. Clicking on the signal value will toggle its state and will also change the state of the corresponding equipment. For example clicking on the Gun2 shutter Signal Value is the same as clicking on the actual shutter indicator on the Operation – Deposition screen.
Signal State 	Click to force signal	Displays the current state of the corresponding discrete input at system startup. Discrete inputs can be forced by clicking on the corresponding Signal State.
Is Forced 	Display only	Indicates whether or not the current signal is forced. False = Unforced signal True = Forced signal
Generate Data Log 	Click to activate	Generates a table in the folder C:\Program Files\Lesker\Company Name\Data\ Datalog.mdb. The table name is the date and time the table was created.
Suspend Screen Updates 	Click to activate	Stops the constant screen update to allow the user to easily select signals to be forced.

ANALOG SCREEN

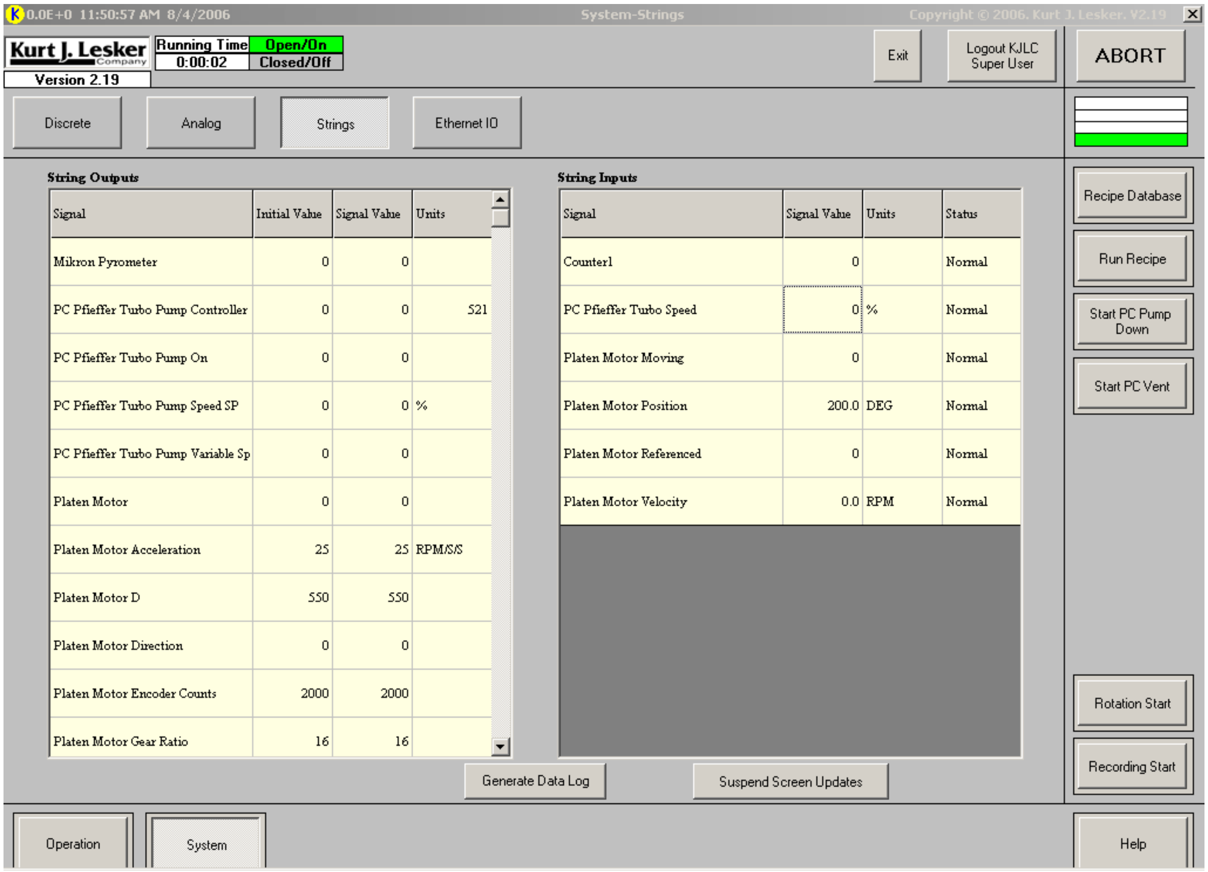


This screen is primarily used for troubleshooting datalogging. It is recommended that operators other than the system administrator do not have access to this screen. Users can be denied access to this screen based upon their login parameters – see the System Users Screen and the Security section of this manual.

CAUTION Forcing analog inputs can override interlocks. When system troubleshooting is complete, you must remember to reset (un-force) signals.

ICON OR DATA FIELD	ACTION	RESULT
Signal Signal	Click to select or deselect	All Analog Outputs and Inputs are listed in alphabetical order
Outputs – Initial Value Initial Value	Display only	Displays the initial condition of the corresponding analog output at system startup or shutdown.
Outputs – Signal Value Signal Value	Click to activate	Displays the actual current value of the corresponding analog output. Clicking on the signal value will display an alphanumeric keypad that allows the signal value to be changed. This will also change the value of the corresponding equipment. For example changing the value of the MFC1 SP is the same as changing the set point on the Operation – Gas Screen.
Units Units	Display only	Displays the corresponding signal's unit of measurement.
Inputs – Value Value	Click to activate	Displays the current value of the corresponding analog inputs. Analog inputs can be forced by clicking on the associated Value for the corresponding signal. A pop up alphanumeric keypad is displayed for data entry.
Inputs – Status Status	Display only	Displays whether or not the current signal is forced. Forced = Corresponding signal is forced Normal = Corresponding signal is normal
Generate Data Log Generate Data Log	Click to activate	Generates a table in the folder C:\Program Files\Lesker\Company Name\Data\ Datalog.mdb. The table name is the date and time the table was created.
Suspend Screen Updates Suspend Screen Updates	Click to activate	Stops the constant screen update to allow the user to easily select signals to be forced.

STRINGS SCREEN

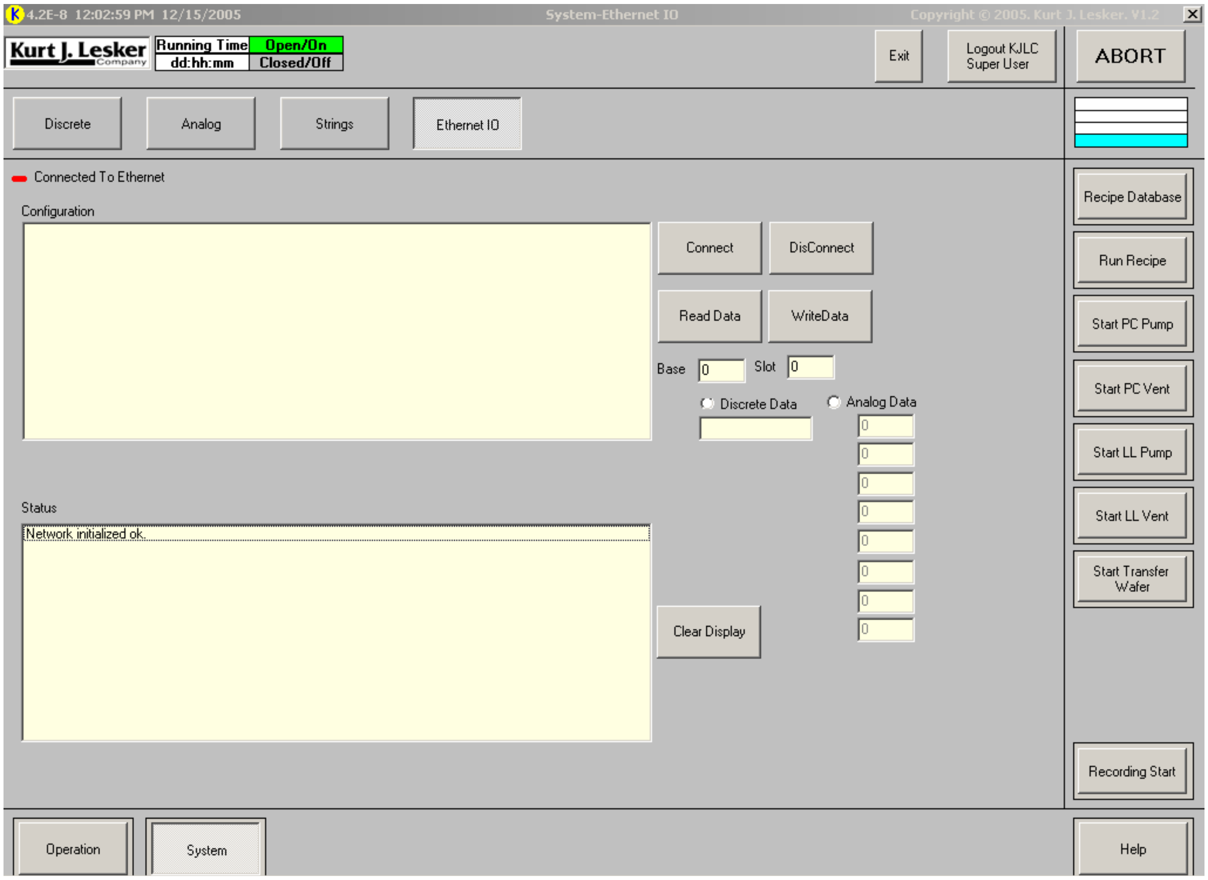


This screen is primarily used for troubleshooting. It is recommended that operators other than the system administrator do not have access to this screen. Users can be denied access to this screen based upon their login parameters – see the System Users Screen and the Security section of this manual.

CAUTION Forcing string inputs can override interlocks. When system troubleshooting is complete, you must remember to reset (un-force) signals.

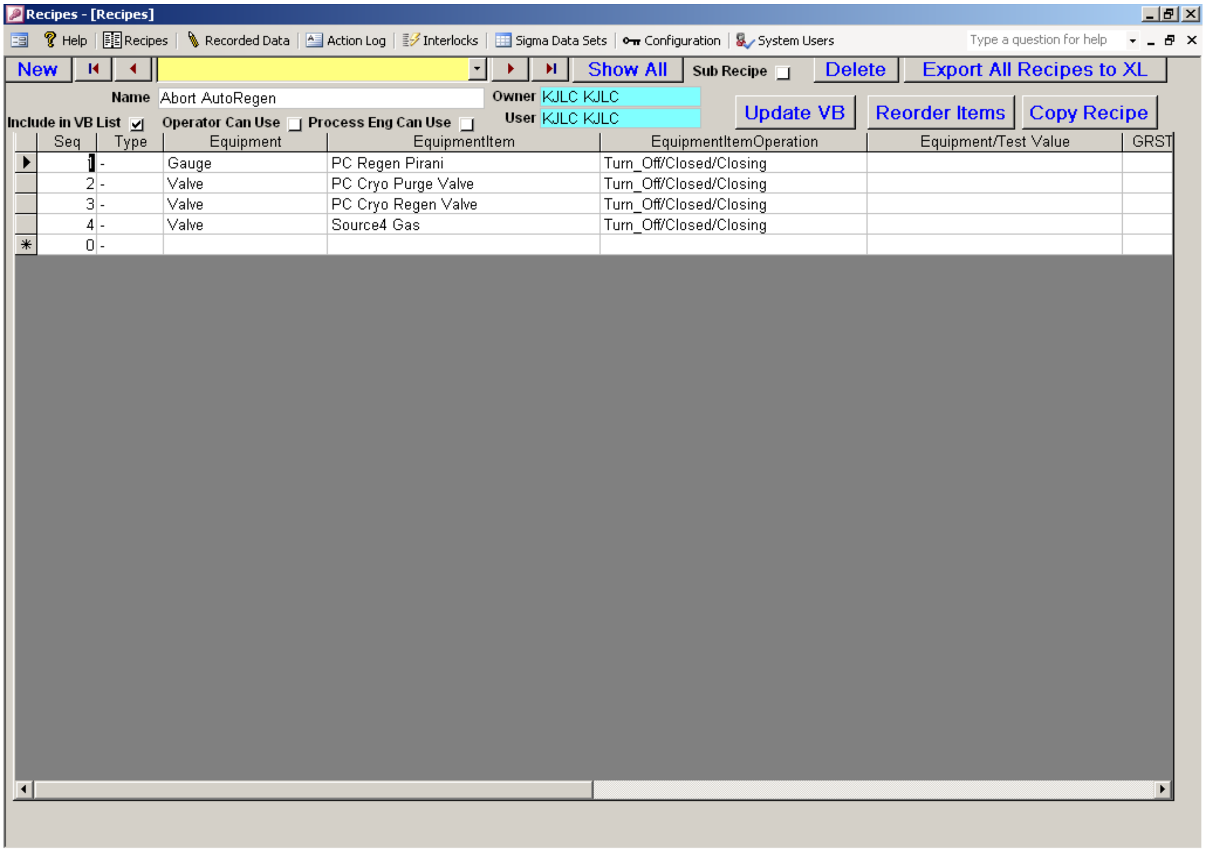
ICON OR DATA FIELD	ACTION	RESULT
Signal	Click to select or deselect	All String Outputs and Inputs are listed in alphabetical order
Outputs – Initial Value	Display only	Displays the initial condition of the corresponding string output at system startup or shutdown.
Signal Value	Click to activate	Displays the actual current value of the corresponding string output/input. Clicking on the signal value will display an alphanumeric keypad that allows the signal value to be changed. This will also change the value of the corresponding equipment. For example changing the value of the Platen Motor Home Offset is the same as changing the set point on the Operation – Motion Screen.
Units	Display only	Displays the corresponding signal's unit of measurement.
Inputs – Status	Display only	Displays whether or not the current signal is forced. Forced = corresponding signal is forced Normal = corresponding signal is normal
Generate Data Log	Click to activate	Generates a table in the folder C:\Program Files\Lesker\Company Name\Data\ Datalog.mdb. The table name is the date and time the table was created.
Suspend Screen Updates	Click to activate	Stops the constant screen update to allow the user to easily select signals to be forced.

ETHERNET I/O SCREEN



This screen contains information useful only to KJLC engineers and System Administrators. It is used in troubleshooting issues with Ethernet connections and modules.

RECIPE DATABASE

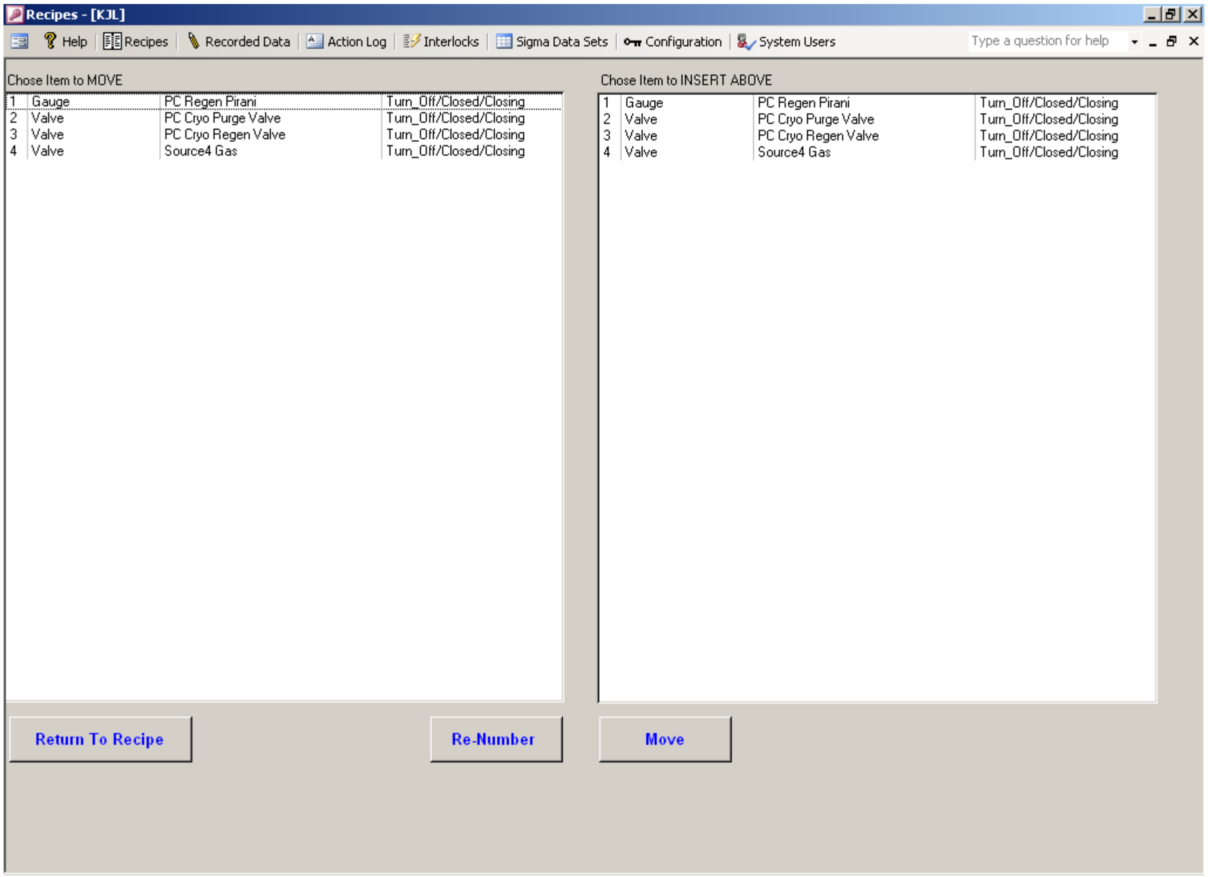


This screen provides the user with an interface for running and maintaining recipes. See the *CWare Operation* section for further instructions.

ICON OR DATA FIELD	ACTION	RESULT
New Recipe New	Click to activate	Starts a new, blank recipe.
Navigation Button	Click to activate	Use these buttons to select the first, previous, last, or next recipe in the recipe list.
Drop Down Recipe List	Click to activate	Click the arrow to display a list of programmed recipes. You can then select one from the list by clicking on it.
Show All Show ALL	Click to activate	Toggles between Show All and Show Main and dictates what list of recipes will be shown in the Drop Down Recipe List box.
Sub Recipe Sub Recipe	Click to activate	Checking this box will allow the chosen recipe to be used as a step in other recipes.
Delete Recipe Delete	Click to activate	Deletes the currently selected/displayed recipe.

ICON OR DATA FIELD	ACTION	RESULT
Export Recipes Export	Click to activate	Copies all recipes to C:\Program Files\Lesker\Customer Name\Excel Files\Recipe Sets.xls
Update VB Update VB	Click to activate	Updates the list of available recipes that will be seen in the Runtime Software and updates changes to recipes in the Runtime Software.
Reorder Items Reorder Items	Click to activate	Opens a new screen that allows the user to change the order of programmed commands.
Copy Recipe Copy Recipe	Click to activate	Copies the selected recipe and prompts for a new name.
Include in VB List Include in VB List ☑	Click to activate	Check this box to include the selected recipe in the “Run a Recipe” menu.
Operator Can Use Operator Can Use ☐	Click to activate	Check this box to allow “Operators” to run the selected recipe.
Process Engineer Can Use Process Eng Can Use ☐	Click to activate	Check this box to allow “Process Engineers” to run the selected recipe.
User User KJLC KJLC	Display only	Current logged in user of recipe
Owner Owner KJLC KJLC	Display only	Original writer of selected recipe.
GRST GRST	Click to enter value	G = Goto sequence number R = Ramp rate S = Skip T = Timeout

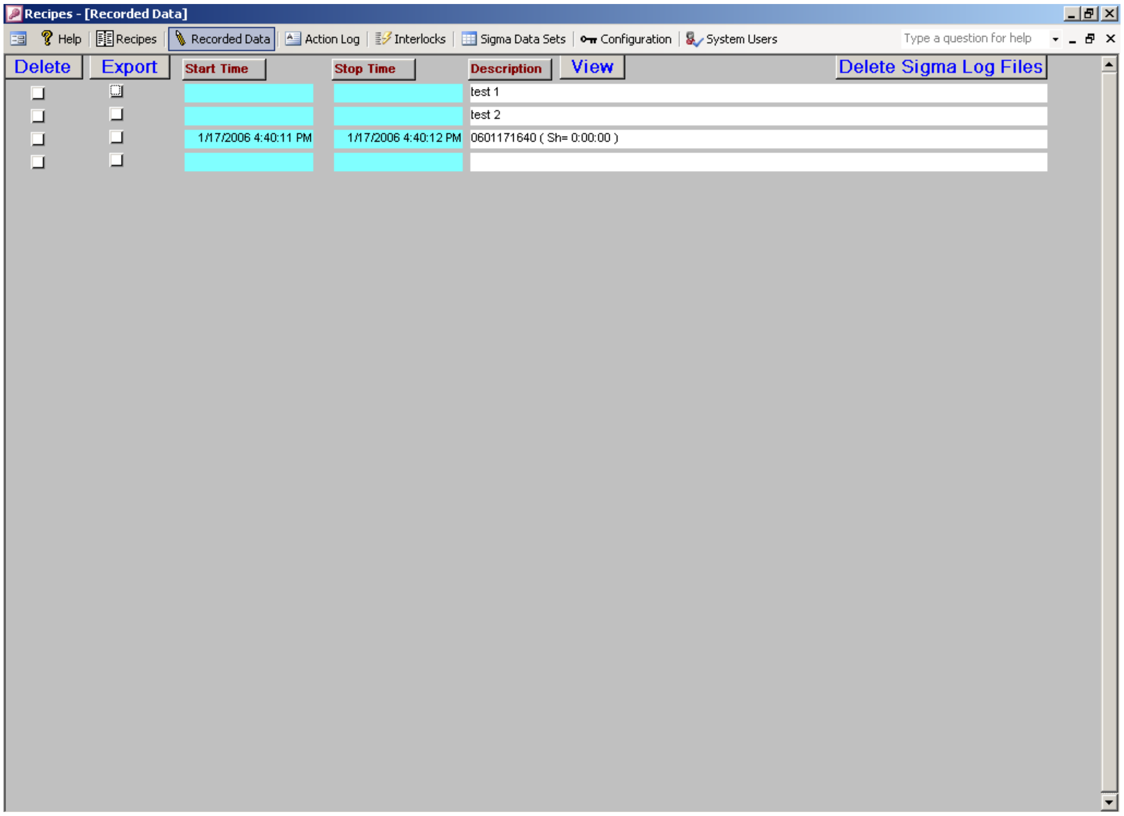
REORDER ITEMS



Use this screen to correct the order of steps in a saved recipe. To access this screen, click on *Reorder Items* on the *Recipe Screen*. See the *CWare Operation* section for further instructions.

ICON OR DATA FIELD	ACTION	RESULT
Chose Item to Move Chose Item to MOVE	Click to activate	Click the step in the column on the left that needs to be moved.
Chose Item to Insert Above Chose Item to INSERT ABOVE	Click to activate	Click the step in the column on the right that the chosen step from the left table needs to be placed before.
Move Move	Click to activate	Moves the location of the step selected on the left.
Re-Number Re-Number	Click to activate	Clicking this button corrects the numerical order of each command.
Return to Recipe Return To Recipe	Click to activate	Click to return to the recipe screen.

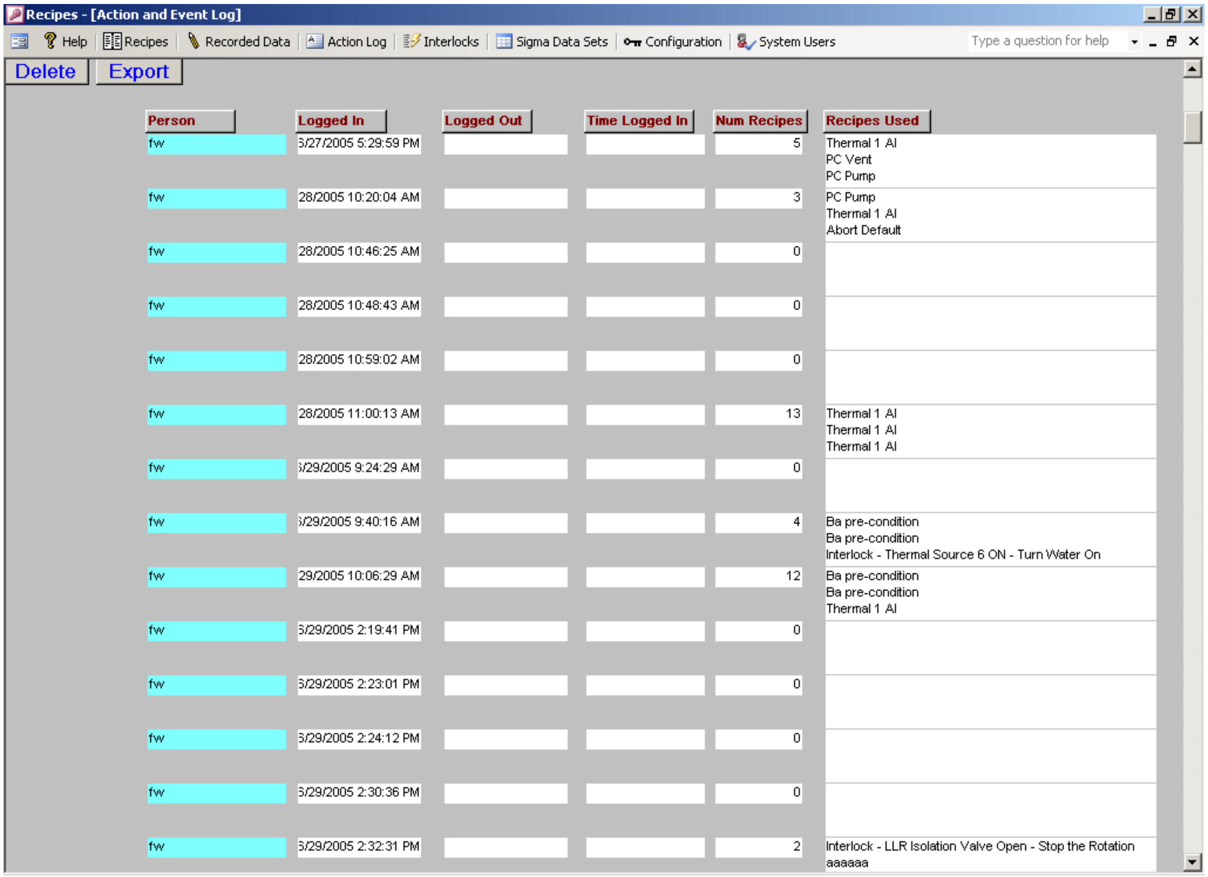
RECORDED DATA



This screen displays recorded system data and provides the user with a means to maintain the data. See the *CWare Operation* section for further instructions.

ICON OR DATA FIELD	ACTION	RESULT
Delete Delete	Click to activate	Deletes the selected data set.
Export Export	Click to activate	Exports the selected data set to Excel.
Start Time Start Time	Display only	Shows the start time of the corresponding data set.
Stop Time Stop Time	Display only	Shows the stop time of the corresponding data set.
Description Description test 1	Display only	Shows the unique system-generated name for a data set. This name can be edited by the user.
View View	Click to activate	Views the selected data set in the table format of an Access database.
Delete Sigma Log Files Delete Sigma Log Files	Click to activate	Deletes Sigma Log Files

ACTION LOG

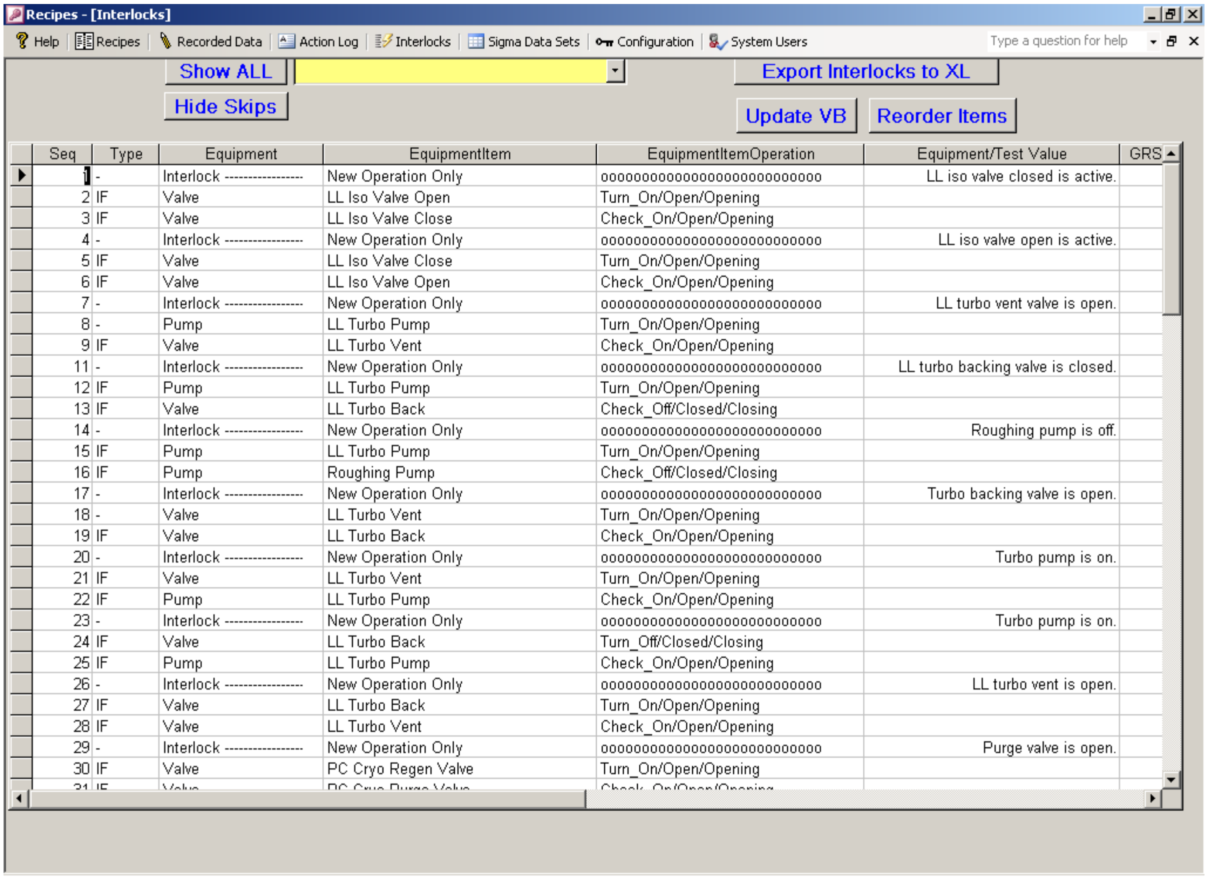


All user actions that have occurred since the last shut down can be viewed and maintained using this screen. See the *CWare Operation* section for further instructions.

ICON OR DATA FIELD	ACTION	RESULT
Delete Delete	Click to activate	Click to remove all entries in the Action Log
Export Export	Click to activate	Click to export a copy of all entries in the Action Log to C:\ProgramFiles\Lesker\Customer Name\Excelfiles
Person Person	Display only	Displays the login name of the person using the system for the corresponding login entry.
Logged In Logged In	Display only	Shows the date and time that the user logged into the system.
Logged Out Logged Out	Display only	Shows the date and time that the user logged out of the system.

ICON OR DATA FIELD	ACTION	RESULT
Time Logged In 	Display only	Shows the elapsed time that the corresponding user was logged into the system.
Number of Recipes 	Display only	Shows a count of the number of recipes that were used by the corresponding user login name.
Recipes Used 	Display only	Lists the recipes that were used by the corresponding user login name.

INTERLOCKS



Seq	Type	Equipment	EquipmentItem	EquipmentItemOperation	Equipment/Test Value	GRS
1	-	Interlock ----------------	New Operation Only	000000000000000000000000000	LL iso valve closed is active.	
2	IF	Valve	LL Iso Valve Open	Turn_On/Open/Opening		
3	IF	Valve	LL Iso Valve Close	Check_On/Open/Opening		
4	-	Interlock ----------------	New Operation Only	000000000000000000000000000	LL iso valve open is active.	
5	IF	Valve	LL Iso Valve Close	Turn_On/Open/Opening		
6	IF	Valve	LL Iso Valve Open	Check_On/Open/Opening		
7	-	Interlock ----------------	New Operation Only	000000000000000000000000000	LL turbo vent valve is open.	
8	-	Pump	LL Turbo Pump	Turn_On/Open/Opening		
9	IF	Valve	LL Turbo Vent	Check_On/Open/Opening		
11	-	Interlock ----------------	New Operation Only	000000000000000000000000000	LL turbo backing valve is closed.	
12	IF	Pump	LL Turbo Pump	Turn_On/Open/Opening		
13	IF	Valve	LL Turbo Back	Check_Off/Closed/Closing		
14	-	Interlock ----------------	New Operation Only	000000000000000000000000000	Roughing pump is off.	
15	IF	Pump	LL Turbo Pump	Turn_On/Open/Opening		
16	IF	Pump	Roughing Pump	Check_Off/Closed/Closing		
17	-	Interlock ----------------	New Operation Only	000000000000000000000000000	Turbo backing valve is open.	
18	-	Valve	LL Turbo Vent	Turn_On/Open/Opening		
19	IF	Valve	LL Turbo Back	Check_On/Open/Opening		
20	-	Interlock ----------------	New Operation Only	000000000000000000000000000	Turbo pump is on.	
21	IF	Valve	LL Turbo Vent	Turn_On/Open/Opening		
22	IF	Pump	LL Turbo Pump	Check_On/Open/Opening		
23	-	Interlock ----------------	New Operation Only	000000000000000000000000000	Turbo pump is on.	
24	IF	Valve	LL Turbo Back	Turn_Off/Closed/Closing		
25	IF	Pump	LL Turbo Pump	Check_On/Open/Opening		
26	-	Interlock ----------------	New Operation Only	000000000000000000000000000	LL turbo vent is open.	
27	IF	Valve	LL Turbo Back	Turn_On/Open/Opening		
28	IF	Valve	LL Turbo Vent	Check_On/Open/Opening		
29	-	Interlock ----------------	New Operation Only	000000000000000000000000000	Purge valve is open.	
30	IF	Valve	PC Cryo Regen Valve	Turn_On/Open/Opening		

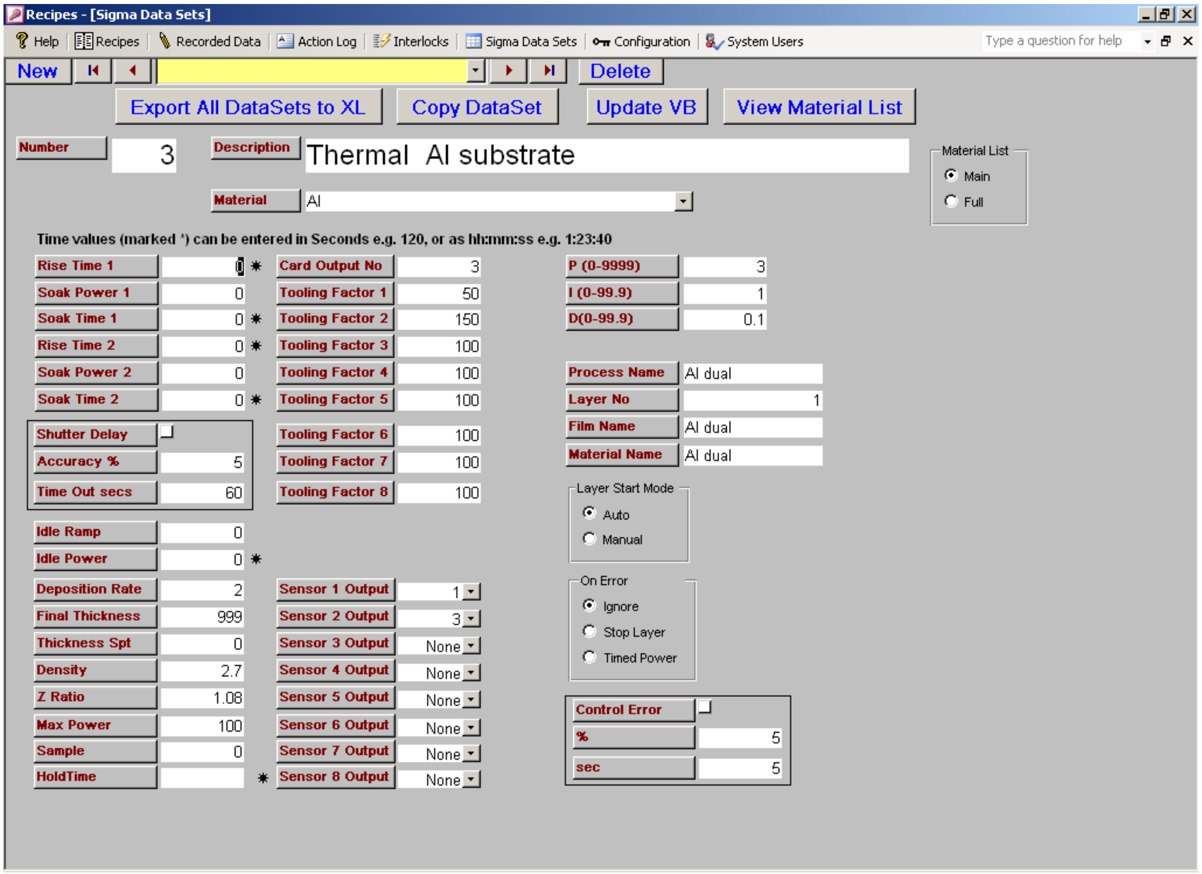
This screen provides detailed information regarding interlocks. Only KJLC Engineers, or System Administrators under the direction of a KJLC Engineer, should change these interlocks. See *CWare Operation* for further instructions.

CAUTION Changes to this screen can damage equipment or cause injury to system users.

ICON OR DATA FIELD	ACTION	RESULT
Show All Show ALL	Click to activate	Shows all interlocks.
Hide Skips Hide Skips	None	Reserved for future use.
Drop Down List	Click to activate	Choose a piece of equipment to see only the interlocks associated with that equipment.
Export Export Interlocks to XL	Click to activate	Exports the interlock data to an Excel spreadsheet.

ICON OR DATA FIELD	ACTION	RESULT
Update VB 	Click to activate	Updates Visual Basic with any changes that have been made.
Reorder Items 	Click to activate	Renumbers the steps after changes have been made

SIGMA DATA SETS

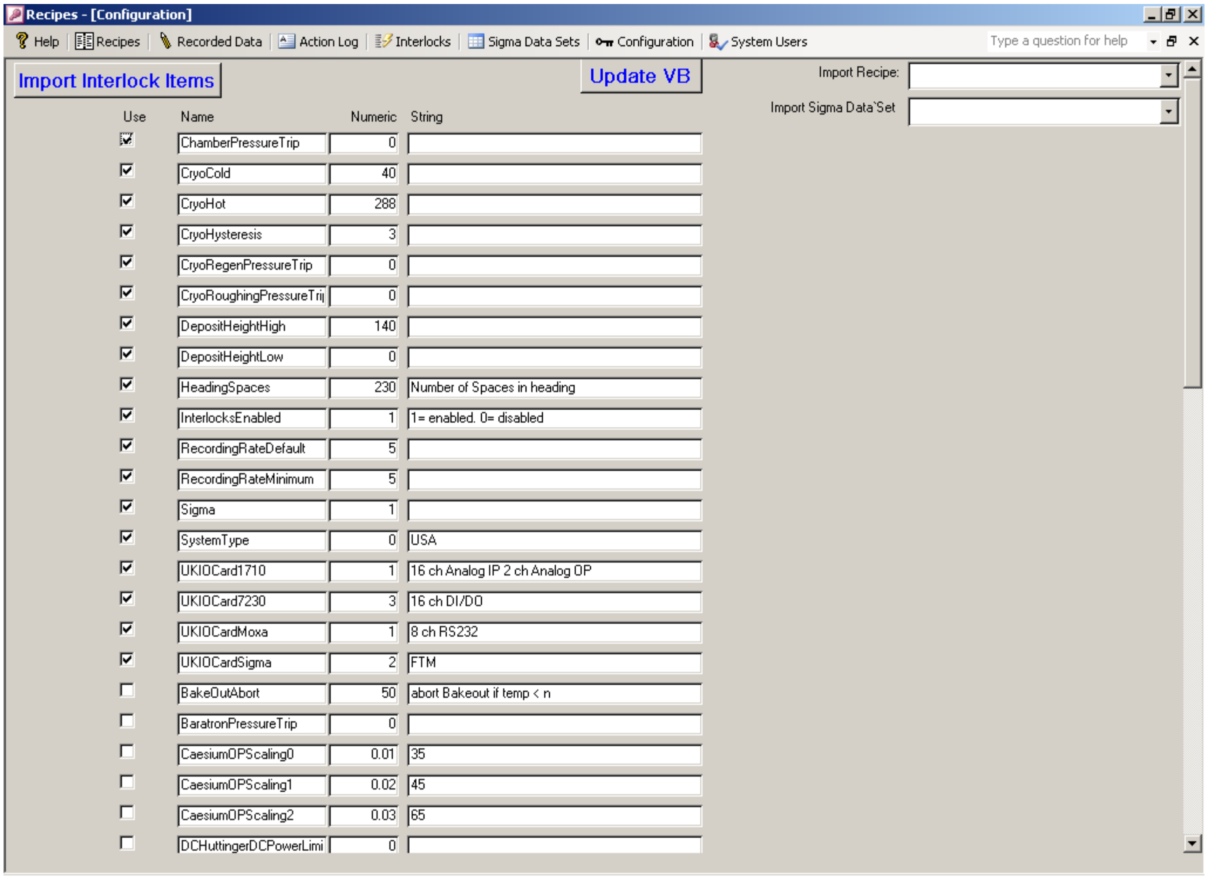


All Sigma Data settings can be viewed and maintained using this screen.

Refer to the Sigma manual for further details regarding data set parameters.

ICON OR DATA FIELD	ACTION	RESULT
New New	Click to activate	Creates a new data set.
Navigation Buttons	Click to activate	Use these buttons to select the first, previous, last, or next data set.
Delete Delete	Click to activate	Deletes the selected data set.
Export to Excel Export	Click to activate	Exports the selected data set to Excel.
Copy Dataset Copy DataSet	Click to activate	Creates a copy of the selected data set.
Update VB Update VB	Click to activate	Updates Visual Basic with any changes that have been made.

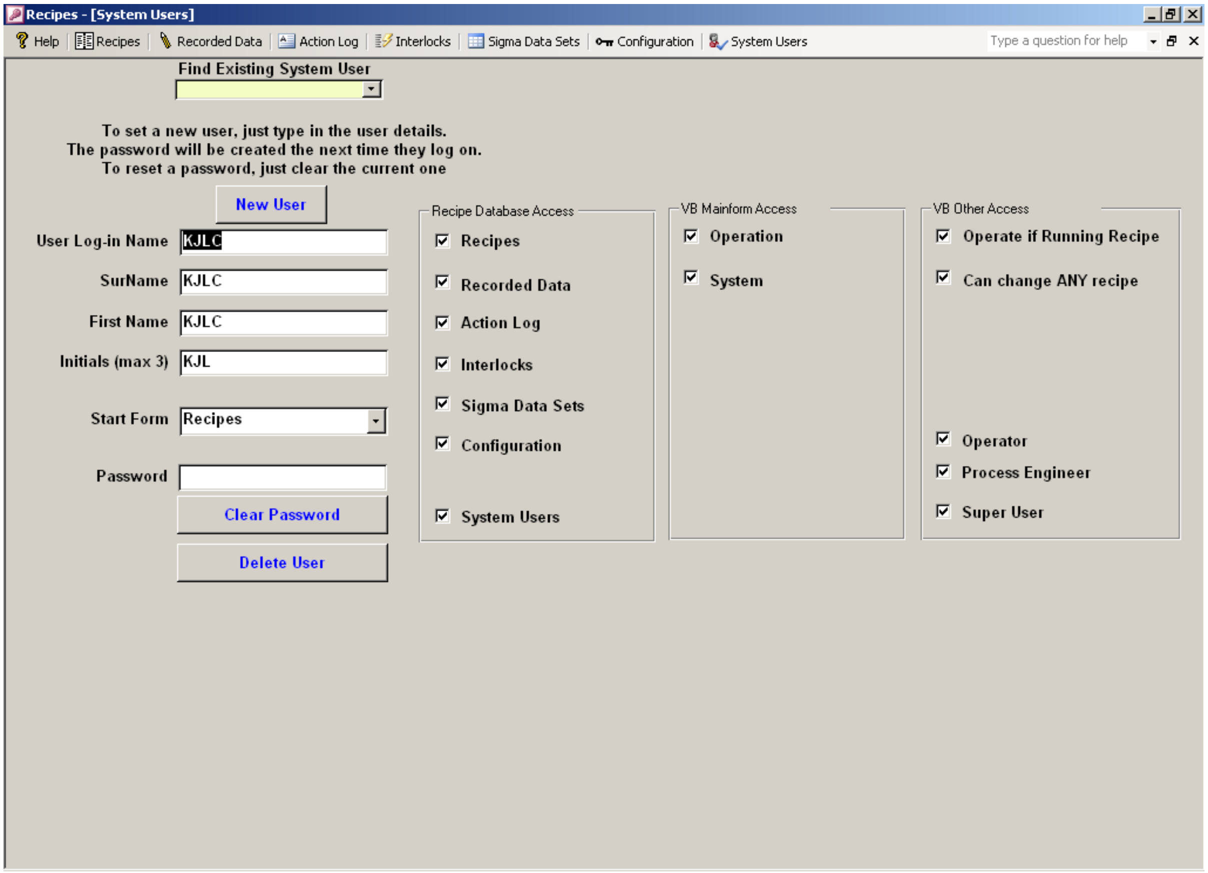
CONFIGURATION



This screen contains important setup information that affects and enables computer control of the system. The only field that customers should change is the *RecordingRateDefault*. Changes to any other data on this screen should only be made by KJLC Engineers or under the guidance of a KJLC Engineer.

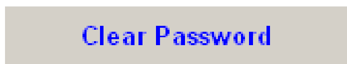
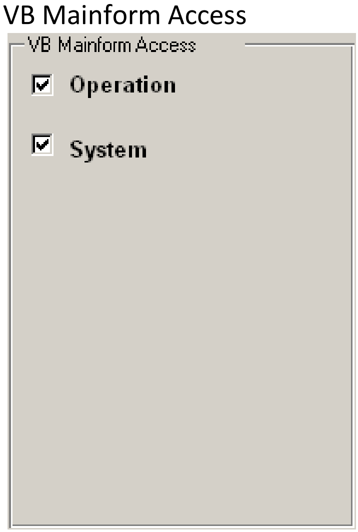
ICON OR DATA FIELD	ACTION	RESULT
Recording Rate Default RecordingRateDefault 5	Click to enter value	Enter the rate (in seconds) at which the computer should record system data.

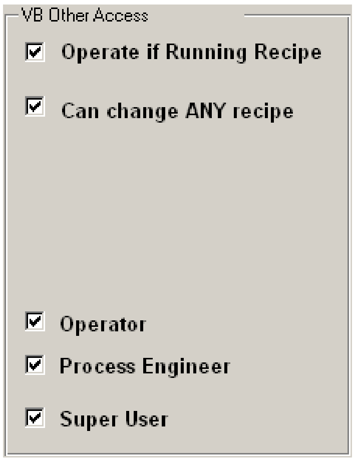
SYSTEM USERS



This chart defines icons and buttons found on the *System Users* Screen.

ICON OR DATA FIELD	ACTION	RESULT
Find Find Existing System User	Click to activate	This field displays a list of all users with access to the system software in drop-down menu format.
New User New User	Click to activate	Click this button to create a new software user using the appropriate boxes below.
Log-in User Log-in Name KJLC	Click to activate	Enter a user's log-in name to log in.
SurName (Last Name) SurName KJLC	Click to activate	Enter the user's last name in this field.
First Name First Name KJLC	Click to activate	Enter the user's first name in this field.
Initials Initials (max 3) KJL	Click to activate	Enter the user's initials in this field.

ICON OR DATA FIELD	ACTION	RESULT
Start Form 	Click to activate	Use this drop down list to choose which screen / form should be the opening screen for the selected user.
Password 	Click to activate	Enter the password for the selected user.
Clear Password 	Click to activate	Removes the existing password for the selected user.
Delete User 	Click to activate	Deletes the selected username.
Recipe Database Access 	Click to activate	Use this list of checkboxes to assign availability of the System Database screens to the selected user.
VB Mainform Access 	Click to activate	Use this list of checkboxes to assign availability of the Runtime Software screens to the selected user.

ICON OR DATA FIELD	ACTION	RESULT
VB Other Access 	Click to activate	Use this list of checkboxes to assign availability of software screens to the selected user. Operate if Running Recipe = Allows the user to operate heaters/shutters on the runtime software screens while a recipe is running Can change ANY recipe = Can amend any recipe, even if the user does not own it. Operator = The user can only run recipes assigned to Operators Process Engineer = The user can only run recipes assigned to Process Engineers Super User = The user can run/amend any recipe

CWARE STARTUP

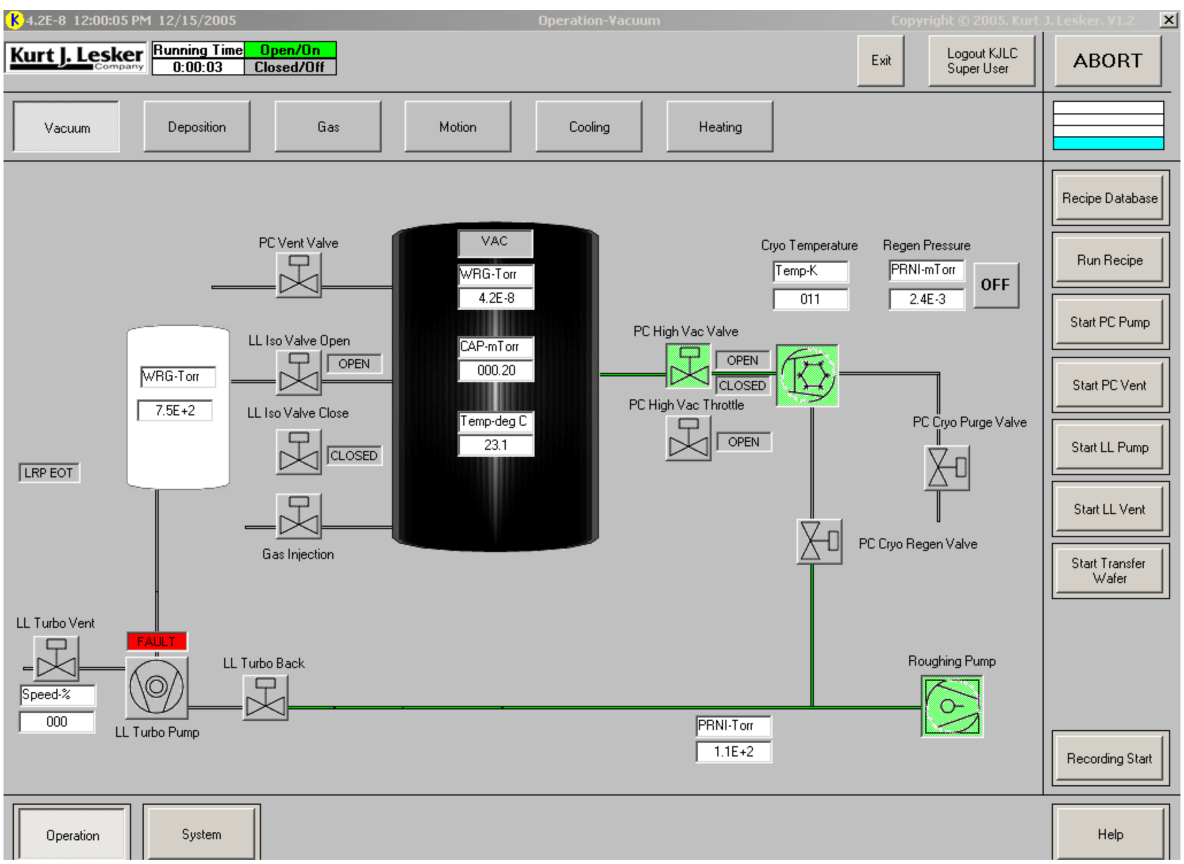
☝ Please review the General Information & Definitions Sections thoroughly prior to operating the system via CWare.

This section provides general information on how to operate the system using the computer interface. Please modify these procedures as necessary to conform to your specific needs.

The system computer is configured to automatically start KJLC software every time it boots up. Additionally, if the Runtime software has been stopped for maintenance purposes, it can be restarted by double-clicking the software icon on the Windows desktop.

Before starting the software or booting the computer, it is generally a good idea to verify the appropriate system components are on and in the correct state (i.e. power supplies on, cryo compressors/turbo controllers on, gauge controller on, etc.). Additionally, all gauges should be turned off manually on the system's vacuum gauge controller (if applicable) prior to starting system software (this is to prevent priority conflicts and communication errors between the gauge controller and the system control software).

The Operation – Vacuum Screen is typically the first screen to appear:



At system startup, the *Login/Logout Button* is in a "Login Here" state. Clicking on this button will display the dialog box shown here:

LOGIN/LOGOUT DIALOG BOX

1) Type your user name in the upper window. Then use the mouse to set the cursor in the password window. Type your password and press the enter key on the keyboard. The "OK" button will then appear.
2) Click "OK" or press the enter key on the keyboard. The dialog box will disappear and the Login/Logout button will now display the "username" and the security access level of the logged in user.
3) At this point, basic system operation is available to the user – pumping, venting, sample loading/unloading, process selection, and process execution. It is usually a good idea to pumpdown the system upon startup (unless the system has a cryo pump that requires regeneration, in which case pumpdown initiation must wait until the pump is ready). Running the standard PC Pumpdown process puts the system into a known state that is typically desirable before selecting and running a deposition process.

Prior to running any process, assure that all system connections have been properly made and all related documentation has been reviewed.

Refer to the *Overview & Definitions* section of *Software Operation* for details regarding the function of Icons and Command Button processes.

STANDARD RECIPES

A recipe is a collection of commands that can be used to perform a set routine. Many recipes are pre-programmed for customers. These programmed recipes can be modified, or copied then modified to suit your specific application. The standard recipes involve basic functions such as abort routines, pumping, venting, testing, wafer transfer, etc. Use the *Recipe Database* screen to view or modify the steps in a recipe.

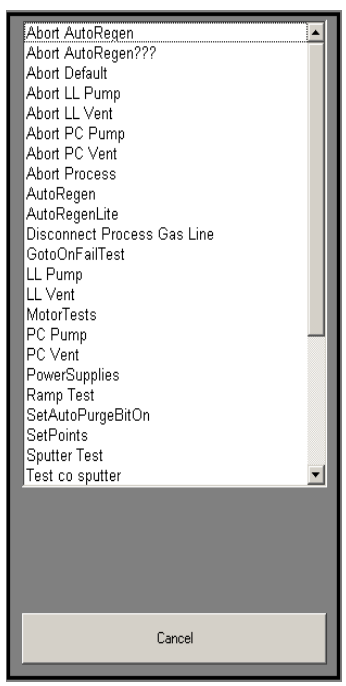
RUNNING RECIPES

A list of available recipes is displayed by pressing the *Run Recipe* button from any *Runtime Engine* screen. Recipe details can also be viewed from the *Recipe* screen of the *System Database*. The list of available recipes is limited by the access level of the logged in user and if the *Include in VB List* box is checked. See *System Users* and *Recipes* screens in the *Overview & Definitions* section for further details.

Skipping certain steps may cause damage to equipment and is done so at the operator's own risk.

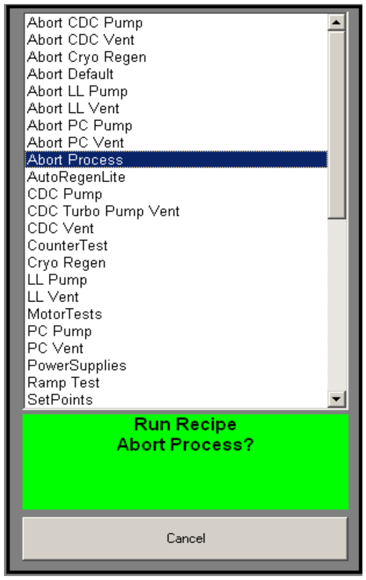
To run a recipe from the *Runtime Software* screens:

1) Click the *Run Recipe* command button found on the right side of any *Runtime Software* screen.



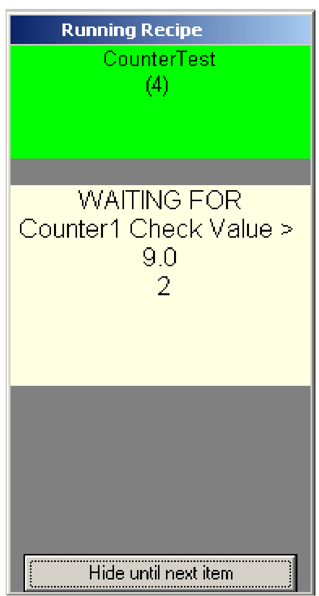
STANDARD RECIPES

2) Select the desired recipe from the list with a single left-click of the mouse. A green box appears below the list just above the Cancel button.



3) Click the green box to start running the recipe. Clicking Cancel will close the *Run Recipe* pop up box.

4) When the recipe starts, a dialog box will appear. The top half displays the recipe name and step number. The bottom half displays the current action of the running recipe.



RECIPE DIALOG BOX

5) The recipe can be aborted at any time by right-clicking the top half (dark red) and selecting abort. This will run the Abort Default recipe or the Abort recipe assigned to the recipe. (See *Standard Recipes*).

WRITING RECIPES

1) On the *Recipe* screen, click New in the upper left corner.
2) Type a name in the white box next to *Name*.
3) Check the *Include in VB List* box so that the recipe will be available from the *Runtime Software*.
4) Click on row 0 in the *Equipment* column, and then select an equipment option from the drop down menu.
5) Tab to, or click on the *EquipmentItem* column and select an option from the drop down menu. The contents of this drop down menu are dependent upon the chosen equipment from step 4 above.
6) Tab to, or click on the E*quipmentItemOperation* column and choose the desired action.
7) In the last column, *Equipment/Test Value*, enter the time or pressure relevant to the chosen action.
8) The column labeled *GRST* allows for Goto sequence number, Ramp rate, Skip, or Timeout steps
9) Repeat steps 1 through 8 for each recipe step. You cannot move to the next recipe step until the current one is complete.
10) When all steps of the recipe are complete, click on the *Update VB* button to save the recipe. This will make the recipe appear on the *Run Recipe* list from the *Runtime Software* screens.

Recipe GoTo on Fail:

IF THIS BOX CONTAINS:	**THEN:**
999 and there is an abort recipe in step 1 of the recipe	The user defined abort recipe in step 1 will run
999 and there is not an abort recipe in step 1 of the recipe	The “Abort Default” recipe will run
A user defined valid recipe step number	It goes to the step number indicated
“0” or is blank	A Timeout Message Box will appear

MODIFYING RECIPES

Any saved recipe can be modified. It is strongly suggested that you copy a recipe and modify the copy using a new recipe name. If you need the original recipe, it will still be saved as it was before you started.

☝ When modifications are complete, you must click Update VB for the changes to be applied in the Runtime Software.

To **change the order** of the steps in a recipe:

1) Use the navigation buttons on the Recipe Database screen to choose the recipe to edit.
2) On the Recipe Database screen, click the Reorder Items button.
3) On the left side of the screen, click the recipe step that needs to be moved.
4) On the right side of the screen, click the recipe step that the chosen step on the left needs to be placed BEFORE.
5) Click the Move button. Both lists display the changed order and the steps have renumbered automatically.
6) Click the Return to Recipe button to return to the main Recipe Database screen.

To **delete** a step in a recipe:

1) Use the navigation buttons on the Recipe Database screen to choose the recipe to edit.
2) Left-click in the leftmost block next to the step number of the recipe step you wish to delete – the entire row should be highlighted black.
3) Press the Delete Key on the keyboard.
4) The sequence number for the deleted step is now missing. If you wish to renumber the remaining steps, use the Reorder Items button, then press the Re-Number button.

To **add** a step to a recipe:

1) Use the navigation buttons on the *Recipe Database* screen to choose the recipe to edit.
2) You must first add the step AFTER all of the other steps in the recipe.
3) When the required step is complete, follow the steps above labeled “change the order of the steps in the recipe” to place the new step in its proper position.

IMPORTING RECIPES

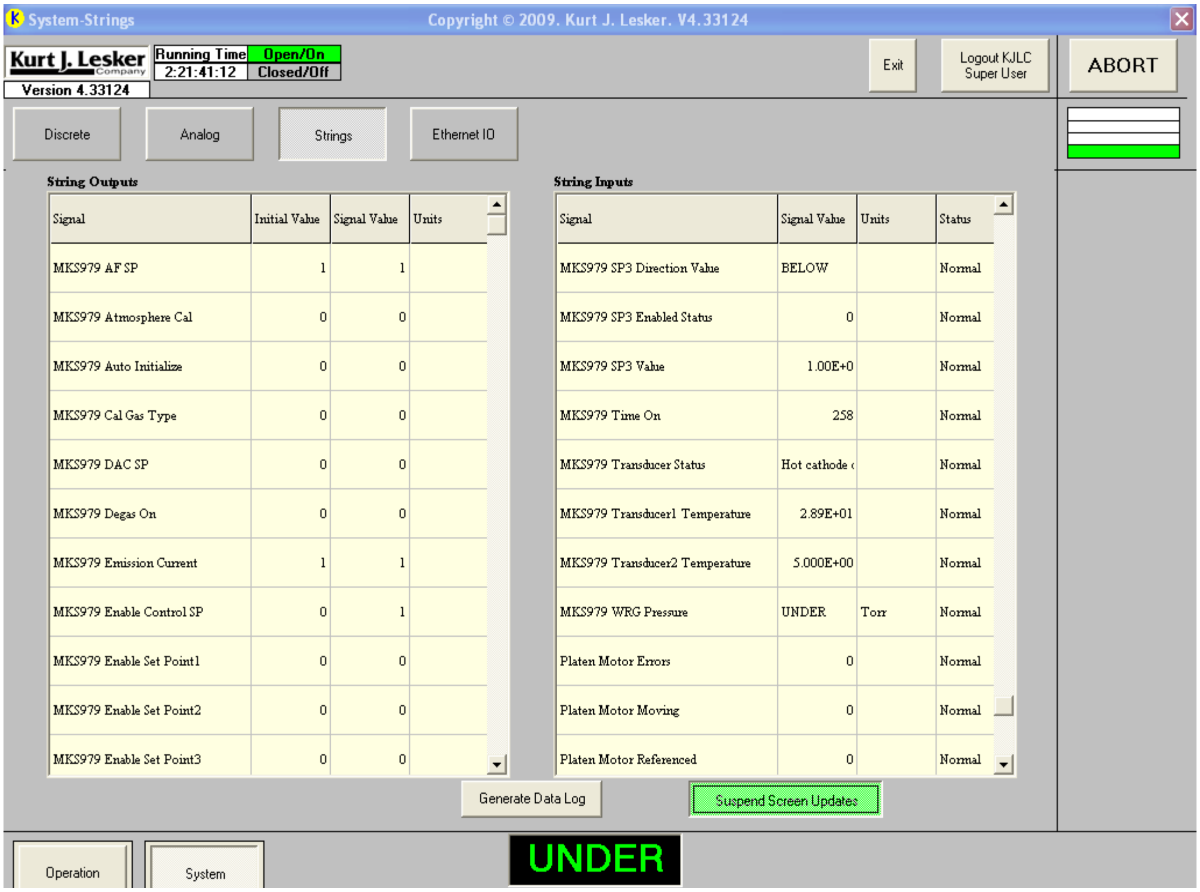
1) Copy the RecipeD.mdb file from the source system to your C:\Program Files\Lesker directory.
2) Start the system and access the recipe database.
3) Select configuration.
4) Click on the Import Recipe drop down box.
5) Select the recipe to import by clicking on it.
6) You will be prompted to accept the import.
7) Click on OK.
8) The new recipe is imported to your system.
9) Click the *Update VB* button.

RECORDING DATA

1) Click on the *Recording Start* button near the lower right corner of any Runtime Engine screen. The caption of this button will change to *Recording Stop* and it will illuminate green each time data is written. Clicking it again will stop recording data.
2) Recorded data is saved in a Microsoft Database format. The file path is: C:\Program Files\Lesker*Customer Name*\Data\RecordingD.mdb
3) The data is saved in a table named tblRecordingData.
4) Data can be accessed by opening the database using Microsoft Access and then double clicking the table file.
5) The first two fields in this table are generated by the software for system use. The remaining fields are the recorded system signals including a Date/Time stamp.
6) Data can be exported or extracted using Microsoft Access Tools.

DATA LOGGING SIGNALS

1) Navigate to the System Screen. You can select signals to Data Log from the Discrete, Analog, or String screens.
2) Click the Suspend Screen Updates.

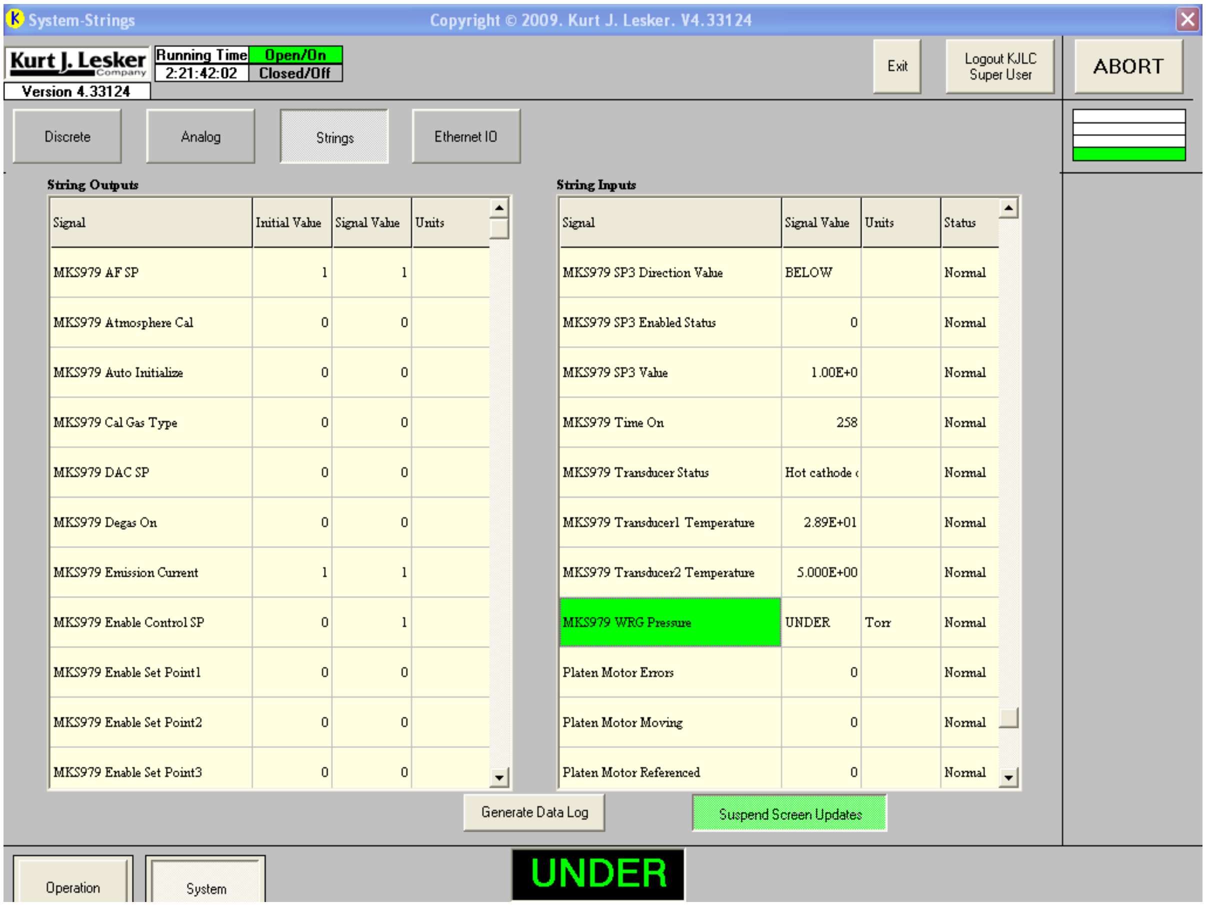


Signal	Initial Value	Signal Value	Units
MKS979 AF SP	1	1	
MKS979 Atmosphere Cal	0	0	
MKS979 Auto Initialize	0	0	
MKS979 Cal Gas Type	0	0	
MKS979 DAC SP	0	0	
MKS979 Degas On	0	0	
MKS979 Emission Current	1	1	
MKS979 Enable Control SP	0	1	
MKS979 Enable Set Point1	0	0	
MKS979 Enable Set Point2	0	0	
MKS979 Enable Set Point3	0	0	

Signal	Signal Value	Units	Status
MKS979 SP3 Direction Value	BELOW		Normal
MKS979 SP3 Enabled Status	0		Normal
MKS979 SP3 Value	1.00E+0		Normal
MKS979 Time On	258		Normal
MKS979 Transducer Status	Hot cathode (		Normal
MKS979 Transducer1 Temperature	2.89E+01		Normal
MKS979 Transducer2 Temperature	5.000E+00		Normal
MKS979 WRG Pressure	UNDER	Torr	Normal
Platen Motor Errors	0		Normal
Platen Motor Moving	0		Normal
Platen Motor Referenced	0		Normal

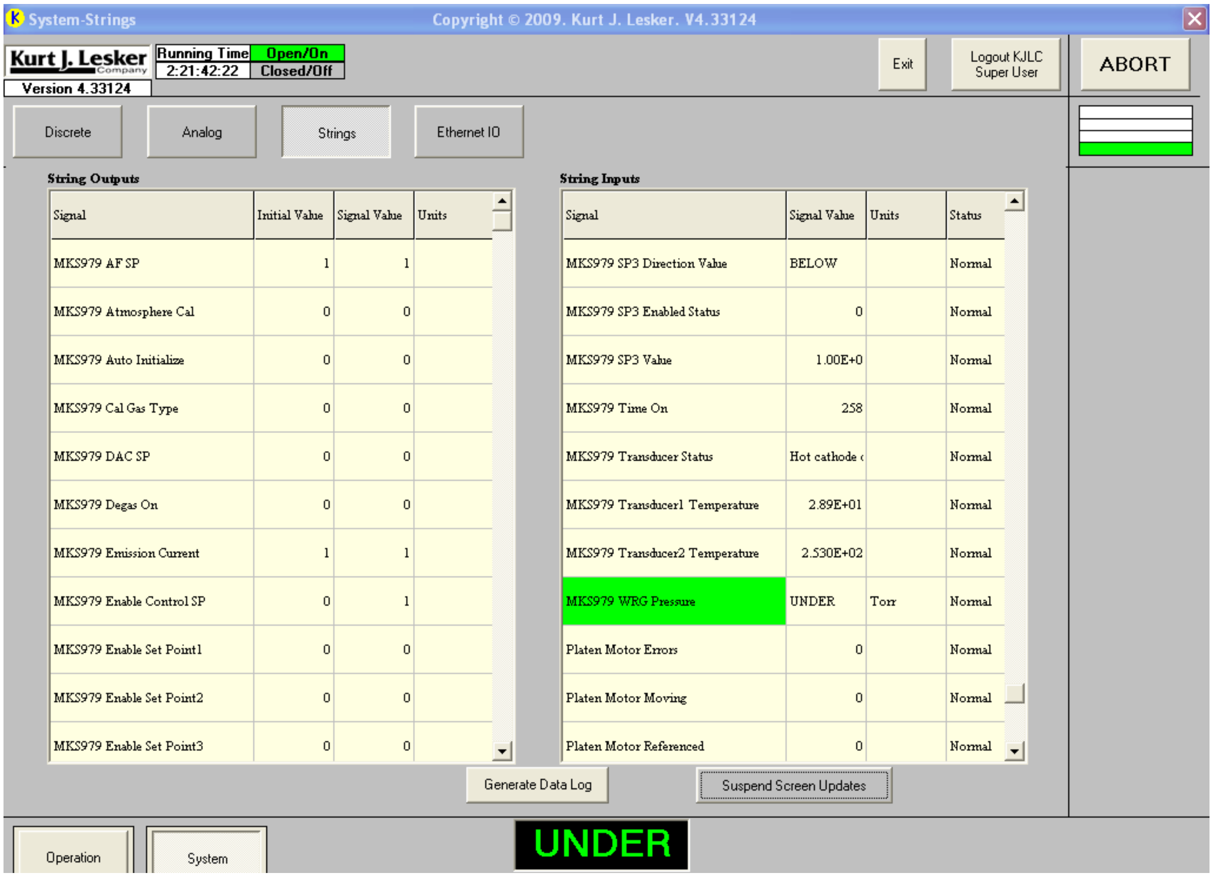
DATALOG SCREEN #1

3) Highlight the signal names that you would like to Data Log.



DATALOG SCREEN #2

4) Click Suspend Screen Updates to deactivate.

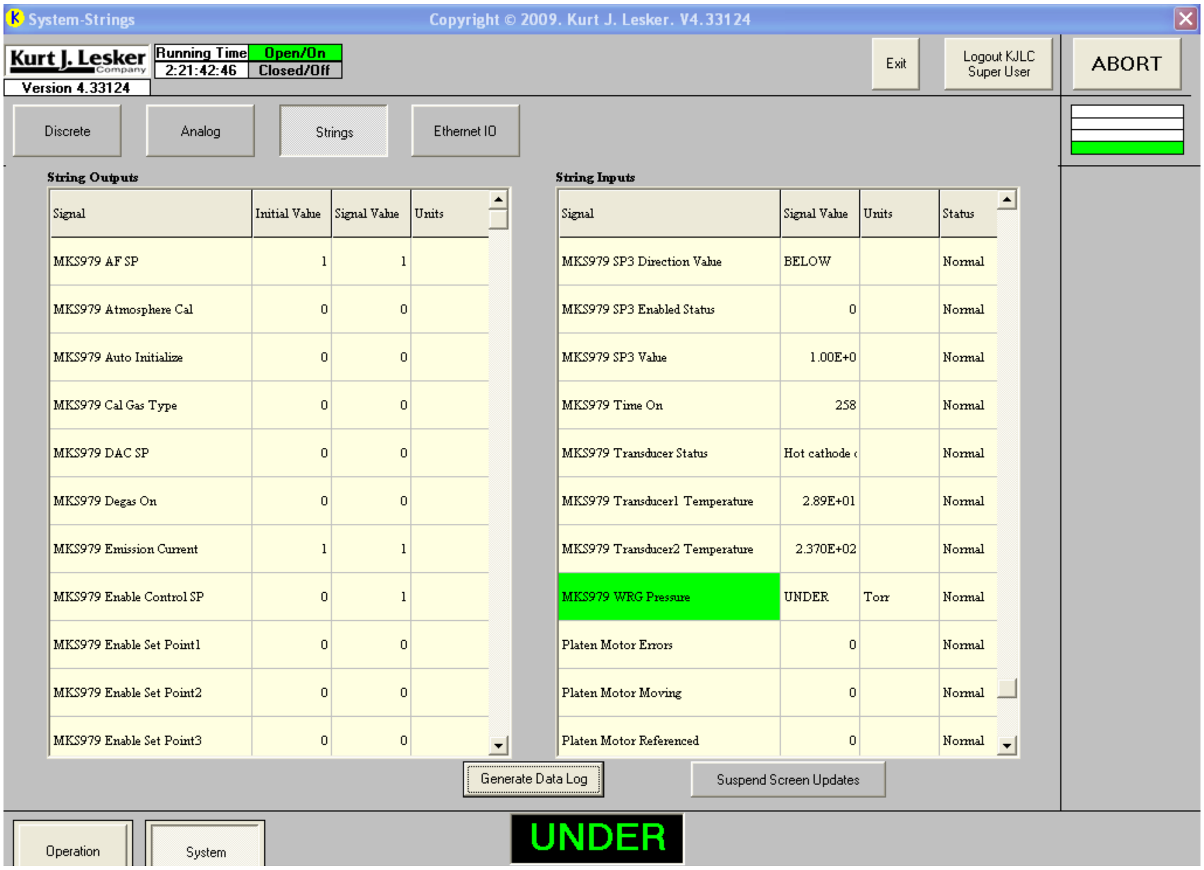


DATALOG SCREEN #3

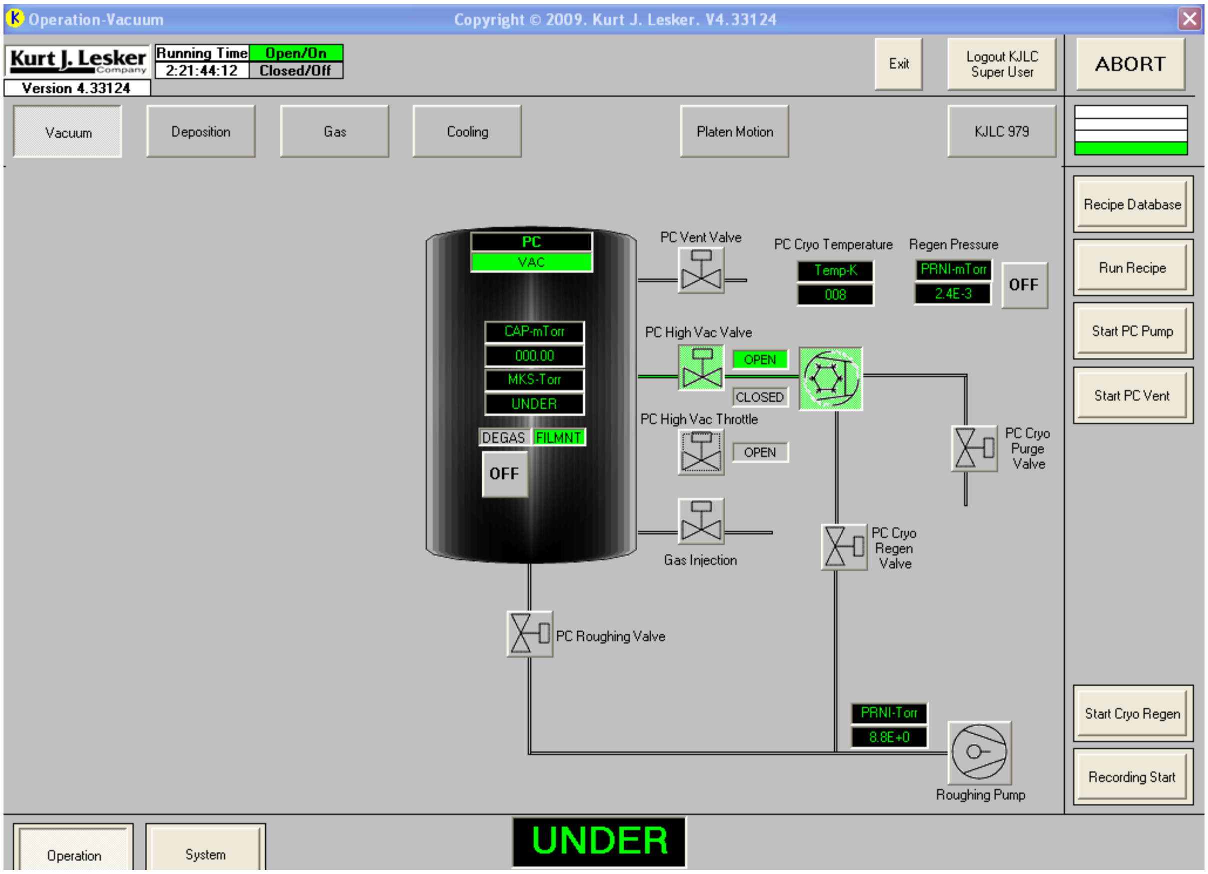
It is important to highlight/suspend again (to deactivate). Otherwise, two instances of the same data will be created due to scan time. This will confuse the Datalog and cause an error.

NOTE: The same protocol **must** be followed for each screen or tab (Click Suspend Screen Updates, highlight signal names to Data Log, and click Suspend Screen Updates to deactivate). Otherwise, only the screen that action is performed on will Datalog.

5) Once all components are selected for datalogging through the various screens, click Generate Data Log.



DATA LOG SCREEN #4



DATA LOG SCREEN #5

6) Click Recording Start to begin recording. Data will be recorded at the specified number of seconds.

To change the specified data collection rate:

- Click Configuration through the Recipe Database button (**NOTE**: This may already be open and located on the bottom toolbar and cannot be closed, only minimized. Closing it will cause it to automatically "reopen").
- Recording Rate Default **AND** Recording Rate Minimum should be set to the same time interval. The data collection interval can be changed at this point, ensuring that the Recording rate default **AND** Recording rate minimum are the same.
- 5 seconds is *typically* the fastest rate desired for scanning. One second intervals are possible; however, data logging uses considerable space and processor speed.
- Data log will continue to run until Recording Stop is depressed
- Entries have a time/date stamp

After data logging is stopped:

1) Go to “C” drive
2) Go to Program files
3) Go to Lesker
4) Go to Company name (XYZ)
5) Go to Data
6) Go to Datalog.mdb

The table name is the date and time the table was created.

- Data log puts the logged information into “cells”.
- These cells can be saved as an Excel file to make graphs, etc.

This should only need done once at the beginning to clean out old signals or if there is an error caused by two of the same line item.

It is imperative to click Data Log before clicking the Record Start and Record Stop. If Data log is not clicked first the data will only APPEND to the last table. Next, click Generate Data log to create a new table.

The Datalog.mdb file will not open from its current location when the Cware software is up. In order to view the data log files while Cware is operating, the user must copy (not cut) the entire datalog.mdb file and place it in another location (for example, in My Documents), to open the file and gain access to the tables.

SHUTDOWN

Pressing the Exit button at the top right of any Runtime Software screen will close both the Runtime Software and the System Database.

If running Sigma, shut Cware down first and then Sigma.

MAINTENANCE

PERSONNEL QUALIFICATIONS

All personnel performing maintenance procedures must have appropriate training.

Vendor supplied instructions and operator manuals should be reviewed prior to maintenance or operation of any equipment or hardware.

GENERAL RECOMMENDATIONS

1) Prior to the installation of any assembly, it is good practice to review the list of parts and ensure all parts are on hand.
2) Prior to installation of any copper gasket or o-ring, ensure the gasket, o-ring and sealing surface are free from defects and debris.
3) Wipe all gaskets and flanges clean with isopropyl alcohol prior to installation to assure cleanliness.
4) When applying vacuum grease to an o-ring, be cautious not to apply too liberally. A thin even film is sufficient.
5) Prior to tightening any QF or Conflat type flanges, ensure that the o-ring or metal gasket is centered and seated properly.
6) When assembling, be sure to use proper vacuum cleanliness techniques (i.e. wearing clean gloves, hair nets and beard masks and using lint free wipes).
7) Use a non-stick lubricant (such as Molybdenum mixed with isopropyl alcohol) on all stainless steel to stainless steel hardware mounting. For internal mounting, only a vacuum compatible lubricant (such as Boron Nitride) should be used.
8) Supplemental Manuals and Information should be reviewed prior to installation or operation of any equipment or hardware.

MAINTENANCE MATERIALS AND ACCESSORIES

ITEM	DESCRIPTION
ELECTRICAL ASSEMBLY	
Wire Stripper	Sizes: 8 – 22 AWG
Wire Cutters	Precision and heavy duty
Terminal Crimper	Sizes: 22 - 10 AWG
Precision Screwdrivers	Standard
MECHANICAL ASSEMBLY	
SAE Socket Set	Sizes: 1/4 inch – 3/4 inch
Metric Socket Set	Sizes: 6 mm – 17 mm
Ratchets	1/4 inch & 3/8 inch
Ratchet Extensions	1/4 inch & 3/8 inch
SAE Wrench Set	Sizes: 1/4 inch – 3/4 inch
Metric Wrench Set	Sizes: 6 mm – 17 mm
Adjustable Wrench	Small & Large
Phillips Head Screwdriver	#1 & #2
Slotted Screwdriver	#1 & #2
SAE Hex Key Set	1/16 inch – 3/8 inch
Metric Hex Key Set	1.5 mm – 10 mm
Slip-Joint Pliers	Standard
Tube Cutter (Metal & Plastic)	1/4 inch – 3/8 inch
RECOMMENDED SUPPLIES	
Isopropyl Alcohol	Used for final cleaning
Acetone	Used for initial degreasing
Alconox	Vacuum cleaning solution
Alpha Wipes	Lint free wipes
Molybdenum Disulfide	Used for lubrication of hardware
Vacuum Grease	Used on o-rings to ensure proper seal
Boron Nitride	High temperature lubricant

Please contact the Kurt J. Lesker Company for ordering information.

COMPONENT PREVENTATIVE MAINTENANCE

The individual component manufacturer's recommended preventative maintenance schedules should be reviewed and followed.

CAUTION Failure to follow the proper preventative maintenance procedures could result in premature failure of the system or components.

DANGER Many of the referenced maintenance procedures have safety dangers, warnings, cautions, and notes associated with them. Read all procedure references and observe all safety measures.

COMPONENT REPAIR/REPLACEMENT

For repair or replacement of specific components, see appropriate schematics and operation manuals. These procedures are associated with features critical to proper system function. In-house performance of component repair or replacement during the warranty period without direction or approval from KJLC Systems Support can result in termination of the warranty.

If an authorized KJLC service representative suggests that a system component be returned to KJLC, a Return Material Authorization (RMA) number must be issued. The RMA number expedites handling and ensures proper service of the equipment.

PROCESS CHAMBER CLEANING

The chamber and internal shielding should be cleaned regularly to remove contaminants and particulates which can affect vacuum integrity and process performance. The user should review the system periodically and perform duties as required to set up a scheduled preventative maintenance procedure.

If required, a recommended cleaning procedure can be supplied by an authorized KJLC representative.

CAUTION Care should be taken to assure that cleaning agents and cleaning procedures do not form a negative reaction with the materials used in the deposition chamber. Refer to MSDS for handling instructions. Run-off from deposition component cleaning may be poisonous and requires appropriate disposal.

As part of the preventative maintenance of the system, all heater bulbs and their connections should be inspected periodically.

PREVENTATIVE MAINTENANCE SCHEDULE

Maintaining your system according to the schedules and procedures given in this document will help to keep your system operation trouble-free while preserving your investment. When your system needs maintenance, your service representative is specially trained in customer service and providing technical support for your unique system. The following information should be used when customer service is required:

North America
Phone: 800-245-1656, ext. 7311 or 7557
Fax: 412-384-2745
E-mail: systemscustomerservice@lesker.com

Europe
Phone: +44 1424-458100
Fax: +44 1424-458103
E-mail: systemcustomerserviceeu@lesker.com

Asia
Phone: 01186-21-50115900
Fax: 01186-21-50115863
Email: systemscustomerservicecn@lesker.com

For all other regions, contact North America customer service.

Actual maintenance intervals may vary depending on tool use. The schedules and procedures in this document are based on projected normal usage and are intended as supplemental information and are to be used as reference ONLY. Where applicable, the individual component manuals should be reviewed for vendor recommended service intervals and procedures. Not all components listed in this schedule may be included on your system.

⚠ DANGER Many of the referenced maintenance procedures have safety dangers, warnings, cautions, and notes associated with them. Read all procedure references and observe all safety measures.

⚠ CAUTION Any interlocks that may have been overridden must be set back to their operational state. Failure to do so may result in component failure or personnel injury.

☝ Any personnel performing preventative maintenance functions must be properly trained on all aspects of the tools operation and safety requirements. Engineering schematics should be referenced for proper assembly.

The manufacturer reserves the right, however, to discontinue or change specifications or design at any time without notice and without incurring any obligation whatsoever. The information and specifications included in this publication were in affect at the time of approval for printing.

SOFTWARE MAINTENANCE

ITEM	DESCRIPTION	PROCEDURE
Datalog	As the machine operates, the data log information stored in the database will continue to grow. The database file size should not exceed 2 gb. Offload data as necessary to maintain a database file size less than 2 gb.	1) Open the recipe database and locate recorded data via the top tabs.
		2) Select the data that you wish to remove from the database and place it into storage by selecting the checkbox.
		3) Select "EXPORT" to put these files into an Excel spreadsheet and place them in "C:\Program Files\Lesker\PVD75\ExcelFiles
		4) Delete unwanted recorded data by selecting the check boxes and selecting "DELETE"
		5) Locate the Action Log tab
		6) Export the Action Log to a separate file. All files not deleted in Item 4 will be copied to your new location.
		7) Delete the original Action Log from the system PC.
Compacting	There are 3 main logging databases. They are RecipeD, RecordingD, and LogD. These databases will grow in size over time and you will need to compact them on a regular basis. When the size of the database reaches 80 mb, a compact procedure must be performed.	1) Open the Compact database located at "C:\Program Files\Lesker\PVD75\Data"
		2) Select the database you wish to compact.

Inspected by: ____ Date:__________________

AUTHORIZED SIGNATURE

MAINTENANCE UPON VENTING

ALL MODULES		
COMPONENT	INSPECT FOR	COMMENTS
Deposition Shielding/ Shutters	Deposition build-up or flaking	Bead blast to remove build-up, vacuum wash and dry thoroughly
Platen Assembly	Deposition build-up or flaking on substrate and mask shelves	Bead blast to remove build-up, vacuum wash and dry thoroughly
	Loose cassette clamping bolts	Assure proper alignment and tighten
Chamber Internals	Cleanliness, debris or particulate.	Remove all particulate and wipe internals with isopropyl alcohol and lint free wipes. If any internals require additional bead blasting or mechanical cleaning, those parts must be properly vacuum washed and dried prior to re-installation.
O-rings/ Sealing Surfaces	Scratches, particulate or wear	Replace cracked or damaged O-rings. Remove contaminated O-rings and clean with isopropyl alcohol and grease with Payson L vacuum grease. Marred sealing surfaces must be corrected via the appropriate mechanical means, such as hand polishing or machine resurfacing.
Bake out and Illumination Lamps	Broken or coated bulbs	Replace bulb
	Conductive coatings on the ceramic insulators. If coated with a conductive film, the bulbs can short out.	Replace ceramic insulators

ALL MODULES		
COMPONENT	**INSPECT FOR**	**COMMENTS**
Film Thickness Monitors Film Thickness Monitors (continued)	Manufacturer's recommended maintenance	Refer to manufacturer's manual
	Securely inserted crystals and proper crystal sensing. It is recommended to replace the crystal when <30% of its life is reached.	If no signal is being displayed then check continuity of the cable and the oscillator. Replace crystal.
	Deposition build-up or flaking on shutters	Bead blast to remove build-up, vacuum wash and dry thoroughly
	Proper shutter operation	Check to ensure shutter operates smoothly over its full range of motion. In the open position, no portion of the crystal should be covered.
	Inspect for proper crystal material. Deposition of certain materials may require use of certain types of crystals.	Refer to manufacturer's manual
Chamber Isolation Valve	Any pressure rise in an adjacent chamber upon venting another chamber. Rising pressure in an adjacent chamber could indicate a leak across the valve.	Clean the sealing surfaces and clean or replace the seal.
Cassette Stages	Z-shift connection	Assure proper alignment and tighten
	Smooth rotation in directions of travel	Clean all motion surfaces. If this does not correct the problem, the guide shaft may be distorted or the guide bushing may need to be replaced.

ALL MODULES		
COMPONENT	INSPECT FOR	COMMENTS
Gears/ Bearings/ Bushings	Wear, debris or misalignment. Components should move freely though their full range of motion.	Adjust, clean and lubricate. Bearings should be lubricated with Fumbling 25/6. Bushings and gears should remain unlubricated; however all particulate should be removed. Replace all worn parts.
Internal Power Connections	Wear or debris on RF contact components and surfaces. Contact springs must be fully engaged with rotating surfaces through the full range of motion.	Remove all particulate and replace all worn components.
	Electrical shorting to ground or signs of arcing. Deposition of conductive coatings can cause shorting of internal connections.	Components should be properly cleaned or replaced. If any internal power connections require additional bead blasting or mechanical cleaning, those parts must be properly vacuum washed and dried prior to re-installation.
	Damaged insulators. Ceramics or wire insulation must remain intact to ensure proper system operation.	Broken ceramics or brittle wire sleeving must be replaced.
	Coated insulators	All coated ceramics must be cleaned or replaced.
	Debris in F/T's. Particulate and debris can cause shorting across electrical posts in F/T ports.	All particulate and debris must be removed.
Gas Ring	Deposition build-up or flaking	Bead blast to remove build-up, vacuum wash and dry thoroughly. All gas inlet holes must be free from particulate, such as bead blasting media.

ALL MODULES		
COMPONENT	INSPECT FOR	COMMENTS
Wedge Tool	Deposition build-up or flaking	Bead blast to remove build-up, vacuum wash and dry thoroughly
	Installation of the blade. The blade must be parallel to the substrate through its range of motion.	Adjust blade
	Signs of damage, arcing or broken insulators on internal wires	Broken ceramics or brittle wire sleeving must be replaced.
	Retracted limit switch. The interlock must be triggered when the wedge tool is retracted.	Verify wire connections and replace wiring or the switch if required.
	Substrate / mask touching wedge interlock switch.	Verify wire connections and replace wiring or the switch if required.
	Cleanliness of Teflon guides	Clean all motion surfaces.
Wide Range Gauge	Atmosphere reading	Refer to manufacturer's manual
Vacuum Switch	Atmosphere reading. When the chamber is vented to atmosphere, the vacuum switch should not indicate a vacuum level. Once the chamber is pumped down, the vacuum switch should then indicate a vacuum level.	Verify wire connections and replace switch if required.

ORGANIC MODULES		
COMPONENT	INSPECT FOR	COMMENTS
Sources	Deposition build-up or flaking on shutters, source covers and chimneys	Bead blast to remove build-up, vacuum wash and dry thoroughly.
	Thermocouple operation. Assure the display reading is showing ROOM temperature.	Check for a short to ground or contact between thermocouple wires throughout the internal routing of the wires. Check for an open circuit on the source base and feed through.
	Heater operation	Check for a short to ground. Check for an open circuit on the source base and chamber.
	Crucible condition	Check for cracks and replenish material as required. If the crucible is cracked it must be replaced.
Pellet Feeder	Deposition build-up or flaking	Bead blast to remove build-up, vacuum wash and dry thoroughly
	Check rotation of feeder	Remove all particulate and wipe internals with isopropyl alcohol and lint free wipes. If any internals require additional bead blasting or mechanical cleaning, those parts must be properly vacuum washed and dried prior to re-installation.
	Material charge	Replenish material as required
	Operation of the cassette indexer	Remove all particulate and wipe internals with isopropyl alcohol and lint free wipes. If any internals require additional bead blasting or mechanical cleaning, those parts must be properly vacuum washed and dried prior to re-installation.

SPUTTER MODULES		
COMPONENT	INSPECT FOR	COMMENTS
Cathodes	Target erosion	Replace target as required
	Gun short circuit to earth	Bead blast and clean thoroughly to remove contamination. Check N type connection for particulates
	Water leaks	Refer to cathode manual
	Deposition build on target clamp screws. Over time, deposits will form in the screw heads and make removal difficult.	Replace as required. Silver plated hardware is required to avoid galling.
	Deposition build up on the main cathode insulator. Visually inspected at each target change.	Remove deposition using a fine scotch-brite or mechanical polishing technique. Care must be taken to protect all o-ring sealing surfaces. Replace as required.
	Chimney and target hold down ring installation	Refer to cathode manual
	Proper alignment of cathode shutters in the open and close position	The shutter should not be touching the top of the dark space shield and should be parallel to the target face when closed. A distance of 1/16" to 1/8" from the top of the dark space shield and bottom of the shutter blade is required. When open, there should be no interference with other components or the substrate.

E-BEAM MODULES		
COMPONENT	INSPECT FOR	COMMENTS
E-Guns	Stray beam damage to hearth or nearby shielding	Adjust filament or beam sweep pattern
	Sufficient material available in the hearth	Refill empty or depleted crucibles
	Spillage or deposition of the material on hearth	Remove all excess material and particulate
	Smooth operation of the hearth indexer	Clean rotary drive and seals
	Filament condition	Replace as required

CENTRAL DISTRIBUTION MODULES		
COMPONENT	INSPECT FOR	COMMENTS
Linear Rack & Pinion (LRP)	Usage	If the total travel is over 4,000 m the bearings must be replaced.
	Smooth movement within the full range of motion	The rollers should be cleaned or replaced if worn. The bearings should be inspected and lubricated with Fomblin 25/6. If cleaning and lubrication do not correct the problem, replace the bearings. Check that the pinion gear is correctly engaging with the rack and replace the pinion gear if worn.
Transfer Forks	Degradation of Dicronite coating. A worn coating can increase the risk of failed transfer or a substrate holder binding within the fork assembly.	Recoat when worn. Contact the manufacturer for information.

THERMAL MODULES		
COMPONENT	INSPECT FOR	COMMENTS
Sources	Deposition build-up or flaking on shutters, source covers and chimneys	Bead blast to remove build-up, vacuum wash and dry thoroughly
	Heater	Check for a short to ground. Check for an open circuit on the source base and chamber.
	Crucible	Check for cracks and replenish material as required. If the crucible is cracked it must be replaced.
Pellet Feeder	Excessive deposition or flaking	Bead blast and clean thoroughly to remove contamination.
	Check rotation of feeder	Bead blast and clean thoroughly to remove contamination.
	Material Charge	Fill with pellets where consumed
	Operation of the cassette indexer.	Bead blast and clean thoroughly to remove contamination.

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DAILY MAINTENANCE

ALL MODULES		
COMPONENT	INSPECT FOR	COMMENTS
Water Flow	Signs of leakage at all connections	Repair and reseal with Teflon tape. Other types of thread sealant must be avoided.
	Bulges or signs of failure in hoses	Replace hoses
	Proper flow indication. If the proper flow is being supplied (or shut OFF), but the indicator is not correct, the flow switch may be clogged or defective.	Remove, clean or replace the flow switch.
Compressed Air	Setting of recommended pressure at each module. Min 70 psig, Max 100 psig	Adjust regulator to the correct value.
Nitrogen	Setting of recommended vent pressure at each module. Set to 10 psig	Adjust regulator to the correct value.
	Setting of recommended cryo purge pressure at each module. Set to 40 psig	Adjust regulator to the correct value.
Process Gas Supply Pressure	Setting of recommended pressure at each module for each gas. Set to 10 psig	Adjust regulator to the correct value.
	Inspect compressed air regulator pressure reading on each module. Set to 80 -90 psig	Adjust regulator to the correct value.
Cryo Pump	Manufacturer's recommended maintenance	Refer to manufacturer's manual
	Cryopump 2nd stage temperature	Regenerate if > 20 K
	Main shaft seal contamination. If the main shaft seal becomes contaminated, the pump will begin to make a loud "clunking" noise. This requires purging of the He lines with UHP He.	Refer to manufacturer's manual
Viewports	Deposition coating, cracks or defects	Remove deposition or replace the viewport if cracked or chipped.
Drive Belts	Signs of wear, cracks or excessive debris below belt	Replace belt
	Belt tension. The belt should be tight, but not to the extent when the pulleys or gears are being excessively stressed and distorting drive shafts.	Adjust belt tension

ALL MODULES		
COMPONENT	INSPECT FOR	COMMENTS
Hoist Operation	Debris due to wear on the internal bushing	Clean all motion surfaces and apply a heavy duty gear lubrication to the drive screw. If lubrication does not correct the problem, the guide bushing may need replacing.
Chamber Pressure	Chamber base pressure. A significant increase in the chamber base pressure can indicate a leak to atmosphere or a failed water connection. Deposition build-up will also affect chamber pressure. Pumping performance should be monitored and logged.	Leak check the system and repair any vacuum leaks. Remove deposition from internal components.
Linear Rack & Pinion (LRP)	Usage	If the total travel is over 4,000 m the bearings must be replaced.
	Smooth movement within the full range of motion	The rollers should be cleaned or replaced if worn. The bearings should be inspected and lubricated with Fomblin 25/6. If cleaning and lubrication do not correct the problem, replace the bearings. Check that the pinion gear is correctly engaging with the rack and replace the pinion gear if worn.
Shutters	Optimal substrate and source shutter speed and travel limits.	Adjust flow controllers on air lines or open and close limits of operation.
Baratron Zeroing	Check that each baratron gauge is set to zero	Refer to manufacturer's manual

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7-DAY MAINTENANCE

ALL MODULES		
COMPONENT	INSPECT FOR	COMMENTS
Limit Switches	Proper operation. Operate each axis of motion in each direction of movement to its limits. The switches should indicate limits of travel in the operation positions.	Verify wire connections and replace wiring or the switch if required.
Proximity Sensors	Proper operation. Check illumination of sensor when at home or in the limit position.	Verify wire connections and replace wiring or the switch if required.
Sample Transfer	Sample transfer to all transfer locations. Transfer should be inspected at each location for the proper placement and pick-up of substrates and masks.	Adjustments should be made at each location. Encoder counts or position values should be logged for reference.
Z-Shifts	Smooth motion in both up & down directions	Clean all motion surfaces and apply Rocol grease on lead screws and Fomblin 25/6 on all bearings. If lubrication does not correct the problem, the guide shafts or lead screw may be distorted or the guide bushing may need replaced. Replace the guide shaft or lead screw as required.
	Operation of limit switches. Operate the Z-shifts in each direction of movement to its limits.	Verify wire connections and replace wiring or the switch if required.
	Operation. The recommended maximum operation of the bellows is 10,000 cycles.	Replace the bellows at or before 10,000 cycles of operation
	Operation. The recommended maximum operation of the lead screws and drive nuts is 10,000 cycles.	Replace the lead screw and drive nuts at or before 10,000 cycles of operation
Cassette and Platen Shafts	Wear, misalignment, debris and free rotation of bearings. Components should move freely.	Clean, adjust and lubricate. Bearings should be lubricated with Fomblin 25/6. If the shaft is misaligned, adjust the bearings to ensure normal travel.

ALL MODULES		
COMPONENT	INSPECT FOR	COMMENTS
External Power Connections	External cable connection shorting. When power cables are removed and reinstalled, conductive particulate can begin to accumulate inside the connector on the insulator.	Thoroughly clean the connector insulator from all particulate or replace the cable.
Mechanical Pumps	Manufacturer's recommended maintenance	Refer to manufacturer's manual
	Poor fore line pressure. Leaking vacuum lines or blocked exhaust ports can affect pumping performance.	Assure vacuum line connections are tight and the exhaust port is free from blockage. Fore line pressures should be logged for reference.

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30-DAY MAINTENANCE

ALL MODULES		
COMPONENT	INSPECT FOR	COMMENTS
Cryo Pump	Pumping performance. Over time the pump can become saturated.	Regenerate all the cryo pumps
	Manufacturer's recommended maintenance	Refer to manufacturer's manual
Hoist Assembly	Wear on bushings and drive couplings	Replace bushing or drive coupling
	Debris on bushings and drive couplings	Clean and lubricate bushings and drive couplings with a heavy duty bearing lubricant
Mechanical Pump	Poor fore line pressure or extended pumpdown times when using oil sealed pumps.	Replace foreline trap adsorbent material (Zeolite)
RGA Scan	Chamber integrity. Comparing periodic RGA scans with a baseline scan can help identify potential problems that could affect pumping performance and film quality.	Compare a new scan to the baseline scan and save for reference. Leak check or clean the system as required.

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90-DAY MAINTENANCE

ALL MODULES		
COMPONENT	INSPECT FOR	COMMENTS
Pneumatic/ Manual Valves	Wear. Seals and bellows should be inspected or replaced at 250,000 cycles. Process induced contamination and bake out temperature above 150 deg C may shorten service intervals significantly.	Replace seals and bellows at or before 250,000 cycles of operation.
Hoist Rotation	Wear or debris on the hoist yoke bearings. Components should move freely.	Clean, adjust and lubricate with a heavy duty gear lubricant. Replace if worn.
Wedge Tool Blade Drive Bearings	Wear and debris. Components should move freely.	Clean, adjust and lubricate with Fomblin 25/6. Replace if worn.

LOAD LOCK MODULES		
COMPONENT	INSPECT FOR	COMMENTS
Door	Wear on latch bearings or spacers.	Replace bearings and spacers
	Wear on hinges or improper door alignment.	Replace or adjust hinges
	Damage to o-ring	Replace o-ring

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YEARLY MAINTENANCE

ALL MODULES		
COMPONENT	INSPECT FOR	COMMENTS
Baratron	Calibration	Refer to manufacturer's manual
MFCs	Calibration	Refer to manufacturer's manual
Mechanical Pump	Pumping performance. Tip seal should be replaced after 9,000 hours of operation.	Replace tip seals at or before 9,000 hours of operation
	Manufacturer's recommended maintenance	Refer to manufacturer's manual
Turbo Pumps	Manufacturer's recommended maintenance	Refer to manufacturer's manual
Transfer Forks	Degradation of Dicronite coating. A worn coating can increase the risk of failed transfer or a substrate holder binding within the fork assembly.	Recoat when worn. Contact the manufacturer for information.
Cooling Lines	Scale or residue buildup in cooling lines. Build up can reduce cooling water flow which could affect the lifetime of the components.	Flush with a de-scaler or cleaner and replace as required.

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SPARE PARTS LIST

The following is a list of recommended spare parts for a standard PVD 75 system and should be used for reference purposes only. The system schematics, Operation Manual, Component Manuals and Preventative Maintenance Schedule should be reviewed for more details and components specific to your system. Spare parts and accessories that have not been supplied by KJLC have also not been tested and approved by us. The fitting and/or use of such products could therefore negatively affect the design characteristics of your machine. KJLC accepts no liability for damages arising from the use of non-original parts and non-original accessories.

SS refers to stainless steel and *Al* refers to aluminum products. All dimensions are in inches unless otherwise specified.

In Stock refers to items typically kept in stock at our main warehouse in Pennsylvania. Availability of these items is subject to change and may or may not be in stock at our satellite offices. Most in stock items will ship within 1 to 2 days of order receipt. Expediting services are available. For up to date availability and ordering, please visit www.lesker.com.

Lead Time refers to the typical time required to manufacture or acquire items not normally kept in stock.

Please refer to the following category descriptions when ordering spare parts.

C - Consumable – Keep on hand
CNS - Critical Item – Not in stock
CS - Critical Item – In stock
R - Reference and information only
W - Wear based on customer use

VACUUM HARDWARE

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
4XVCR-GAC	Copper Gasket, ¼ VCR	R	Y	---	10
GA-0133	Copper Gasket, 1.33 CF	R	Y	---	2
GA-0275	Copper Gasket, 2.75 CF	R	Y	---	2
GA-0450	Copper Gasket, 4.5 CF	R	Y	---	1
GA-0600	Copper Gasket, 6 CF	R	Y	---	1
GA-0800	Copper Gasket, 8 CF	R	Y	---	1
GA-1000	Copper Gasket, 10 CF	R	Y	---	1
QF16-075-ARV	QF16 Al Centering Ring / Viton O-Ring	R	Y	---	1
QF25-100-ARV	QF25 Al Centering Ring / Viton O-Ring	R	Y	---	1
QF100-AAVR	QF100 Al Centering Ring / Viton O-Ring	R	Y	---	1
QF160-AAVR	QF160 Al Centering Ring / Viton O-Ring	R	Y	---	1
QF250-AAVR	ISO 250 Al Centering Ring / Viton O-Ring	R	Y	---	1

FBH-100AL	1" Blank-Off, Aluminum	R	Y	---	1
FBH-100S	1" Blank-Off, SS	R	Y	---	1
O-V006	1/8" Vac Coupling O-Ring	R	Y	---	3
O-V012	O-Ring For 3/8" Vac Coupling	R	Y	---	2
O-V116	¾" Vac Coupling O-Ring	R	Y	---	3
S-012-P	SS Plug - 1/8" Vacuum Coupling	R	Y	---	As Required
S-075-P	SS Plug - 3/4" Vacuum Coupling	R	Y	---	As Required
SS-4WVCR6400	¼" FVCR to ¼" Swagelok Adapter	R	N	6 Days	As Required
4FVCR-CP	¼ SS VCR Cap	R	Y	---	As Required
4MVCR-P	¼ SS VCR Plug	R	Y	---	As Required
SS-400-C	¼ SS Swagelok Cap	R	N	6 Days	As Required
SS-400-P	¼ SS Swagelok Plug	R	N	6 Days	As Required
SS-200-SETS	1/8 SS Ferrule Set	R	Y	---	1
SS-400-SETS	¼ SS Ferrule Set	R	Y	---	1
B-400-SETS	¼ Brass Ferrule Set	R	Y	---	1
SS-600-SETS	3/8 SS Ferrule Set	R	Y	---	1
B-600-SETS	3/8 Brass Ferrule Set	R	Y	---	1

VACUUM MEASUREMENT & CONTROL

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
390410-0-YG-T	390 Combination Gauge, Hot Ion / Pirani	CS	Y	---	1
PTR26950	Pirani Gauge, QF16	CS	Y	---	1
VACSWITCH1	Vacuum Switch, ¼ MVCR	CS	Y	---	1
1179A01312CR1BV	Mass Flow Controller, 0 - 100 sccm	R	Y	---	1
626B.1TLE	Capacitance Manometer - 0.1 Torr	R	Y	---	1
SS-4BK-1C	Inline Vent Valve, ¼ Swagelok	R	Y	---	1
SS-4BK-V511C	Inline Process Gas Valve, ¼ FVCR	R	N	6 Days	1
SST-0025CI	Tubing, 316L SS, ¼ "OD, Electro-polished	R	Y	---	As Required
SG0600MV-ON	Gate/Bonnet O-ring Set - SGP0600 Series Gate Valve	W	N	31 Days	1
SG0800MV-ON	Gate/Bonnet O-ring Set - SGP0800 Series Gate Valve	W	Y	---	1
SG1000PV-ON	Gate/Bonnet O-ring Set - SGP1000 Series Gate Valve	W	N	31 Days	1
SG1200PV-ON	Gate/Bonnet O-ring Set - SGP1200 Series Gate Valve	W	N	10 Days	1

ROUGHING / BACKING

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
PFEGL915QF25	Oil Mist Eliminator with Pressure Relief	R	Y	---	1
PFEGL915	PFEGL915QF25 Replacement Element	C	Y	---	1
AV-104200	Oil Mist Eliminator, Pump Models 2005 - 21SD	R	Y	---	1
AV-068304	AV-104200 Replacement Element	C	Y	---	1
TAR4CS100QF	Rechargeable Foreline Trap	R	Y	---	1

TAR4S	TAR4CS100QF Mesh Element, SS Wool	C	Y	---	1
PFI843KF25	Inlet Vacuum Filter, QF25	R	N	10 Days	1
PFI843KF40	Inlet Vacuum Filter, QF40	R	N	10 Days	1
PFI843	PFI813HF25 / 40 Polyester Element	C	N	3 Days	1
PFIZE842	PFI813HF25 / 40 Zeolite Cartridge	C	Y	---	1

HIVAC – TURBO PUMP

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
PM016207AU	HiPace 80 Centering Ring with Screen, ISO	R	N	25 Days	1
PM016211-U	HiPace 300 Protective Screen, ISO 100	R	N	25 Days	1
PM016339	HiPace 700 Protective Screen, 8" CF	R	N	20 Days	1

HIVAC – CRYO PUMP

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
8080250K036	Purge Gas Heater For Cryopump 230V	R	N	10 Days	1
8080255K001	Absorber, SC or 8200 Compressors	C	N	10 Days	1
O-V026	Exhaust O-Ring 1-1/4 ID – 1/16, Viton	R	Y	---	1

CHAMBER DOOR

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
8476K47	Borosilicate Glass 4 x 6 x 5/8 - Door Window	R	N	15 Days	1
8476K471	Borosilicate Glass 4 x 6 x 1/8 - Window Cover	C	N	13 Days	1
O-V251	O-Ring 5-1/8 x 1/8 – Window Seal	R	Y	---	1
O-V473	O-Ring 24 x 1/4 – Chamber Seal	R	N	10 Days	1

LOW TEMP PLATEN ASSEMBLY (150 – 550°C) – QLH LAMPS

Reference Schematics: A0025397, A0038879 and A0038851

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
HEATER					
QJ-1M	Quartz Lamp Socket	W	Y	---	2
FCM	Lamp, Quartz, 1000W, 120VAC	C	Y	---	2
QLH1000	Substrate Heater Assembly (includes QJ-1M and FCM)	W	Y	---	2
KTIN-18G-18	Inconel Sheathed K-Type T/C	CS	Y	---	2
FTAWCU094	OFHC Copper Wire, .094 DIA.	W	Y	---	2 ft
FTACERB116	Ceramic Beads	W	Y	---	2 ft
69405K64	Ring Terminal, Nickel, #10 Stud	W	Y	---	8
PLATEN – INCLUDING BIAS OPTION					
P0021446	6" Diameter Substrate Holder	W	Y	---	1
P0015229	12" Diameter Substrate Holder	W	Y	---	1

SHA-08S003	Substrate Holder Clip	C	Y	---	6
SB440025P	Substrate Holder Clip Hardware, #4-40 x 0.25	C	Y	---	6
W4-SAE	Substrate Holder Clip Washer, #4	C	Y	---	6
CA4101MTRHSW	Home Switch Assembly (includes PM-K24)	CS	N	10 Days	1
PM-K24	Photoelectric Sensor for CA4101MTRHSW	CS	Y	---	1
A6R3-060037	Timing Belt, 60 Teeth – Platen Rotation	W	Y	---	1
A6G3-065037	Timing Belt, 65 Teeth – Platen Rotation	W	N	5 Days	1
A6G3-070037	Timing Belt, 70 Teeth – Platen Rotation	W	Y	---	1
N8-32A	Hex Nut, Alumina 8-32	C	Y	---	2
PLA-28S039	RF End Conductor, Alumina Insulator	C	Y	---	1
PLA-28S034	RF End Conductor, Alumina Insulator Elbow	C	Y	---	2
P0020768	RF Conductor, Alumina Leg Cover	C	N	5 Days	1
273-0010-1-S	3/4 x 3/8 inch Ceramic Standoff, 6-32 Threads	C	N	5 Days	4
P0037919	Ceramic Insulator Tube, ½ x 20 inch	W	Y	---	1
LSM5MLLUB	Z-Shift Lubricant, 5 ml Syringe (ROCOL)	W	N	10 Days	1
O-V022	KLFDHC100 Rotary F/T, Inner Shaft O-Ring	C	Y	---	2
O-V037	KLFDHC100 Rotary F/T, Outer Housing O-Ring	C	Y	---	2

HIGH TEMP PLATEN ASSEMBLY (550 - 800°C) – BOX HEATER

Reference Schematics: PLA-2806 and HTR-3230

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
HEATER					
Q240V1500	Lamp, Quartz, 1500W, 240VAC	C	Y	---	4
52408	1/2 OD x 1 x 3/8 inch Ceramic Standoff, 8-32	W	Y	---	2
KTIN-18G-18	Inconel Sheathed K-Type T/C	CS	Y	---	2
FTAWCU094	OFHC Copper Wire, .094 DIA.	W	Y	---	2 ft
FTACERB116	Ceramic Beads	W	Y	---	2 ft
69405K64	Ring Terminal, Nickel, #10 Stud	W	Y	---	8
HTR-32S015	Main Heater Reflector	W	Y	---	1
HTR-32S014	Side Heater Reflector	W	Y	---	2
PLATEN – INCLUDING BIAS OPTION					
N8-32A	Hex Nut, Alumina 8-32	C	Y	---	2
PLA-28S039	RF End Conductor, Alumina Insulator	C	Y	---	1
PLA-28S034	RF End Conductor, Alumina Insulator Elbow	C	Y	---	2
PLA-28S038	RF Conductor, Alumina Leg Cover	C	N	5 Days	1
273-0010-1-S	3/8 OD x 3/4 inch Ceramic Standoff, 6-32	C	N	5 Days	4
PLA-28S051	Ceramic Insulator Tube, ½ x 21.75 inch	W	Y	---	1
CA4101MTRHSW	Home Switch Assembly (includes PM-K24)	CS	N	10 Days	1
PM-K24	Photoelectric Sensor for CA4101MTRHSW (rotation)	CS	Y	---	1
V3L-3-D8	Micro Roller Switch (z-position)	CS	Y	---	2
A6R3-060037	Timing Belt, 60 Teeth – Platen Rotation	W	Y	---	1

A6G3-065037	Timing Belt, 65 Teeth – Platen Rotation	W	N	5 Days	1
A6G3-070037	Timing Belt, 70 Teeth – Platen Rotation	W	Y	---	1
LSM5MLLUB	Z-Shift Lubricant, 5 ml Syringe (ROCOL)	W	N	10 Days	1
O-V022	KLFDHC100 Rotary F/T, Inner Shaft O-Ring	C	Y	---	2
O-V037	KLFDHC100 Rotary F/T, Outer Housing O-Ring	C	Y	---	2

HIGH TEMP PLATEN ASSEMBLY (550 – 850°C) – PBN ELEMENT STYLE (EPICENTER)

Reference Schematics: ECP-MS-001B, ECP-HMCA-001B, ECP-MS-002B, ECP-HMCA-002B, EC-SA-007, EC-SA-008 and EC-SA-011

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
EC-SA-011	Earth Contact Assembly	W	N	15 Days	1
EC-RBC-049	RF Bias Plunger Assembly - Contact Pad	W	N	15 Days	1
EC-SA-008	RF Bias Plunger Assembly, 4 – inch Platen	W	N	15 Days	1
EC-SA-007	RF Bias Plunger Assembly, 6 – inch Platen	W	N	15 Days	1
IFTHG013052	H-N Type Feed Thru (50 ohm)	R	Y	---	1
4095-211	Type K, 1/16" Inconel Sheath, Grounded T/C	CNS	N	15 Days	2
HM-100-PGG-ELEMENT	Pyrolitic Graphite on Graphite Heater Element, 100 mm (4-inch)	CNS	N	15 Days	1
HM-150-PGG-ELEMENT	Pyrolitic Graphite on Graphite Heater Element, 150 mm (6-inch)	CNS	N	15 Days	1
HM-100-SSIC-ELEMENT	Silicon Carbide Coated Graphite Heater Element, 100 mm (4-inch)	CNS	N	15 Days	1
HM-150-SSIC-ELEMENT	Silicon Carbide Coated Graphite Heater Element, 150 mm (6-inch)	CNS	N	15 Days	1
HM-HSK-100PGG	Spares Kit for 100 mm Heater Module	R	N	15 Days	1
HM-HSK-150PGG	Spares Kit for 150 mm Heater Module	R	N	15 Days	1
RMF-052	Moly Wire, 0.5 mm	R	N	15 Days	6 inches
FRM-001	M4 Tantalum Nut	R	N	15 Days	6
FRM-002	M4 Moly Washer	R	N	15 Days	6
HE-001	M4 Grafoil Washers	R	N	15 Days	4
EC-HMP-004	Moly Conductor	R	N	15 Days	2
CC-M-001	Ceramic Spacer 6 x 4 x 4.5 mm	R	N	15 Days	4
306-00034	Ceramic Spacer 14 x 6.4 x 1.5 mm	R	N	15 Days	4
CC-005	Ceramic Spacer 7 x 5 x 20 mm	R	N	15 Days	4
CC-006	Ceramic Washer 8 x 5 x 5 mm	R	N	15 Days	6
E329	Ceramic Top Hat	R	N	15 Days	6
S-002	Haynes Spring Washer – M4	R	N	15 Days	6

PROCESS CONTROL

NOTE: All crystal sensors come in a package of 10.

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
008-009-G10	6Mhz Crystal Sensor, Silver (clean room pkg)	C	N	5 Days	1
LI008010G10	6Mhz Crystal Sensor, Gold	C	Y	---	1
750-679-G1	6Mhz Crystal Sensor, Alloy (clean room pkg)	C	N	15 Days	1
008-007	Crystal Snatcher Removal Tool	R	N	10 Days	1

NOTE: Quantities for deposition sources listed below are for one source. For systems with multiple sources, quantities should be adjusted.

TORUS® HV SPUTTER SOURCE 2-INCH

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
TRS2CC-00300	Magnet Assembly, 2" Standard Strength	W	Y	---	1
TRS2CC-HS300	Magnet Assembly, 2" High Strength	W	Y	---	1
TRS2CC-00600	Target Hold Down Ring	W	Y	---	1
TRS2CC-00650	Target Hold Down Ring Spacer	W	Y	---	1
TRS2CC-KHDW2	Hardware Only Kit,TRS2	W	N	15 Days	1
TRS2CC-RBKIT	Rebuild Kit (All hardware, o-rings & tubing)	W	N	4 Days	1

TORUS® HV SPUTTER SOURCE 3-INCH

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
TM03CC-00300	Magnet Assembly, 3" Standard	W	Y	---	1
TM03CC-HS300	Magnet Assembly, 3" High Strength	W	Y	---	1
TM03UC-00600	Target Hold Down Ring	W	Y	---	1
TM03UC-00650	Target Hold Down Ring Spacer	W	Y	---	1
TM03CC-KHDW3	Hardware Only Kit,TRS3	W	Y	---	1
TM03CC-RBKIT	Rebuild Kit (All hardware, o-rings & tubing)	W	N	5 Days	1

TORUS® HV SPUTTER SOURCE 4-INCH

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
TM04CC-00300	Magnet Assembly, 4" Standard	W	Y	---	1
TM03CC-HS400	Magnet Assembly, 4" High Strength	W	Y	---	1
TM04CC-00600	Target Hold Down Ring	W	Y	---	1
TM04CC-00650	Target Hold Down Ring Spacer	W	Y	---	1
TM04CC-KHDW4	Hardware Only Kit,TRS4	W	Y	---	1
TM04CC-RBKIT	Rebuild Kit (All hardware, o-rings & tubing)	W	N	15 Days	1

TORUS® LINEAR SOURCE

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
SB832037P	Top Shield Bolts	W	Y	---	18
TML00SC-4001	Long Dss Top	W	N	15 Days	2
SB832062P	Target Bolts	W	Y	---	18
TML00SC-6001	Long Target Clamp	R	N	15 Days	2
O-V216	Insulator O-Ring	C	Y	---	4
TML00SC-5001	Insulator Seal	C	N	15 Days	2
TML00SC-4002	Short DSS Top (3.5” x 8” source)	W	N	15 Days	2
TML00SC-6002	Short Target Clamp (3.5” x 8” source)	R	N	15 Days	2
TML00SC-6005	Membrane (3.5” x 8” source)	R	N	15 Days	1
O-V259	Target/Flange O-Ring (3.5” x 8” source)	C	N	10 Days	2
O-V281	Flange O-Ring (3.5” x 8” source)	C	N	10 Days	1
TML00SC-4004	Short DSS Top (5” x 8” source)	W	N	15 Days	2
TML00SC-6004	Short Target Clamp (5” x 8” source)	R	N	15 Days	2
TML00SC-6006	Membrane (5” x 8” source)	R	N	15 Days	1
O-V262	Target/Flange O-Ring (5” x 8” source)	W	Y	---	2
O-V281	Flange O-Ring (5” x 8” source)	R	N	10 Days	1

THERMAL SOURCE

NOTE: Tungsten boats are supplied as standard. Depending the on the material being evaporated, other types of boats or heaters are available. Reference drawing A0015177.

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
PVD75SW3B	3 Boat Shutter Weldment	W	Y	---	1
PVD75CCS	Cross Contamination Shield	W	Y	---	2
SB440025VP	Cross Contamination Shield Hardware	W	Y	---	4
SB37516050	3 Boat Buss Bar Hardware 3/8-16 x ½”	W	Y	---	3
1618002-7	Relay, 600A, 24 VDC	CS	Y	---	1
SB37516100VP	Electrical F/T Hardware 3/8-16 x 1”	W	Y	---	4
O-V216	Electrical F/T O-Ring (FTT0013754)	W	Y	---	4
FSCINS001	Small Teflon Insulator	W	N	21 Days	4
FSCINS002	Large Teflon Insulator	W	N	21 Days	4
EVS8D010W	Tungsten Boat, 4"L X 1"W X 1/4" Deep	C	Y	---	3
EVS7005TA	Tantalum Boat, 3"L X 3/4"W X 1/8" Deep	C	Y	---	3
EVSSO10	SIO Baffle Box Source	c	y	--	3
EVCH1	Crucible Heater, 2-3/4”L X 1-1/4” W X 5/8” Deep	C	Y	---	3
EVCH5	Crucible Heater, 4”L X 1-3/4” W X 1-1/8” Deep	C	Y	---	3
EVCH12A	Crucible Heater, 3-1/2”L X 1-1/8” W X 1” Deep	C	Y	---	3
EVC1AO	Aluminum Oxide Crucible for EVCH1	C	Y	---	3
EVC1BN	Boron Nitride Crucible for EVCH1	C	Y	---	3

EVC5AO	Aluminum Oxide Crucible for EVCH5 and EVCH12A	C	Y	---	3
EVC5BN	Boron Nitride Crucible for EVCH5 and EVCH12A	C	Y	---	3

LTE SOURCE

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
EVCEF-1AO	Aluminum Oxide Crucible, 1cc	C	N	30 Days	2
EVCEF-10AO	Aluminum Oxide Crucible, 10cc	C	N	30 Days	2
EVCEF-30AO	Aluminum Oxide Crucible, 30cc	C	N	30 Days	2

E-BEAM SOURCE, KL-6 & KL-8

NOTE: Fabmate liners are supplied as standard. Depending the on the material being evaporated, other types of liners are available.

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
SHU-A0020780	Shutter Blade	W	N	5 Days	1
EVCFABEB-4	KL-6 Fabmate Crucible Liner, 4 Pocket	C	Y	---	As Required
EVCFABEB-22	KL-6 Fabmate Crucible Liner, 6 Pocket	C	Y	---	As Required
EVCFABEB-32	KL-8 Fabmate Crucible Liner, 4 Pocket	C	N	45 Days	As Required
EVCFABEB-29	KL-8 Fabmate Crucible Liner, 6 Pocket	C	Y	---	As Required
1-700310	Filament Block Assembly – Bent Filament	W	N	15 Days	1
EBKL1-703000	Filament Set (5 pcs) – Bent Filament	C	N	15 Days	1
1-700317	Ceramic Insulator – Bent Filament	W	N	15 Days	1
1-703022	Screw Set – Bent Filament	W	N	15 Days	1
1-700314	Filament Clamp – Long – Bent Filament	W	N	15 Days	1
1-700315	Filament Clamp – Short – Bent Filament	W	N	15 Days	1
EBKL1-700321	Filament Block Assembly– Straight Filament	W	N	15 Days	1
1-703008	Filament Set (5 pcs) – Straight Filament	C	N	15 Days	1
1-931100	KL-6 O-Ring Set	W	N	15 Days	1
1-931103	KL-8 O-Ring Set	W	N	15 Days	1
1-610800	KL-6 Magnet Current Deflection System	W	N	15 Days	1
1-611800	KL-8 Magnet Current Deflection System	W	N	15 Days	1
0-601786	Rotary F/T Upper and Middle O-Ring	W	N	15 Days	2
0-601077	Rotary F/T Lower O-Ring	W	N	15 Days	1

COMPRESSED GAS

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
ARG20-N01G1H-Z	Compressed Air Regulator,7-125 PSI	R	Y	---	1
ARG20-DUN02815	Compressed Nitrogen Regulator,0-60 PSI	R	Y	---	1
PET012	Poly tubing, 1/8" Clear - Pneumatics	R	Y	---	As Required
PET025	Poly tubing, ¼" Clear - Pneumatics	R	Y	---	As Required
TT025	Teflon, ¼" OD Clear – Vent Gas	R	Y	---	As Required
639PL-2	Solenoid Plug 1/8"	R	Y	---	As Required

INSTRUMENT COOLING / WATER FLOW

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
181130-10	Flow Switch, Brass, 0.15 GPM	W	Y	---	1
168443-10	Flow Switch, Brass, 0.5 GPM	W	N	15 Days	1
178353-10	Flow Switch, Brass, 2.0 GPM	W	Y	---	1
B-400-7-6	¼" Tube Press Fitting	R	Y	---	---
B-600-7-6	3/8" Tube Press Fitting	R	Y	---	---
44075K61	Water Filter, 25 GPM Max	C	N	15 Days	---
4912K72	Ball Valve ¼ MNPT x ¼ FNPT	R	Y	---	As Required
PET025B+	Poly tubing, ¼" BLUE - Cooling	R	Y	---	As Required
PET025R+	Poly tubing, ¼" RED - Cooling	R	Y	---	As Required
PET037B+	Poly tubing, 3/8" BLUE - Cooling	R	Y	---	As Required
PET037R+	Poly tubing, 3/8" RED - Cooling	R	Y	---	As Required

LOAD LOCK / LRP

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
SME-8-O-K-LED-24	Proximity Sensor Normally CLOSED	CS	Y	---	1
SME-8-K-LED-24	Proximity Sensor Normally OPEN	CS	Y	---	1

ELECTRICAL / CONTROLS

PART NUMBER	DESCRIPTION	CATEGORY	IN STOCK	LEAD TIME	QUANTITY
WK4748-ND	Fuse, 5 X 20MM, 1A, Medium Time-Lag	W	Y	---	2
WK4757-ND	Fuse, 5 X 20MM, 2A, Medium Time Lag	W	Y	---	2
WK4850-ND	Fuse, 5 X 20MM, 250V, 1.25A, Time Delay	W	Y	---	2
WK4857-ND	Fuse, 5 X 20MM, 2A, 250V, Time-Lag	W	Y	---	2
WK4860-ND	Fuse, 5 X 20MM, 3A, Time-Lag	W	Y	---	2
WK4763-ND	Fuse, 5 X 20MM, 5A, Medium Time-Lag	W	Y	---	2
JJS-30	Fuse, Class T, 600V, 30A	W	N	5 Days	2
JJS-50	Fuse, 50A, 600V, Very Fast Acting	W	N	6 Days	2
1N4007-T	Diode, 1N4007, DO-41, 1000V, 1A	W	Y	---	2

FNQ-R-1/4	Fuse, Class CC, FNQ, 1/4A	W	N	5 Days	2
FNQ-R-1/2	Fuse, Class CC, FNQ, 1/2A	W	Y	---	2
FNQ-R-1	Fuse, Class CC, NDQ, 1A	W	N	5 Days	2
FNQ-R-2	Fuse, Class CC, FNQ, 2A	W	Y	---	2
FNQ-R-3	Fuse, 3A, Class CC	W	Y	---	2
LFJLS30	Fuse, Class J, No Delay, 30A	W	Y	---	2
C9A41DX24VDC	Relay, 4P, 24 VDC	W	Y	---	1
700-HLTlZ24	Relay, SPDT, 24 VDC, 250 V / 6A	W	N	5 Days	1
S9-M	Relay Socket	W	Y	---	1
D2-16TD1-2	D205 16 Discrete Output Module	CS	Y	---	1
D2-32ND3	D205 32 Discrete Input Module	CS	Y	---	1
D2-32TD1	D205 32 Discrete Output Module	CS	Y	---	1
F2-04THM	D205 Thermocouple Module	CS	Y	---	1
F2-8AD4DA-2	Analog Output Module	CS	Y	---	1
H2-EBC	D205 Ethernet Port Module	CS	Y	---	1
L0024478	SCR, 0-10 V	W	Y	---	1
SC-E03G24VDC	Contactor, 10A	W	Y	---	1
CS10.241	24 VDC power supply	CS	Y	---	1
SAPCBALDDIS	Discrete Circuit Board	CS	Y	---	1
SAPCBALDANA	Analog Circuit Board	CS	Y	---	1

APPENDIX

VACUUM TECHNOLOGY

WHAT IS VACUUM?

Commonly, the word “vacuum” is applied to an enclosed volume containing gas at a lower pressure than the surrounding atmospheric pressure. So many applications, processes, and products involve vacuum that attempting to classify them appears futile. However, using very broad definitions, vacuum applications fit into six headings...

LARGE HADRON COLLIDERS

Moving electrons (or ions) from here to there as in x-ray tubes, beam lines, mass spectrometers, etc, demands high vacuum. Why? Because electrons/ions will be deflected by, attach to, or ionize any residual gas molecules they encounter. *Vacuum creates conditions in which charged or uncharged particles can be moved around without collision.*

MIRRORS

Evaporating aluminum as a thin coating on glass or plastic makes a wonderful headlamp reflector, DVD, or rear-view mirror. But try evaporating aluminum in air and the result is aluminum oxide, a white substance not noted for its reflective properties. *Vacuum prevents chemical reaction with air.*

CAMERAS

All good camera lenses are coated with an anti-reflective layer so the maximum amount of light arrives at the film or digital processor. By contrast, architectural glass is coated with partially reflective layers for visible or infra-red wavelengths. Any oil or water vapor absorbed on the glass surface prior to coating ruins the process. *Vacuum helps removes absorbed contamination from surfaces.*

HALLOWEEN MASKS

Vacuum forming is a common process for making plastic Halloween masks, compartmented lunch trays, and disposable razors. The plastic sheet is heated to a deforming temperature and the air removed between it and a metal mold. *Vacuum removes air to create a differential pressure.*

NEON SIGNS

Neon signs contain...neon (and other gases for different colors); electrical switchgear is backfilled with SF6 to prevent arcs; and all fluorescent lights are backfilled with mercury vapor. *Vacuum removes air in preparation for backfilling with an appropriate gas, vapor, or liquid.*

CLEAN SURFACES

Tribology experiments (the science of wear and friction of clean surfaces) often starts with breaking a crystal under vacuum to get a clean surface that has no absorbed contaminants. If the chamber's pressure is one millionth of an atmosphere, the initially clean surface is coated with a mono-layer of residual gas within ~1 second. If the chamber is at one billionth of an atmosphere, the time increases to ~1000 seconds. *Vacuum reduces the flux of the residual gas on a surface.*

PRESSURE

WHAT IS PRESSURE?

Since vacuum is described as a "reduced pressure" we must have some understanding of what pressure means. There are two ways of presenting it: (a) every-day experience with atmospheric pressure; and (b) what is really happening at the molecular level.

GRAND SCALE

The layer of air surrounding the earth is not thick (roughly 100 km, compared to the earth's diameter of 12,800 km). However, a column of air 1" square (6.45 cm^2) at sea level projected to the top of the atmosphere weighs about 14.7 pounds (6.7 kg) on the average day. Expressed another way, this air column creates a pressure at sea level of 14.7 pounds per square inch (psi) (1.035 kg/cm^2). But air is a fluid and 14.7 psi applies to all surfaces no matter what their orientation. If we evacuate a 1" cubic box at sea level, then the top (horizontal) surface will experience 14.7 psi pushing down and the bottom (horizontal) surface will experience 14.7 psi pushing up. Equally, opposite sides of the cube experience forces of 14.7 psi pushing left and right. So the cube experiences no net force pushing it in any direction (other than gravity, of course).

NANO SCALE

Air is a mixture of molecules (nitrogen, oxygen, carbon dioxide, etc) and atoms (argon, helium, etc), which at normal temperatures are all moving at high speed, making a huge number of elastic collisions with each other in a gas phase and non-elastic collisions with surfaces. At room temperature, the average nitrogen molecule is traveling at ~900 mph (474 m/s.). At any moment, ~90% of the N_2 molecules have velocities between 100 mph and 1,800 mph. But N_2 has the mass of only 4.8×10^{-23} gm, so despite its high velocity its kinetic energy is unnoticeably small. However, as noted in Number Density (below), 1 cubic centimeter (cc) of air contains a gigantic number of atoms/molecules. It is the force generated by the high speed surface bombardment of those myriad tiny particles that we experience as pressure.

PRESSURE UNIT

All pressure measurement units are of the form force per unit area. However, for many units this relationship is hard to identify. A few of the more commonly used pressure units in vacuum applications are noted here with approximate conversion factors to 1 atmosphere pressure (1 atm) to show their relative magnitude.

- millimeter of mercury: 760 mmHg = 1 atm
- Torr*: 760 Torr = 1 atm
- millitorr: 760000 mTorr = 1 atm
- micron of mercury: 760000 µHg = 1 atm
- bar: 1.013 bar = 1 atm
- millibar: 1013 mbar = 1 atm
- pascal**: 101325 Pa= 1 atm

* Preferred unit in the USA and used throughout these notes
* SI units (1 Pa = 1 newton/m^2)

BASIC VACUUM CONCEPTS

Our concept of solids and liquids depends largely on our ability to see/touch them. If we have two lumps of solid, roughly the same volume and one lump is light while the other is heavy, we say the heavy lump has a higher density - mass per unit volume (lb/in^3, g/cc, kg/m^3, etc.). Gases present a challenge to our ability to see/touch and new terms have been introduced to describe the "gaseous state". *(The gas laws used to derive the values quoted below are correct only for ideal gases. However, in room temperature chambers as pressure decreases, all gases approach ideal behavior. For vacuum applications, the appropriately scaled value - to allow for pressure change - will be sufficiently accurate for precise calculations).*

NUMBER DENSITY

Avogradro determined that equal volumes of gas at the same temperature and pressure contained equal numbers of molecules. It does not matter if the gas is pure N^2, CO^2, Ar, H^2, or a mixture of all four. Later, Loschmidt determined that 22.4 liters of gas at 760 Torr and 0º C contain 6.022×10^{23} molecules (the present day value, often called Avogadro's number). Since gas fills any volume that contains it, its "density" (in g/cc units) depends on that volume, the gas composition, and molecular weights of the components. If instead of density (mass per unit volume) we use number density (number of molecules in 1 cc) we can describe a "quantity" of gas without knowing anything about composition or molecular weights. From Avogadro's number (which refers to 22.4 liters) we know the number density (which refers to 1 cc) of any gas at 760 Torr and 0° C is 2.69×10^{19} cm^{-3}.

MEAN FREE PATH

The huge number density at atmospheric pressure and the high velocities of the gas molecules mean that in each cc there are many, many gas phase collisions every second. Expressed another way, even though a molecule travels at high speed, on average it travels a very short distance before hitting another gas phase molecule. This average distance is called the mean free path (mfp). For air at 760 Torr the mfp is 6.5×10^{-6} cm.

PARTICLE FLUX

In addition to colliding with each other in the gas phase, gas molecules hit the containing vessel walls and every other surface inside the enclosure. The rate at which they hit these surfaces, called particle flux, depends on the gas's number density. The flux of air at 760 Torr and 0º C is 2.9×10^{23} cm^{-2} s^{-1}.

REDUCING PRESSURE

If we remove some molecules from an enclosed container initially at 760 Torr, what happens to number density, mfp, and particle flux? The easiest quantity to understand is number density. If we remove half of the molecules from the container, the number density goes from 2.7×10^{19} cm^{-3} to 1.35×10^{19} cm^{-3}. If we remove 99% of the original molecules, the number density is 2.7×10^{17} cm^{-3}, still a huge number. The table shows the relationship between pressure, number density, mean free path, flux, and the time taken to completely cover a clean surface with a monolayer, for air at room temperature. With respect to the monolayer coverage, it depends on: particle flux, molecular diameter, and the sticking coefficient of the gas molecules on the surface. The numbers given are for air which has an average molecular diameter of 3.7 Å and the sticking coefficient is ~1 on a clean, unheated surface.

BASE PRESSURE

When a chamber has no leaks, has no gas deliberately flowing into it, and has been pumped for several days, the pressure reaches an equilibrium value called the base pressure. In truth, because the pressure approaches equilibrium asymptotically and the outgassing rate undergoes exponential decay, even after a long time under vacuum, the chamber, theoretically, will never quite reach a stable pressure. But variations in vacuum gauge calibration, room temperature, pumping speed, backstreaming from the pump, etc., mask or counter any real pressure reduction and the chamber appears to have reached a steady state. Often what happens is: the operator pumps the chamber for a few hours, grows tired of waiting, and claims the chamber is at base pressure. This is not necessarily wrong. After all, if the pressure falls from 5×10^{-7} Torr to 4×10^{-7} Torr by waiting another ten hours, is all that much gained? Perhaps it doesn’t conform to formal definition, but in a sense the base pressure is reached whenever the operator says it is and starts using the chamber.

WORKING PRESSURE

The term base pressure defines conditions where no gas is deliberately flowing into the system. But sometimes the chamber is first pumped to its base pressure (to check for leaks or remove contamination) and then back-filled with a gas to an intermediate pressure. This is how processes such as sputter deposition, plasma etching, and CVD are done. This intermediate pressure is called the working pressure. To establish and maintain a working pressure, it is rarely sufficient to just close the pumping port, back-fill with gas, and walk away. Most back-fill applications require a flow of fresh gas to sweep away contaminants desorbing from the chamber walls. Often the back-fill pressure is stabilized with a feedback control system.

Pressure (Fractions of an Atmosphere)	Pressure (Torr)	Number Density (cm^{-3})	Mean Free Path (cm)	Particle Flux (cm^{-2} sec^{-1})	Time for a Monolayer (sec)
1/1,000	0.76	2.7×10^{16}	0.0065	2.9×10^{20}	3×10^{-6}
1/10,000	7.6×10^{-2}	2.7×10^{15}	0.065	2.9×10^{19}	3×10^{-5}
1/100,000	7.6×10^{-3}	2.7×10^{14}	0.65	2.9×10^{18}	3×10^{-4}
1/1,000,000	7.6×10^{-4}	2.7×10^{13}	6.5	2.9×10^{17}	3×10^{-3}
1/10,000,000	7.6×10^{-5}	2.7×10^{12}	65	2.9×10^{16}	3×10^{-2}
1/100,000,000	7.6×10^{-6}	2.7×10^{11}	650	2.9×10^{15}	3×10^{-1}

ULTIMATE PRESSURE

Vacuum pump manufacturers gives two specifications: pumping speed and ultimate pressure (also called ultimate vacuum). The ultimate pressure is measured by capping the pump's inlet and finding the equilibrium pressure after operating the pump for many hours. Because it is measured under "ideal" circumstances, it is crucial to remember that a chamber connected to this pump will never reach the quoted ultimate pressure! Perhaps worse, pump manufacturers measure the ultimate pressure of mechanical pumps using a McLeod gauge that cannot measure vapors such as pump oil and water. Consequently, the so-called ultimate (partial) pressure of a rotary vane pump may be quoted in the 10^{-5} Torr range, causing much confusion when the practical ultimate pressure (using a gauge that responds to oil and water vapor) is two decades higher.

FLOW REGIMES

The mean free path (described above) and the chamber/component dimensions determine the gas's flow conditions or flow regime. If the mfp is:

- Very short compared with the chamber's 'characteristic dimension's', the gas is in *continuum* flow
- Shorter than the chamber's characteristic dimensions but approaches them, the gas is in *transitional* flow
- Equal to or longer than the chamber's characteristic dimensions then the gas is in *molecular* flow

The flow regime is used to identify the appropriate equations needed to calculate conductances, pump down times, and other characteristics.

VACUUM DOESN'T SUCK!

There is a common misunderstanding that vacuum pumps suck. *There is no such force as suction.* If the gas molecules in one "section" of a vacuum volume could be instantaneously removed, molecules from the remaining section, in their normal high-speed flight, would randomly collide and bounce off walls until they filled the whole volume at a lower pressure.

For vacuum pumping, this means that until a gas molecule in its random flight enters the pumping mechanism, that molecule cannot be removed from the volume. In effect the pump acts like a one-way valve: gas molecules may enter but not return. But for that to happen, molecules must first arrive at the pump...it cannot reach out and grab them. Understanding that *vacuum doesn't suck* makes the basic aspects of vacuum technology much easier to grasp.

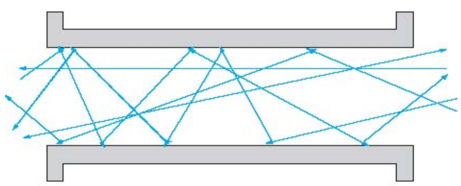
CONDUCTANCE

Vacuum technology novices have difficulty distinguishing conductance from pumping speed (discussed later). These terms seem to describe similar concepts and use identical flow units of volume per unit time. But they should not be confused.

The formal definition of conductance is: The ratio of throughput, under steady-state conservation conditions, to the pressure differential between two specified isobaric sections inside the pumping system.

PRACTICAL INTERPRETATION

The conductance of a 'passive' vacuum component (e.g. tube, nipple, elbow, tee, valve, non-cooled baffle, etc.) is a measure of that component's ability to transmit gas molecules from end-to-end in some given time. High conductance is of paramount importance in achieving rapid chamber pump down times and low base pressures. One characteristic that determines conductance is the clear diameter of the opening through the component. A wide opening offers a bigger target for molecules to enter during their random flights around the chamber and, obviously, until a molecule enters the component it cannot be transmitted. Another characteristic is the number of wall collisions molecules make during their transmission through the component. When molecules hit surfaces they are not reflected like light from mirror. Rather, they "stick", often for a very short time, lose all information about their arrival direction, and desorbs following a cosine distribution. This distribution gives the molecules an equal chance of heading in either direction along the tube and a maximum probability of heading diametrically across the tube. The more surface hits a molecule makes, the less likely it is to complete the journey quickly and the lower is that component's conductance.



GAS CONDUCTANCE OF A PASSIVE COMPONENT

CONDUCTANCE UNITS

Conductance is a volumetric flow measured in units of volume per unit time, specifically: liters per second (L/s); cubic meters per hour (m3/h); cubic feet per minute (cfm); liters per minute (L/m); etc. Expressing conductances as volumetric flows has two benefits: (a) conductances can be combined by simple math (see below) and (b) in the molecular flow regime, a component's conductance is constant and independent of pressure.

CALCULATING CONDUCTANCES

The time to calculate conductances is before any vacuum component is purchased. The approximate operating characteristics of a soon-to-be-built or about-to-be-modified system should be known while it is still a scratch-pad idea. When the system is constructed, it is a trivial matter to reduce conductance but an expensive re-build to increase conductances that are too low.

MANUAL CALCULATION

Since conductance in molecular flow is independent of pressure and since most high vacuum applications are in molecular flow, the calculations discussed here and in the sidebar are appropriate only for that flow regime. Two books edited by J.M. Lafferty are invaluable when making conductance calculations. The first is *Scientific Foundations of Vacuum Technique*, by Saul Dushman, 2nd ed., J.M. Lafferty, editor, from which we have reprinted a table from p.99 with permission from John Wiley & Sons ©1962. The second is *Scientific Foundations of Vacuum Science and Technology*, J.M. Lafferty, editor, John Wiley & Sons ©1998 which has a chapter by R. Gordon Livesey with a wealth of information and equations for calculating conductances in molecular, transitional, and continuum flow regimes. Examples of conductance calculations for straight cylindrical components using Dushman's table are given in the sidebar. To calculate conductances of non-cylindrical components, find the appropriate equation in Lafferty's 2nd book or, for less accurate estimates, use Dushman's table and some rules of thumb:

- Right-Angle Bends: Measure the tube length "L" as the shortest distance (along the inside of the bend). Calculate the conductance from the table as if the tube were straight, and then divide by 2 for every right-angle bend.
- Non-Cylindrical Cross-Section: Calculate the "open" area of the tube or annulus and find the radius of a cylindrical tube with an equal area. Calculate the conductance of this "equivalent tube".
- Diameter Changes: If a tube changes diameter along its length, the safest way to calculate conductance is to use the smaller diameter to calculate "a" (the radius). But if the smaller diameter portion is short compared to the total tube length, the underestimation may be extreme. In such cases, calculate the conductance of the small diameter and large diameter section as separate tubes and combine them in series (see *Combining Conductances*).

a (cm)	F_O	F_t Conductance of Tube (liters sec.$^{-1}$) for air at 25° C L/a = 1 K = 0.672	2 0.514	4 0.359	8 0.232	12 0.172	16 0.137	30 0.080
0.1	0.367	0.246	0.188	0.132	0.085	0.063	0.050	0.029
0.2	1.466	0.986	0.753	0.527	0.340	0.252	0.200	0.117
0.3	3.300	2.217	1.664	1.184	0.764	0.567	0.451	0.263
0.4	5.866	3.943	3.013	2.106	1.358	1.008	0.802	0.468
0.5	9.166	6.160	4.708	3.291	2.122	1.575	1.253	0.731
0.6	13.200	8.872	6.779	4.739	3.057	2.269	1.805	1.052
0.7	17.970	12.080	9.228	6.449	4.161	3.088	2.457	1.432
0.8	23.470	15.770	12.050	8.424	5.436	4.033	3.208	1.871
0.9	29.700	19.960	15.250	10.660	6.879	5.105	4.061	2.368
1.0	36.660	24.640	18.830	13.160	8.492	6.302	5.013	2.922
2.0	146.600	98.560	75.340	52.650	33.970	25.210	20.050	11.690
3.0	330.000	221.700	166.400	118.400	76.420	56.710	45.110	26.300
4.0	586.600	394.300	301.300	210.600	135.800	100.800	80.210	46.770
5.0	916.600	616.000	470.800	329.100	212.200	157.500	125.300	73.100
6.0	1320.00	887.200	677.900	473.900	305.700	226.900	180.500	105.200
7.0	1797.00	1208.00	922.800	644.900	416.100	308.800	245.700	143.200
8.0	2347.00	1577.00	1205.00	842.400	543.600	403.300	320.800	187.100
9.0	2970.00	1996.00	1525.00	1066.00	687.900	510.500	406.100	236.800
10.	3666.00	2464.000	1883.000	1316.000	849.200	630.200	501.300	292.200

COMBINING CONDUCTANCES

Since a component's conductance in molecular flow is independent of pressure and is quoted as a volumetric flow, conductances for various components can be combined in series or parallel. If two chambers are connected together by: (a) a narrow tube on chamber 1; (b) a right angle valve; and (c) a large port on chamber 2, their separate conductances can be combined as reciprocals to give a total conductance between the two chambers (see sidebar *Series Conductances*). Notice that the total conductance is much less than any individual conductance. In addition, look at the table. Here, just two conductances, one variable and the other fixed at 10 L/s, are added together. The Total Conductance column demonstrates a critical rule in series conductances– *the smallest conductance rules.*

Alternatively, if two chambers are connected by two tubes of different diameters, each tube has its own conductance. To determine the total conductance between chambers simply add the conductances together (see sidebar *Parallel Conductances*).

COMPUTER CALCULATIONS

Calculating Conductance

The conductance of an **orifice**—a hole in an infinitely thin plate—is determined as follows:

- Measure the orifice's radius in centimeters.
- Enter the table at the appropriate "a" (radius) row. Go right to the F_0 column and read the conductance in L/s.

The conductance of a **straight cylindrical tube** is calculated as follows:

- Measure the (overall) length of the tube in any convenient units.
- Measure the tube's I.D. in the same units.
- Divide the I.D. by 2 to give the radius.
- Divide the length by the radius (this gives the "L/a" ratio used in the table).
- Convert the radius to centimeters (this gives "a" (cm) to use in the table).
- Enter the table at the appropriate "a" row.

Go right until under the value of the calculated "L/a" ratio. If the exact match is not available, use the next larger "L/a" value or interpolate.

A component's conductance in continuum or transitional flow depends on gas pressure and uses different equations than those governing molecular flow. Calculating conductances from atmospheric pressure to high vacuum requires iterative processes ideally suited to computer calculation. PEC's VacTran, described on page 17-21, is an exceptionally powerful program for vacuum technology calculations including the calculation of series and parallel conductances for any pressure range and many different cross-sectional shapes (cones, slots, ovals, annuli, and triangles).

PUMPING

The formal definition of pumping speed is: The ratio of the throughput of a given gas to the partial pressure of that gas at a specific point near the inlet port of the pump.

PUMPING INTERPRETATION

With less formality, but perhaps more clarity, pumping speed is a measure of the pump's ability to permanently remove gas from its inlet port.

Conductance C1	Conductance C2	Total Conductance 1/(1/C1 + 1/C2)
10	10	5 L.sec.
10	100	9.1 L/sec.
10	1,000	9.9 L/sec.
10	10,000	9.99 L/sec.
10	100,000	9.999 L/sec.
10	1,000,000	9.9999 L/sec.

Series Conductances

Series conductances are added as reciprocals:

1/Ctotal = 1/C1 + 1/C2 + 1/C3

Given:

Narrow Tube—120 L/s (C1)

Angle Valve—230 L/s (C2)

Large Port—1,400 L/s (C3)

The total conductance is:

$1/C_{total} = 1/120 + 1/230 + 1/1,400$

$1/C_{total} = 0.0083 + 0.0043 + 0.0007$

$1/C_{total} = 0.01339$

$C_{total} = 1/ 0.01339$

Total Series Conductance = 74.6 L/s

Parallel Conductances

Using two conductances simultaneously between two chambers or between a chamber and pump is not common but such arrangements do occur and are easily calculated. Suppose the two tubes have conductances of 1,800 L/s and 2,300 L/s. The total conductance is:

$C_{total} = C1 + C2$

$C_{total} = 1,800 + 2,300$

Total Parallel Conductance = 4,100 L/s

PUMPING SPEED UNITS

Pumping speed is a volumetric flow measured in units of *volume per unit time* – specifically: liters per second (L/s); cubic feet per minute (cfm); cubic meters per hour (m^3/h); or liters per minute (L/m). As with conductance, expressing pumping speed as volumetric flows has the benefits that pumping speed and conductances can be combined by simple math (see *Effective Pumping Speed*).

PUMPING SPEED CURVES

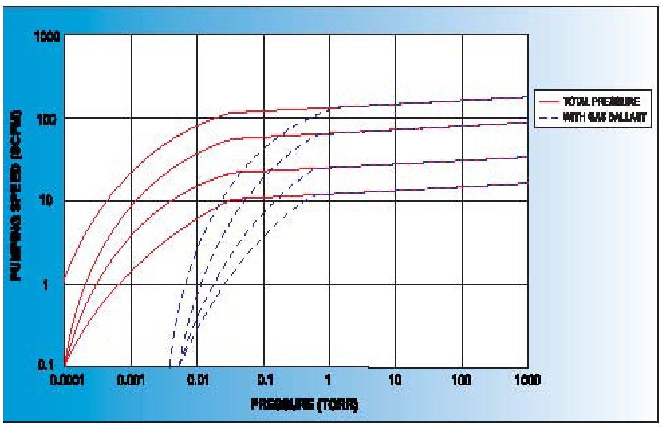


Figure 2

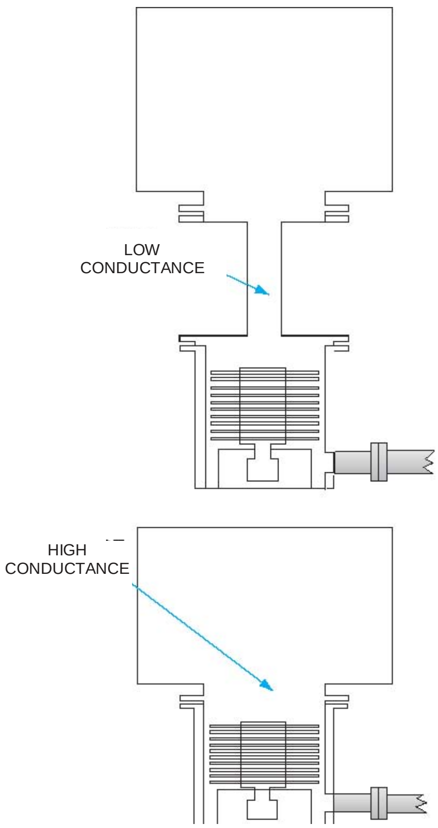
Various standards organizations in the US, Europe, and Asia have specified methods for measuring *pumping speed*. As far as we are aware, all suggest capping the pump with a small volume dome at its inlet port and monitoring the pressure at various gas flow rates into the dome (from a calibrated mass flow controller). The results are plotted as *pumping speed* vs. *pressure* as shown in Figure 2. Because a pump's pumping speed is measured under ideal conditions, its numerical value will be unobtainable in a practical system–the connection between any pump and any chamber affects the pumping speed (see *Effective Pumping Speed*).

DISPLACEMENT AND CAPACITY

Unfortunately, many mechanical pump manufacturers quote a value called *free air displacement* or *capacity* for their pumps. The units are volumetric flow rate and the value is easily mistaken for a measured pumping speed. However, displacement/capacity appears to be a theoretical pumping speed the pump might have if the gas had no mass or viscosity; negotiated the entrance port and constrictions into the pumping mechanism instantaneously; and did so without turbulence or boundary layer effects. Why pump manufacturers indulge in such an exaggeration is unknown. It only confuses those attempting vacuum calculations. We strongly suggest displacement/capacity values be ignored or, in the absence of a measured pumping speed, multiplying displacement by ~0.75 to get an approximation of the real pumping speed.

EFFECTIVE PUMPING SPEED (EPS)

WHAT IS EPS?



As pointed out above, a pump's quoted pumping speed is the maximum value measured under ideal conditions. In practical situations, a pump is connected to a chamber via a series of passive components such as a tube, valve, and perhaps a trap. Each passive device has its own ability to transfer gas, and clearly that ability will affect the flow of gas from chamber to pump inlet. It is the combination of the conductances of these passive devices and the pumping speed of the pump that determines the overall pumping speed from the chamber, called the *effective pumping speed* (EPS) or sometimes the *delivered pumping speed*. (We will use the former.) The EPS's value is critical since it determines the chamber's pump-down characteristics and base pressure.

Since EPS is a combination of conductance and pumping speed, it retains the units of *volume per unit time*, such as: liters per second (L/s); cubic feet per minute (cfm); cubic meters per hour (m^3/h); or liters per minute (L/m).

CALCULATING EPS

Consider a 500 L/s high vacuum pump connected to a chamber by a pumping port of 4" (10 cm) internal diameter x 4" (10 cm) long. Calculating the port's conductance from Dushman's table gives ~500 L/s. Pumping speed and conductance are combined to give the EPS in exactly the same way two series conductances are combined.

$$1/EPS = 1/PS + 1/C$$

So a 500 L/s pump and a 500 L/s port combine as 1/500 + 1/500. That is, the EPS from the chamber is 250 L/s. The simplest connection between pump and chamber halved the pump's quoted pumping speed. Obviously, this is a serious issue and adding a trap or valve to the connection can only further reduce the pumping speed from the chamber. Unfortunately, all too often we see connections between pump and chamber that are just plain silly. For example, a 500 L/s diffusion pump connected to a chamber by a 0.7" (1.8 cm) I.D. x 1.42" (3.6 cm) long tube. Dushman's table gives the tube's conductance as ~10.7 L/s. Combining this with the pump (1/500 + 1/10.7) gives an EPS of ~10.5 L/s. There is no clearer illustration of the maxim: the smallest conductance rules.

Measuring EPS

One method of measuring EPS uses the fact that in molecular flow the system follows first-order reaction kinetics:

$$P_{final} = P_{original} \times e^{-kt}$$

Integrating with respect to time

$$EPS = V/t \times \log_e(P_o/P_f)$$

Where V is chamber volume, t is time, and P_o and P_f are the start and final pressures.

Example: a 150 L chamber has a base pressure of 1 x 10^{-8} Torr. Gas is injected through a valve at a rate that keeps the pressure at 4 x 10^{-4} Torr with the pumps operating. The valve is shut at time zero 0 s and 16 s later the chamber has reached 6 x 10^{-6} Torr.

$EPS = 150/16 \times \log_e(4 \times 10^{-4}/6 \times 10^{-6})$

$EPS = 9.38 \times \log_e 66.67$

$EPS = 9.38 \times 4.2$

EPS = 39 L/sec.

Limitations to measuring the EPS this way:

- Formula only works for molecular flow conditions.
- Results are invalid if P_o edges into transitional flow.
- If P_f is <50x the chamber's base pressure, wall outgassing will affect the time measurement.

Other measurement methods are under Tech Info at www.lesker.com.

GAS LOAD

WHAT IS GAS LOAD?

When discussing pressures and pumping, we are really speaking about molecules in the gas-phase, which are the only ones we can measure or pump. However, if we could remove all gas-phase molecules instantaneously from a vacuum vessel, the result would not be zero pressure. Molecules are continuously entering the gas phase from various sources which can be summarized as:

- **Real leaks** at welds, gaskets, flanges, or porous construction materials
- **Virtual leaks** such as trapped volumes at welds, screw threads, or mating surfaces
- **Outgassing**, which includes gas/vapor...

  — **Desorbing** from the wall surfaces (which is important enough to warrant its own section)
  — **Diffusing** from the wall matrix
- **Evaporation** of materials with high vapor pressure
- **Permeation** through elastomeric gaskets
- **Permeation** through the glass or walls
- **Backstreaming** gases from the pump
- **Backstreaming oil vapor** from an oil-sealed pump
- **Backstreaming condensable vapors** (e.g. solvents) coming out of the pump oil
- **Desorbing gas** from a saturated trap
- **Desorbing gas** from a cryogenic trap with a falling cryogen level
- **Deliberately injected gas** required by the process

The rate at which molecules enter into the chamber's gas phase from all these sources is called the chamber's gas load.

GAS LOAD UNITS

Gas load is a mass flow rate and is measured in units of **volume x pressure per unit time**, such as: Torr.liters per second (T.L/s); mbar.liters per second (mbar.L/s); Pascal.cubic meters per hour (Pa.m^3/h); Torr.liters per minute (T.L/m); or std.cubic centimeters per minute (sccm).

OUTGASSING

WHAT IS OUTGASSING?

In a well-designed, well-constructed vacuum system, in the absence of deliberately injected gas, the major contributor to the gas load is the desorption of gases/vapors from the vacuum surfaces - *outgassing*. More specifically, the outgassing rate is the amount of gas leaving some unit area of surface in unit time.

OUTGASSING RATE UNITS

Any combination of units for pressure, volume, area, and time, can be used but there are just three combinations commonly quoted:

- Torr x liter per square centimeter per second (mostly in the USA)
- millibar x liter per square centimeter per second (mostly in Europe)
- pascal x cubic meter per square meter per second (the SI unit)

NOTE: By manipulating units the last combination can be transformed into the seemingly bizarre but correct W/m^2 and is quoted this way in some literature collections. To transform rates in W/m^2 into Torr-L/(cm^2-s) divide the former value by 1,333.2.

OUTGASSING SOURCES

Surfaces are active places that absorb gases and vapors to reduce the 'unfulfilled' bonding forces of the surface atoms. This means that all surfaces, no matter what material is under consideration, outgas under vacuum. Some of the worst materials are: plastics, elastomers, and glues; porous ceramics and porous metals; lubricating, sealing, or heat transfer greases; and us (fingerprints, hair, skin cells, dust mites, spittle droplets when talking, and food)! The most common gases/vapors outgassing from surfaces are: water vapor; oil and grease vapors; solvents and volatile organic materials; and (when approaching ultrahigh vacuum pressures) hydrogen and carbon monoxide from stainless steel used in the chamber's construction.

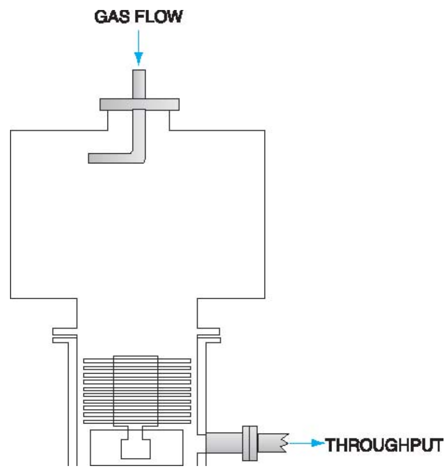
REDUCING OUTGASSING

As stated above, nothing can be pumped from the chamber until it is in the gaseous phase. The outgassing rate is reduced by methods that cause adsorbed gas/vapor to enter the gaseous phase:

- Heat: baking the chamber increases the desorption rate of the gas/vapor
- Light: intense short wavelength UV breaks bonds between surface and adsorbed gas/vapor
- Plasma: active plasma products break bonds and react with adsorbed gas/vapor forming more volatile compounds
- Chemistry: reactive chemical vapors convert adsorbed water into HCl (very limited utility)

THROUGHPUT

WHAT IS THROUGHPUT?



Pump manufacturers supply pumping speed vs. pressure curves for each pump. Multiplying pumping speed at some pressure by that pressure gives a measurement called *throughput* (or sometimes *pump throughput*). It is essentially a measure of the *quantity* of gas the pump removes from its inlet in unit time, where the word *quantity* can be substituted by *amount, mass,* or *number of molecules.*

THROUGHPUT UNITS

Throughput is a mass flow rate and is measured in units of **volume x pressure per unit time**, such as: Torr.liters per second (T.L/s); mbar.liters per second (mbar.L/s); Pascal.cubic meters per hour (Pa.m^3/h); Torr.liters per minute (T.L/m); or std.cubic centimeters per minute (sccm).

MEASURING THROUGHPUT

One method of measuring/calculating *(effective) throughput* is to measure/calculate the EPS from the chamber (see above) and multiply that value by the chamber pressure. As an example: the measured EPS is 83 L/s when the chamber's working pressure is 5 x 10^{-6} Torr. The effective throughput is then: 83 L/s x 5 x 10^{-6} Torr which is **4.15 x 10^{-4} Torr.L/s**

Another measurement method is listed under Tech Info at www.lesker.com.

GAS LOAD & THROUGHPUT

COMPARISON & CALCULATIONS

The *gas load* was defined above as the total amount of gas entering the system while *throughput* is the total amount of gas leaving the system. Both have units of *volume x pressure per unit time*. The critical point here is to recognize that when the chamber's pressure is constant, *gas load* must equal *throughput*. To express the concept fully: the mass of gas entering the system in a given time must equal the mass of gas leaving the system in the same time or the pressure will change. To use a less rigorous but more memorable expression, at constant pressure:

Gas In = Gas Out

This identity is used when sizing pumps for applications that have known mass flow of gas injected. The common unit for measuring mass flows of gas is *standard cubic centimeters* per *minute* or *sccm*, popularly called "skims". (Note the units: *standard* refers to 760 Torr or 1013.2 mbar at 0° C; *cubic centimeters* is a volume; and *minute* is, obviously, time). As an example, let us calculate the pumping speed needed to maintain a working pressure of ~13 mTorr when injecting 100 sccm of argon. First we convert the gas flow units (sccm) into pump flow units (say L/s if we are dealing with a high vacuum pump situation or cfm, L/m, etc. for a roughing pump). Here we will consider just a high vacuum pump:

100 sccm = 100 x 760 Torr.ccm = (100 x 760)/1000 Torr.liter/min
= (100 x 760)/(1000 x 60) Torr.liter/sec

Gas In = 1.27 T.L/s

Since ***Gas Out*** must also equal 1.27 T.L/s and we know the chamber pressure must be ~13 mTorr with the gas flowing, we calculate the minimum effective pumping speed by dividing 1.27 T.L/s by 0.013 T:

1.27/0.013 = ~100 L/s
Minimum effective pumping speed 100 L/s

Clearly, the pump's quoted pumping speed must be higher than this since the pumping port's conductance will reduce it. However, it can be much higher and simply trimmed to 100 L/s using a throttle valve between chamber and pump.

PUMP-DOWN TIMES

MANUAL CALCULATIONS

Can pump-down time be calculated? The short answer is yes. But the longer answer is: this is an iterative process involving exponential decay and manual calculation can be involved and tedious, even using a spreadsheet program.

COMPUTER CALCULATIONS

Over the years, computer algorithms have been developed for iterative techniques needed to calculate conductances, throughputs, gas loads, effective pumping speeds, and pump-down times across continuum, transitional, and molecular flow regimes using the available formulas from vacuum technology. Typically, the user keys in the pump's pumping speed curve, chamber dimensions, surface outgassing rates, start/finish pressure, etc., and the calculations are done automatically with the program choosing the appropriate formula at each iteration. We have used successive updates of the **VacTran**® program (from Professional Engineering Computations) for over 17 years. We find it invaluable and, of the programs we have examined, the easiest to use and most versatile. **VacTran**® is particularly valuable during system re-design. The existing system's measured pump-down characteristics determine the real gas load which is used for the model. The designer then makes the proposed design changes on the model and re-runs pump-down iterations. Since the model's gas load reflects reality, the calculated results closely parallel real-world experience when the re-design changes are made. If you have a one-time question to which **VacTran**® can be applied, try our Tech Info service at **techinfo@lesker.com** and we may be able to help. If you are facing vacuum design issues that involve a number of 'what if' conditions, we urge you to buy this program. But note, successful computer modeling depends on the nature of the problem and the operator's understanding of vacuum technology.

SLOW PUMPDOWN

At techinfo@lesker.com a frequently asked question runs along these lines: "Pumping from atmosphere to 1×10^{-6} Torr is taking over five hours. What's the problem?" Obviously, there is no hope of answering without a long assessment that could easily be made by the questioner:

- Given the chamber's volume, cleanliness, pumps used, conductance from chamber to pumps, is a pump-down time of <5 hours reasonable?
- Is this the first time the chamber has been pumped down?
- Does it take five hours for every pump down?
- Has the time slowly increased?
- Has the time suddenly increased? Let's examine each of these questions.

"CHAMBER VOLUME . . ."

A) Is the chamber volume very large and the rough pump speed very small?

B) Does the chamber contain very large surface areas and is the high vacuum pump small?

C) Is the high vacuum pump's base pressure close to 1 x 10-6 Torr?

D) Are the chamber walls clean or dirty, oily, pitted, or corroded?

E) Does the high vacuum pumping port have the same I.D. as the high vacuum pump inlet?

F) Is the high vacuum pumping port's length more than 3 times its I.D.?

"FIRST PUMP-DOWN"

A) Patience! The initial pump-down removes the loosely bound vapor layers absorbed on every surface. Regard it as 'vacuum conditioning'. Pump the system for several hours, let up to atmosphere with dry nitrogen and pump-down again. Then, if the pumpdown still takes five hours, consider B and C.

B) Examine the simple things that can cause long pump-down: check for leaks with a leak detector; regenerate the foreline trap; check that gas inlet valves are fully closed; consider the outgassing characteristics of the construction materials; check that the cross-over pressure is appropriate for both rough and high vacuum pumps; check if the foreline pressure is at an acceptable value for the high vacuum pump.

C) Did someone goof in the original design? Check using a computer modeling program such as **VacTran®**. When you allow for typical outgassing rates, are the results consistent with the measured pump-down time?

"FIVE HOURS EVERY TIME"

Convince yourself the system does not leak and then, using **VacTran®,** model the system. Check that the calculated pump-down time is similar to the measured one. If not, add outgassing sources (roughly modeling the real parts in the chamber) until the pump-down time equals 5 hours. Now you have two options:

A) Reduce the gas load by either: (a) modeling the removal of non-essential components or reducing surface areas; or (b) modeling a reduced outgassing rate achieved by baking or plasma cleaning; this is usually the least expensive option to improving pump-down times

B) If little can be done about the total gas load, play 'what if' games with the model by changing pumps and conductances to see what must be done to improve the pump-down time. This is always an expensive option.

"SLOWLY GOTTEN WORSE"

Time to consider maintenance issues:

A) Is the fluid in any oil-sealed pump contaminated with a vapor?
B) Are the foreline or system traps overloaded?
C) Is something inside the chamber thermally decomposing?
D) Have the fill-full sensors of an LN2 trap changed position?
E) Are the chamber walls contaminated with oil from the pumps?
F) Are o-rings aging due to high temperatures?
G) Does the cryo-pump need regeneration?

More potential issues can be added but the real question is, can the main cause be detected? Fortunately, in most cases the answer is yes, so attach an RGA. Of course, there are drawbacks: RGAs are not cheap and you must learn to interpret spectra. But, as a vacuum diagnostics tool, the RGA has no equal.

"SUDDENLY GOTTEN WORSE"

A) Check your vacuum system's logbook. What did you last do? Change a flange or gasket? Add a component? Change the pump fluid? Then check that the change did not cause a leak, increase the outgassing rate, or reduce the effective pumping speed.
B) If the sudden increase in base pressure occurs after the first chamber bakeout or after three or four pump-downs following system commissioning (when no changes have been made), then make another leak check of the whole system. Real leaks are easily blocked by ice (the effect of vacuum on water trapped in the leak during the final chamber cleaning) or a combination of machining oils and "residues." When the blockage evaporates or disperses, suddenly the chamber has a leak that was previously not there.

UNIT CONVERSION TABLES

Pressure Units

Pressure Units	Atmosphere	Bar	dynes/cm²	in. Hg	in. Water	kg/cm²	mbar	mTorr	Pa	psi	Torr
1 atm.	1	1.01325	1.01325 x 10^6	29.9212	406.78	1.03322	1013.25	7.6 x 10^5	1.01325 x 10^5	14.696	760
1 bar	0.9869	1	1 x 10^6	29.53	401.46	1.0197	1,000	7.5006 x 10^5	1 x 10^5	14.504	750.06
1 dyne/cm²	9.869 x 10^{7}	1 x 10^{6}	1	2.953 x 10^{5}	4.0146 x 10^{-4}	1.0197 x 10^{6}	1 x 10^{3}	0.75006	0.1	1.4504 x 10^{6}	7.5006 x 10^{4}
1 in. Hg	3.342 x 10^{2}	3.386 x 10^{2}	3.386 x 10^4	1	13.595	3.4532 x 10^{-2}	33.863	2.54 x 10^4	3.3864 x 10^3	0.4912	25.4
1 in. water	2.458 x 10^{3}	2.491 x 10^{3}	2.491 x 10^3	7.356 x 10^{2}	1	2.54 x 10^{3}	2.4909	1.868 x 10^3	2.4909 x 10^2	3.613 x 10^{2}	1.868
1 kg/cm²	0.9678	0.9807	9.807 x 10^5	28.959	3.937 x 10^2	1	9.8067 x 10^2	7.3556 x 10^5	9.8067 x 10^4	14.223	7.3556 x 10^2
1 mbar	9.869 x 10^{4}	1 x 10^{3}	1 x 10^3	2.953 x 10^{2}	0.4015	1.0197 x 10^{-3}	1	7.5006 x 10^2	100	1.450 x 10^{2}	0.75006
1 mTorr	1.316 x 10^{6}	1.3332 x 10^{6}	1.3332	3.927 x 10^{5}	5.352 x 10^{4}	1.3595 x 10^{-6}	1.3332 x 10^{3}	1	0.13332	1.934 x 10^{5}	1 x 10^{3}
1 Pa	9.869 x 10^{6}	1 x 10^{5}	10	2.953 x 10^{4}	4.0146 x 10^{-3}	1.0197 x 10^{-5}	0.01	7.5006	1	1.4504 x 10^{-4}	7.5006 x 10^{3}
1 psi	6.805 x 10^{2}	6.895 x 10^{2}	6.895 x 10^4	2.036	27.68	7.031 x 10^{2}	68.95	5.1715 x 10^4	6.8948 x 10^3	1	51.715
1 Torr	1.316 x 10^{3}	1.333 x 10^{3}	1.333 x 10^3	3.937 x 10^{2}	0.5352	1.360 x 10^{3}	1.3332	1 x 10^3	1.3332 x 10^2	1.934 x 10^{2}	1

Pumping Speed Units

Flow	CFM	L/min	L/s	m³/hr	m³/min
1 CFM	1	28.317	0.47195	1.69902	2.8317x10^{-2}
1 L/min	3.5311x10^{-2}	1	1.6667x10^{-2}	6.0x10^{-2}	0.001
1 L/s	2.11887	60	1	3.6	0.06
1 m³/hr	0.5885	16.667	0.27778	1	1.6667x10^{-2}
1 m³/min	35.311	1,000	16.667	60	1

Mass Flow Units

Mass Flow	sccm	micron.L/s	molecules/s	Pa.L/s	Torr.L/s
1 sccm	1	12.667	4.4807x10^{17}	1.6887	1.2667x10^{-2}
1 micron.L/s	7.895x10^{-2}	1	3.5374x10^{16}	0.1333	0.001
1 molecules/s	2.232x10^{-18}	2.827x10^{-17}	1	3.769x10^{-18}	2.827x10^{-20}
1 Pa.L/s	0.5922	7.50	2.653x1017	1	7.5x10^{-3}
1 Torr.L/s	78.95	1,000	3.537x1019	1.333x10^2	1

(Note: 1sccm = 1.0916 atm.cc/min at 25° C)

Leak Rate Units

Leak Rate	atm.cc/s	Pa.m³/s	Torr.L/s	mbar.L/s	micron.L/s
1 atm.cc/s	1	0.1013	0.76	1.013	7.6x10^2
1 Pa.m3/s	9.869	1	7.50	10	7.50x10^3
1 Torr.L/s	1.316	0.1333	1	1.333	1000
1 mbar.L/s	0.9869	0.1	0.75	1	7.50x10^2
1 micron.L/s	1.316x10^{-3}	1.333x10^{-4}	0.001	1.333x10^{-3}	1

Outgassing Rate Units

Outgas Rate	mbar.L/(cm².s)	Pa.L/(m² .s)	Pa.m³/(m².s)	W/m²	Torr.L/(cm².s)
1 mbar.L/(cm².s)	1	1x10^6	1x10^3	1x10^3	0.75
1 Pa.L/(m² .s)	1x10^{-6}	1	1x10^{-3}	1x10^{-3}	7.5x10^{-7}
1 Pa.m³/(m².s)	1x10^{-3}	1x10^3	1	1	7.50x10^{-4}
1 W/m²	1x10^{-3}	1x10^3	1	1	7.50x10^{-4}
1 Torr.L/(cm².s)	1.333	1.333x10^6	1.333x10^3	1.333x10^3	1

Weights & Measures

To Convert	Into	Multiply By
ampere-turn	gilbert	1.257
ampere-turn/cm	ampere-turn/in	2.54
ampere-turn/in	gilbert/cm	0.495
ampere-turn/in	ampere-turn/cm	0.3937
ampere/cm^2	ampere/in^2	6.452
angstrom	microinch	0.00393
angstrom	millimicron	0.1
angstrom	cm	10^{-8}
angstrom	nanometer	0.1
angstrom	micron	10^{-4}
b/mil ft	grams/cm^3	2.306x10^{-6}
Btu	joule	1054
Btu	kilowatt-hour	2.929x10^{-4}
Btu	ft-lb	777.6
Btu/minute	watt	17.57
calorie (kg)	joule	4184
calorie (kg)	Btu	3.968
calorie (kg)	horsepower hr	1.558x10^{-3}
calorie (kg)	ft-lb	3086
calories (kg)	kilowatt-hour	1.162x10^{-3}
circular mil	cm^2	5.067x10^{-6}
circular mil	in^2	7.854x10^{-7}
circular mil sq	mil	0.7854
cm	mil	393.7
cm	inch	0.3937
cm	angstrom	10^{8}
cm^2	ft^2	1.076x10^{-3}
cm^2	circular mil	1.974x10^{5}
cm^2	in^2	0.155
cm^3	gallon	2.642x10^{-4}
cm^3	in^3	6.102x10^{-2}
cm^3	quarts (liquid)	1.057x10^{-3}
cm^3	liter	10^{-3}
cm^3	ft^3	3.531x10^{-5}
cm^3	pints (liquid)	2.113x10^{-3}
coulombs/in^2	coulombs/cm^2	0.155
degree (angle)	minute	60
degree (angle)	second	3600
degree (angle)	radian	0.01745
degree/sec	radian/sec	0.01745
degree/sec	revolution/sec	0.002778
degree/sec	rpm	0.1667
dyne	pound	2.248x10^{-6}
dyne	gram	1.020x10^{-3}
dynes/cm^2	bar	10^{-6}
erg	dyne-cm	1
erg	kg-meter	1.020x10^{-8}
erg	gram-cm	1.020x10^{-3}
erg	ft-lb	7.376x10^{-8}
erg	kg-calorie	2.390x10^{-11}
erg	joule	10^{-7}
erg	Btu	9.486x10^{-11}
ergs/sec	Btu/min	5.691x10^{-9}
ergs/sec	kilowatt	10^{-10}
ergs/sec	ft-lb/min	4.42x10^{-6}
feet	cm	30.48
feet	meter	0.3048
ft-lb	meter-kilogram	0.1383
ft-lb	cm-gram	13.826
ft-lb	cm-dyne	1.356x10^{7}

To Convert	Into	Multiply By
ft^2	in^2	144
ft^2	m^2	0.0929
ft^2	cm^2	929
ft^3	lb. water	62.4
ft^3	liter	28.32
ft^3	pint (liquid)	59.84
ft^3	cm^3	2.832x10^{4}
ft^3	in^3	1728
ft^3	m^3	0.02832
ft^3	quart (liquid)	29.92
ft^3	gallon	7.481
ft^3	yd^3	0.03704
ft^3/min	gallon/sec	0.1247
ft^3/min	cm^3/sec	471.9
ft^3/min	liter/sec	0.4719
gallon	quart (liquid)	4
gallon	liter	3.785
gallon	cm^3	3785
gallon	pint (liquid)	8
gallon	ft^3	0.1337
gallon	lb. water	8.34
gallon	in^3	231
gallon	m^3	3.785x10^{-3}
gallon/min	liter/sec	0.064
gallon/min	ft^3/sec	2.228x10^{-3}
gauss	lines/in^2	6.452
gilbert	ampere-turn	0.7958
gram	oz	0.03527
gram	dyne	980.7
gram	lb	2.205x10^{-3}
gram-calorie	Btu	3.968x10^{-3}
gram-cm	kg-meter	10^{-5}
gram-cm	joule	9.807x10^{-5}
gram-cm	ft-lb	7.233x10^{-5}
gram-cm	erg	980.7
gram-cm	Btu	9.302x10^{-8}
gram-cm	kg-calorie	2.344x10^{-8}
gram/cm	lb/in	5.6x10^{-3}
gram/cm^3	lb/circular mil ft	3.405x10^{-7}
gram/cm^3	lb/in^3	0.03613
gram/cm^3	lb/ft^3	62.43
horsepower	horsepower(metric)	1.014
horsepower	watt	745.7
in^2	ft^2	6.944x10^{-3}
in^2	cm^2	6.452
in^2	sq mil	10^{6}
in^2	mm^2	645.2
in^2	circular mil	1.273x10^{6}
in^3	pint (liquid)	0.0346322
in^3	quart (liquid)	0.01732
in^3	liter	1.639x10^{-2}
in^3	gallon	4.329x10^{-3}
in^3	m^3	1.639x10^{-5}
in^3	ft^3	5.787x10^{-4}
in^3	cm^3	16.39
inch	angstrom	2.54x10^{8}
inch	cm	2.54
joule	watt-hour	2.778x10^{-4}
joule	kg-meter	0.102
joule	kg-calorie	2.390x10^{-4}

To Convert	Into	Multiply By
joule	ft-lb	0.7377
joule	erg	10^{7}
joule	Btu	9.486x10^{-4}
kilogram	tons (short)	1.102x10^{-3}
kilogram	lb	2.2046
kilogram (force)	dyne	980665
kilogram-meter	kilowatt-hour	2.724x10^{-6}
kiloline	maxwell	10^{3}
kilometer	mile	0.6214
kilometer	feet	3281
kilowatt	ft-lb/sec	737.6
kilowatt	ft-lb/min	4.425x10^{4}
kilowatt	Btu/minute	56.92
kilowatt-hour	kilogram-meter	3.671x10^{5}
kilowatt-hour	joule	3.6x10^{6}
kilowatt-hour	ft-lb	2.655x10^{6}
kilowatt-hour	Btu	3415
km/hour	m/min	16.67
km/hour	mile/hour	0.6214
km/hour	ft/sec	0.9113
km/hour	ft/min	54.68
km/hour	cm/sec	27.78
km^2	ft^2	1.076x10^{7}
lb water	gallon	0.1198
lb water	in^3	27.68
lb water	ft^3	0.01602
lb water/min	ft^3/sec	2.669x10^{-4}
lb/ft	kg/meter	1.488
lb/ft^2	kg/m^2	4.882
lb/ft^2	ft. water	0.01602
lb/ft^2	lb/in^2	6.944x10^{-3}
lb/in	grams/cm	178.6
lb/in^2	lb/ft^2	144
lb/in^2	kg/m^2	703.1
lb/in^2	in. Hg	2.036
lb/in^2	ft. water	2.307
lb/in^2	atmosphere	0.06804
lines/cm^2	gauss	1
lines/in^2	gauss	0.155
liter	quart (liquid)	1.057
liter	pint (liquid)	2.113
liter	gallon	0.2642
liter	in^3	61.02
liter	ft^3	0.03531
liter/min	gallon/sec	4.403x10^{-3}
liter/min	ft^3/sec	5.885x10^{-4}
lumen/ft^2	foot-candle	1
m/min	miles/hour	0.03728
m/min	km/hour	0.06
m/min	ft/sec	0.05468
m/sec	miles/min	0.03728
m/sec	km/min	0.06
m/sec	km/hr	3.6
m/sec	ft/sec	3.281
m/sec	ft/min	196.8
m/sec	miles/hour	2.237
m^2	sq mile	3.861x10^{-7}
m^2	ft^2	10.764
m^3	quarts (liquid)	1057
m^3	pints (liquid)	2113

Weights & Measures

To Convert	Into	Multiply By
m^3	gallon	264.2
m^3	in^3	61024
m^3	ft^3	35.31
m^3	cm^3	10^6
maxwell	kiloline	36802
megaline	maxwell	10^6
meter	inch	39.37
meter	feet	3.2808
meter	angstrom	10^{10}
mhos/mil ft	megmhos/in^3	15.28
mhos/mil ft	megmhos/cm^3	6.015
microhm/cm^3 ohms/mil	ft	6.015
microhm/cm^3	microhms/in^3	0.3937
microhm/in^3	microhm/cm^3	2.54
microinch	angstrom	254
micromicron	angstrom	0.01
micron	angstrom	10000
mil	inch	36802
mil	cm	0.0025
milliliter	cm^3	1
millimeter	mil	39.37
millimeter	micron	1000
millimeter	inch	0.03937
millimeter	angstrom	10^7
millimicron	angstrom	10
minute	seconds (angle)	60
minutes (angle)	radian	$2.909 x 10^{-4}$
mm^2	in^2	$1.55 x 10^{-3}$
mm^2	cm^2	0.01
mm^2 circular	mil	$1.974 x 10^3$
nanometer	micron	10^{-3}
ohms/mil ft	microhm/in^3	0.06524
ohms/mil ft	microhm/cm^3	0.1662
ounces (fluid)	liter	0.02957

To Convert	Into	Multiply By
radians/sec	revolutions/sec	0.1592
radians/sec	rpm	9.549
revolution	radian	6.283
revolution	quadrant	4
revolution	degree	360
revolutions/sec	rpm	60
revolutions/sec	radians/sec	6.283
revolutions/sec	degrees/sec	360
rpm	revolutions/sec	0.01667
rpm	radians/sec	0.1047
rpm	degrees/sec	6
seconds (angle)	radian	$4.848 x 10^{-6}$
spheres (solid angle)	steradian	12.57
spherical rt. angle	steradian	1.571
spherical rt. angle	sphere	0.125
spherical rt. angle	hemisphere	0.25
steradian	sphere	0.07958
steradian	hemisphere	0.1592
stere	liter	10^3
tons (short)	lb	2000
tons (short)	kg	907.2
tons (metric)	lb	2205
tons (metric)	kg	10^3
tons (long)	lb	2240
tons (long)	kg	1016
watt	kilowatt	36802
watt	ft-lb/sec	0.7376
watt	ft-lb/min	44.25
watt	ergs/sec	10^7
watt	Btu/min	0.05692
watt-hour	kilogram-meter	367.1
watt-hour	ft-lb	2655
watt-hour	Btu	3.414
weber	maxwell	10^8

MATERIAL DEPOSITION

Key to Symbols: * influenced by composition; ** Cr-plated rod or strip; ***all metals alumina coated; **C** = carbon; **Gr** = graphite; **Q** = quartz; **Incl** = Inconel; **VC** = vitreous carbon; **SS** = stainless steel; **Ex** = excellent; **G** = good; **F** = fair; **P** = poor; **S** = sublimes; **D** = decomposes; **RF** = RF sputtering is effective; **RF-R** = reactive RF sputter is effective; **DC** = DC sputtering is effective; **DC-R** = reactive DC sputtering is effective

					Temp. (° C) for Given Vap. Press. (Torr)			Evaporation Techniques						
									Thermal Sources					
Material	Symbol	MP (° C)	S/D	g/cm³	10^{-8}	10^{-6}	10^{-4}	E-Beam	Boat	Coil	Basket	Crucible	Sputter	Comments
Aluminum	Al	660	—	2.70	677	821	1,010	Ex	—	—	W	TiB_2-BN, ZrB_2, BN	DC	Alloys W/Ta/Mo. Flash evap or use BN crucible
Aluminum Antimonide	AlSb	1,080	—	4.3	—	—	—	—	—	—	—	—	RF	—
Aluminum Arsenide	AlAs	1,600	—	3.7	—	—	~ 1,300	—	—	—	—	—	RF	—
Aluminum Bromide	$AlBr_3$	97	—	2.64	—	—	~ 50	—	Mo	—	—	Gr	—	—
Aluminum Carbide	Al_4C_3	~1,400	D	2.36	—	—	~ 800	F	—	—	—	—	RF	n 2.7
Aluminum, 2% Copper	Al2%Cu	640	—	2.82	—	—	—	—	—	—	—	—	DC	Wire feed & flash. Co-evap difficult
Aluminum Fluoride	AlF_3	1,291	S	2.88	410	490	700	P	Mo, W, Ta	—	—	Gr	RF	—
Aluminum Nitride	AlN	>2,200	S	3.26	—	—	~1,750	F	—	—	—	—	RF-R	Decomposes. R-evap Al in 10^{-3} T N_2 with glow discharge.
Aluminum Oxide	Al_2O_3	2,072	—	3.97	—	—	1,550	Ex	W	—	W	—	RF-R	Forms smooth, hard films. n 1.66
Aluminum Phosphide	AlP	2,000	—	2.42	—	—	—	—	—	—	—	—	RF	—
Aluminum, 2% Silicon	Al2%Si	640	—	2.69	—	—	1,010	—	—	—	—	TiB2-BN	RF, DC	Wire feed & flash. Co-evap difficult
Antimony	Sb	630	S	6.68	279	345	425	P	Mo*** Ta***	Mo, Ta	Mo, Ta	BN, C, Al_2O_3	RF, DC	Sublimes rapidly at low temp
Antimony Oxide	Sb_2O_3	656	S	5.2	—	—	~300	G	Pt	—	Pt	BN, Al_2O_3	RF-R	Decomposes on W. n 2.09, 2.18, 2.35
Antimony Selenide	Sb_2Se_3	611	—	—	—	—	—	—	Ta	—	—	C	RF	Composition variable
Antimony Sulfide	Sb_2S_3	550	—	4.64	—	—	~200	G	Mo, Ta	—	Mo, Ta	Al_2O_3	—	No decomposition. n 3.19, 4.06, 4.3
Antimony Telluride	Sb_2Te_3	629	—	6.50	—	—	600	—	—	—	—	C	RF	Decomposes over 750° C
Arsenic	As	817	S	5.73	107	150	210	P	C	—	—	Al_2O_3, BeO, VC	—	Dedicated vacuum system. Sublimes rapidly at low temp.
Arsenic Oxide	As_2O_3	312	—	3.74	—	—	—	—	—	—	—	—	—	—
Arsenic Selenide	As_2Se_3	~360	—	4.75	—	—	—	—	—	—	—	Al_2O_3, Q	RF	—
Arsenic Sulfide	As_2S_3	300	—	3.43	—	—	~400	F	Mo	—	—	Al_2O_3, Q	RF	n 2.4, 2.81, 3.02
Arsenic Telluride	As_2Te_3	362	—	—	—	—	—	—	—	—	—	—	—	Flash. See JVST. 1973; 10:748
Barium	Ba	725	—	3.51	545	627	735	F	W, Ta, Mo	W	W	Metals	RF	Wets without alloying; reacts with ceramics
Barium Chloride	$BaCl_2$	963	—	3.92	—	—	~650	—	Ta, Mo	—	—	—	RF	Preheat gently to outgas. n 1.73
Barium Fluoride	BaF_2	1,355	S	4.89	—	—	~700	G	Mo	—	—	—	RF	n 1.47
Barium Oxide	BaO	1,918	—	5.72	—	—	~1,300	P	Pt	—	Pt	Al_2O_3	RF, RF-R	Decomposes slightly. n 1.98
Barium Sulfide	BaS	1,200	—	4.25	—	—	1,100	—	Mo	—	—	—	RF	n 2.16
Barium Titanate	$BaTiO_3$	—	D	6.02	—	—	—	—	—	—	—	—	RF	Gives Ba. Co-evap OK. Sputter OK. n 2.40
Beryllium	Be	1,278	—	1.85	710	878	1,000	Ex	W, Ta	W	W	BeO, C, VC	DC	Wets W/Ta/Mo. Evaporates easily
Beryllium Carbide	Be_2C	>2,100	D	1.90	—	—	—	—	—	—	—	—	—	—
Beryllium Chloride	$BeCl_2$	405	—	1.90	—	—	~150	—	—	—	—	—	RF	—
Beryllium Fluoride	BeF_2	800	S	1.99	—	—	~200	G	—	—	—	—	—	n <1.33
Beryllium Oxide	BeO	2,530	—	3.01	—	—	1,900	G	—	—	W	—	RF, RF-R	No decomposition from E-beam. n 1.72
Bismuth	Bi	271	—	9.80	330	410	520	Ex	W, Mo, Ta	W	W	Al_2O_3, VC	DC	Resistivity high.
Bismuth Fluoride	BiF_3	727	S	5.32	—	—	~300	—	—	—	—	Gr	RF	n 1.74
Bismuth Oxide	Bi_2O_3	860	—	8.55	—	—	~1,400	P	Pt	—	Pt	—	RF, RF-R	n 1.91
Bismuth Selenide	Bi_2Se_3	710	D	6.82	—	—	~650	G	—	—	—	Gr, Q	RF	Co-evap OK. Sputter OK
Bismuth Sulfide	Bi_2S_3	685	D	7.39	—	—	—	—	—	—	—	—	RF	n 1.34, 1.46
Bismuth Telluride	Bi_2Te_3	573	—	7.7	—	—	~600	—	W, Mo	—	—	Gr, Q	RF	Co-evap OK. Sputter OK
Bismuth Titanate	$Bi_2Ti_2O_7$	—	D	—	—	—	—	—	—	—	—	—	RF	Sputter OK. R-co-evap in 10^{-2} T O_2
Boron	B	2,079	—	2.34	1,278	1,548	1,797	Ex	C	—	—	C, VC	RF	Forms carbide with container
Boron Carbide	B_4C	2,350	—	2.52	2,500	2,580	2,650	Ex	—	—	—	—	RF	—
Boron Nitride	BN	~3,000	S	2.25	—	—	~1,600	P	—	—	—	—	RF, RF-R	Decomposes. R-sputter preferred
Boron Oxide	B_2O_3	~450	—	1.81	—	—	~1,400	G	Pt, Mo	—	—	—	—	n 1.48
Boron Sulfide	B_2S_3	310	—	1.55	—	—	800	—	—	—	—	Gr	RF	—
Cadmium	Cd	321	—	8.64	64	120	180	P	W, Mo, Ta	—	W, Mo, Ta	Al_2O_3, Q	RF, DC	Dedicated vacuum system. High VP. Low sticking coeff
Cadmium Antimonide	Cd_3Sb_2	456	—	6.92	—	—	—	—	—	—	—	—	—	—
Cadmium Arsenide	Cd_3As_2	721	—	6.21	—	—	—	—	—	—	—	Q	RF	—
Cadmium Bromide	$CdBr_2$	567	—	5.19	—	—	~300	—	—	—	—	—	—	—
Cadmium Chloride	$CdCl_2$	568	—	4.05	—	—	~400	—	—	—	—	—	—	—
Cadmium Fluoride	CdF_2	1,100	—	6.64	—	—	~500	—	—	—	—	—	RF	n 1.56
Cadmium Iodide	CdI_2	387	—	5.67	—	—	~250	—	—	—	—	—	—	—
Cadmium Oxide	CdO	>1,500	D	6.95	—	—	~530	—	—	—	—	—	RF-R	Decomposes. n 2.49
Cadmium Selenide	CdSe	>1,350	S	5.81	—	—	540	G	Mo, Ta	—	—	Al_2O_3, Q	RF	Evaporates easily. n 2.4
Cadmium Sulfide	CdS	1,750	S	4.82	—	—	550	F	W, Mo, Ta	—	W	Al_2O_3, Q	RF	Substrate temp. affects sticking coeff Composition varies. n 2.51, 2.53

					Temp. (° C) for Given Vap. Press. (Torr)			Evaporation Techniques	Thermal Sources					
Material	Symbol	MP (° C)	S/D	g/cm^3	10^{-8}	10^{-6}	10^{-4}	E-Beam	Boat	Coil	Basket	Crucible	Sputter	Comments
Cadmium Telluride	CdTe	1,121	—	5.85	—	—	450	—	W, Mo, Ta	W	W, Ta, Mo	—	RF	Substrate temp. affects composition. n~2.6
Calcium	Ca	839	S	1.54	272	357	459	P	W	W	W	Al_2O_3, Q	—	Film reacts in air.
Calcium Fluoride	CaF_2	1,423	—	3.18	—	—	~1,100	—	W, Mo, Ta	—	W, Mo, Ta	Q	RF	Rate control important. Preheat gently to outgas. n 1.43
Calcium Oxide	CaO	2,614	—	~3.3	—	—	~1,700	—	W, Mo	—	—	ZrO_2	RF-R	Forms volatile oxides with W/Mo. n 1.84
Calcium Silicate	$CaSiO_3$	1,540	—	2.91	—	—	—	G	—	—	—	Q	RF	n 1.61, 1.66
Calcium Sulfide	CaS	—	D	2.5	—	—	1,100	—	Mo	—	—	—	RF	Decomposes. n 2.14
Calcium Titanate	$CaTiO_3$	1,975	—	4.10	1,490	1,600	1,690	P	—	—	—	—	RF	Decomposes in evap. Sputter OK. n 2.34
Calcium Tungstate	$CaWO_4$	—	—	6.06	—	—	—	G	W	—	—	—	RF	n 1.92
Carbon	C	~3,652	S	1.8–2.1	1,657	1,867	2,137	Ex	—	—	—	—	PDC	E-beam or Arc evap. Poor film adhesion.
Cerium	Ce	798	—	~6.70	970	1,150	1,380	G	W, Ta	W	W, Ta	Al_2O_3, BeO, VC	DC, RF	—
Cerium Fluoride	CeF_3	1,460	—	6.16	—	—	~900	G	W, Mo, Ta	—	Mo, Ta	—	RF	Preheat gently to outgas. n ~ 1.7
Cerium (III) Oxide	Ce_2O_3	1,692	—	6.86	—	—	—	F	W	—	—	—	—	Alloys. Use thick W boat. n 1.95
Cerium (IV) Oxide	CeO_2	~2,600	—	7.13	1,890	2,000	2,310	G	W	—	—	—	RF, RF-R	Little decomposition.
Cesium	Cs	28	—	1.88	-16	22	80	—	SS	—	—	Q	—	—
Cesium Bromide	CsBr	636	—	3.04	—	—	~400	—	W	—	—	—	RF	n 1.70
Cesium Chloride	CsCl	645	—	3.99	—	—	~500	—	W	—	—	—	RF	n 1.64
Cesium Fluoride	CsF	682	—	4.12	—	—	~500	—	W	—	—	—	RF	n 1.48
Cesium Hydroxide	CsOH	272	—	3.68	—	—	550	—	Pt	—	—	—	—	—
Cesium Iodide	CsI	626	—	4.51	—	—	~500	—	W	—	—	Pt, Q	RF	n 1.79
Chiolote	$Na_5Al_3F_{14}$	—	—	2.9	—	—	~800	—	Mo, W	—	—	—	RF	n 1.33
Chromium	Cr	1,857	S	7.20	837	977	1,157	G	**	W	W	VC	DC	Films very adherent. High rates possible.
Chromium Boride	CrB	2,760(?)	—	6.17	—	—	—	—	—	—	—	—	RF	—
Chromium Bromide	$CrBr_2$	842	—	4.36	—	—	550	—	Incl	—	—	—	RF	—
Chromium Carbide	Cr_3C_2	1,980	—	6.68	—	—	~2,000	F	W	—	—	—	RF	—
Chromium Chloride	$CrCl_2$	824	—	2.88	—	—	550	—	Fe, Incl	—	—	—	RF	—
Chromium Oxide	Cr_2O_3	2,266	—	5.21	—	—	~2,000	G	W, Mo	—	W	—	RF, RF-R	Loses O_2, reoxidizes at 600° C in air. n 2.55
Chromium Silicide	$CrSi_2$	1,490	—	5.5	—	—	—	—	—	—	—	—	RF	—
Chromium-Silicon Monoxide	Cr-SiO	—	S	*	*	*	*	G	W	—	W	—	RF	Flash evap
Cobalt*	Co	1,495	—	8.9	850	990	1,200	Ex	W, Nb	—	W	Al_2O_3, BeO	DC	Alloys with W/Ta/Mo
Cobalt Bromide	$CoBr_2$	678	D	4.91	—	—	400	—	Incl	—	—	—	RF	—
Cobalt Chloride	$CoCl_2$	724	D	3.36	—	—	472	—	Incl	—	—	—	RF	—
Cobalt Oxide	CoO	1,795	—	6.45	—	—	—	—	—	—	—	—	DC-R, RF-R	Sputter preferred.
Copper	Cu	1,083	—	8.92	727	857	1,017	Ex	Mo	W	W	Al_2O_3, Mo, Ta	DC	Adhesion poor. Use interlayer (Cr). Evap OK.
Copper Chloride	CuCl	430	—	4.14	—	—	~600	—	—	—	—	—	RF	n 1.93
Copper Oxide	Cu_2O	1,235	S	6.0	—	—	~600	G	Ta	—	—	Al_2O_3	DC-R, RF-R	n 2.71
Copper Sulfide	Cu_2S	1,100	—	5.6	—	—	—	—	—	—	—	—	—	—
Cryolite	Na_3AlF_6	1,000	—	2.9	1,020	1,260	1,480	Ex	W, Mo, Ta	—	W, Mo, Ta	VC	RF	Large chunks reduce spitting Little decomposition
Dysprosium	Dy	1,412	—	8.55	625	750	900	G	Ta	—	—	—	DC	—
Dysprosium Fluoride	DyF_3	1,360	S	—	—	—	~800	G	Ta	—	—	—	RF	—
Dysprosium Oxide	Dy_2O_3	2,340	—	7.81	—	—	~1,400	—	Ir	—	—	—	RF, RF-R	Loses O_2.
Erbium	Er	1,529	S	9.07	650	775	930	G	W, Ta	—	—	—	DC	—
Erbium Fluoride	ErF_3	1,350	—	—	—	—	~750	—	Mo	—	—	—	RF	See JVST. 1985; A3(6):2320.
Erbium Oxide	Er_2O_3	—	—	8.64	—	—	~1,600	—	Ir	—	—	—	RF, RF-R	Loses O_2.
Europium	Eu	822	S	5.24	280	360	480	F	W, Ta	—	—	Al_2O_3	DC	Low Ta solubility
Europium Fluoride	EuF_2	1,380	—	6.50	—	—	~950	—	Mo	—	—	—	RF	—
Europium Oxide	Eu_2O_3	—	—	7.42	—	—	~1,600	G	Ir, Ta, W	—	—	ThO_2	RF, RF-R	Loses O_2. Films clear and hard.
Europium Sulfide	EuS	—	—	5.75	—	—	-	G	—	—	—	—	RF	—

Material	Symbol	MP (° C)	S/D	g/cm³	Temp. (° C) for Given Vap. Press. (Torr)			Evaporation Techniques					Sputter	Comments
									Thermal Sources					
					10^{-8}	10^{-6}	10^{-4}	E-Beam	Boat	Coil	Basket	Crucible		
Gadolinium*	Gd	1,313	—	7.90	760	900	1,175	Ex	Ta	—	—	Al_2O_3	DC	High Ta solubility
Gadolinium Carbide	GdC_2	—	—	—	—	—	1,500	—	—	—	—	C	RF	Decomposes under sputtering
Gadolinium Oxide	Gd_2O_3	2,330	—	7.41	—	—	—	F	Ir	—	—	—	RF, RF-R	Loses O_2.
Gallium	Ga	30	—	5.90	619	742	907	G	—	—	—	Al_2O_3, BeO, Q	—	Alloys with W/Ta/Mo. E-beam OK.
Gallium Antimonide	GaSb	710	—	5.6	—	—	—	F	W, Ta	—	—	—	RF	Flash evap
Gallium Arsenide	GaAs	1,238	—	5.3	—	—	—	G	W, Ta	—	—	C	RF	Flash evap
Gallium Nitride	GaN	800	S	6.1	—	—	~200	—	—	—	—	Al_2O_3	RF, RF-R	R-evap Ga in 10^{-3} T N_2
Gallium Oxide	Ga_2O_3	1,900	—	6.44	—	—	—	—	Pt, W	—	—	—	RF	Loses O_2. n 1.92
Gallium Phosphide	GaP	1,540	—	4.1	—	770	920	—	W, Ta	—	W	Q	RF	No decomposition. Rate control important.
Germanium	Ge	937	—	5.35	812	957	1,167	Ex	W, C, Ta	—	—	Q, Al_2O_3	DC	E-beam film excellent
Germanium Nitride	Ge_3N_2	450	S	5.2	—	—	~650	—	—	—	—	—	RF-R	Sputter preferred
Germanium (II) Oxide	GeO	710	S	—	—	—	500	—	—	—	—	Q	RF	n 1.61
Germanium (III) Oxide	GeO_2	1,086	—	6.24	—	—	~625	G	Ta, Mo	—	W, Mo	Q, Al_2O_3	RF-R	Loses O_2; Film mostly GeO
Germanium Telluride	GeTe	725	—	6.20	—	—	381	—	W, Mo	—	W	Q, Al_2O_3	RF	
Glass, Schott® 8329	—	—	—	2.20	—	—	—	Ex	—	—	—	—	RF	Melt in air before evaporating.
Gold	Au	1,064	—	19.32	807	947	1,132	Ex	W***Mo***W	—	—	Al_2O_3, BN, VC, W	DC	Films soft; Adhesion poor. Use Cr interlayer
Hafnium	Hf	2,227	—	13.31	2,160	2,250	3,090	G	—	—	—	—	DC	—
Hafnium Boride	HfB_2	3,250	—	10.5	—	—	—	—	—	—	—	—	DC, RF	—
Hafnium Carbide	HfC	~3,890	S	12.20	—	—	~2,600	—	—	—	—	—	RF	—
Hafnium Nitride	HfN	3,305	—	—	—	—	—	—	—	—	—	—	RF, RF-R	—
Hafnium Oxide	HfO_2	2,758	—	9.68	—	—	~2,500	F	W	—	—	—	RF, RF-R	Loses O_2. Film HfO
Hafnium Silicide	$HfSi_2$	1,750	—	7.2	—	—	—	—	—	—	—	—	RF	—
Holmium	Ho	1,474	—	8.80	650	770	950	G	W, Ta	W	W	—	—	—
Holmium Fluoride	HoF_3	1,143	—	—	—	—	~800	—	—	—	—	Q	DC, RF	—
Holmium Oxide	Ho_2O_3	2,370	—	8.41	—	—	—	—	Ir	—	—	—	RF, RF-R	Loses O_2
Inconel	Ni/Cr/Fe	1,425	—	8.5	—	—	—	G	W	W	W	—	DC	Fine wire wrapped on W Low rate for smooth films
Indium	In	157	—	7.30	487	597	742	Ex	W, Mo	—	W	Gr, Al_2O_3	DC	Wets W and Cu. Mo liner OK.
Indium Antimonide	InSb	535	—	5.8	—	—	—	—	W	—	—	—	RF	Decomposes. Sputter preferred; Co-evap OK.
Indium Arsenide	InAs	943	—	5.7	780	870	970	—	W	—	—	—	RF	—
Indium Nitride	InN	1,200	—	7.0	—	—	—	—	—	—	—	—	—	—
Indium (I) Oxide	In_2O	~600	S	6.99	—	—	650	—	—	—	—	—	RF	Decomposes under sputtering
Indium (III) Oxide	In_2O_3	850	—	7.18	—	—	~1,200	G	W, Pt	—	—	Al_2O_3	—	—
Indium Phosphide	InP	1,070	—	4.8	—	630	730	—	W, Ta	—	W, Ta	Gr	RF	Films are P rich
Indium Selenide	In_2Se_3	890	—	5.67	—	—	—	—	—	—	—	—	RF	Sputter preferred; Co-evap OK. Flash evap
Indium (I) Sulfide	In_2S	653	—	5.87	—	—	650	—	—	—	—	Gr	RF	—
Indium (II) Sulfide	InS	692	S	5.18	—	—	650	—	—	—	—	Gr	RF	—
Indium (III) Sulfide	In_2S_3	1,050	S	4.90	—	—	850	—	—	—	—	Gr	RF	Decomposes. Film In_2S
Indium (II) Telluride	InTe	696	—	6.29	—	—	—	—	—	—	—	—	—	—
Indium (III) Telluride	In_2Te_3	667	—	5.78	—	—	—	—	—	—	—	—	RF, DC-R	Sputter preferred; Co-evap OK. Flash evap
Indium Tin Oxide	In_2O_3–SnO_2	1,800	S	—	—	—	—	—	—	—	—	—	—	—
Iridium	Ir	2,410	—	22.42	1,850	2,080	2,380	F	—	—	—	ThO_2	DC	—
Iron*	Fe	1,535	—	7.86	858	998	1,180	Ex	W	W	W	Al_2O_3, BeO	DC	Attacks W. Films hard, smooth. Preheat gently to outgas.
Iron Bromide	$FeBr_2$	684	D	4.64	—	—	561	—	—	—	—	Fe	RF	—
Iron Chloride	$FeCl_2$	670	S	3.16	—	—	300	—	—	—	—	Fe	RF	n 1.57
Iron Iodide	FeI_2	—	—	5.32	—	—	400	—	—	—	—	Fe	RF	—
Iron (II) Oxide	FeO	1,369	—	5.7	—	—	—	P	—	—	—	—	RF, RF-R	Decomposes; sputter preferred. n 2.32
Iron (III) Oxide	Fe_2O_3	1,565	—	5.24	—	—	—	G	W	—	W	—	—	Decomposes to Fe_3O_4 at 1,530° C. n 3.01
Iron Sulfide	FeS	1,193	D	4.74	—	—	—	—	—	—	—	Al_2O_3	RF	Decomposes

Material	Symbol	MP (° C)	S/D	g/cm³	Temp. (° C) for Given Vap. Press. (Torr) 10^{-8}	10^{-6}	10^{-4}	Evaporation Techniques E-Beam	Thermal Sources Boat	Coil	Basket	Crucible	Sputter	Comments
Kanthal	FeCrAl	—	—	7.1	—	—	—	—	W	W	W	—	DC	—
Lanthanum	La	921	—	6.15	990	1,212	1,388	Ex	W, Ta	—	—	Al_2O_3	RF	Films react in air
Lanthanum Boride	LaB_6	2,210	D	2.61	—	—	—	G	—	—	—	—	RF	—
Lanthanum Bromide	$LaBr_3$	783	—	5.06	—	—	—	—	—	—	Ta	—	RF	Films hygroscopic. n 1.94
Lanthanum Fluoride	LaF_3	1,490	S	~6.0	—	—	900	G	Ta, Mo	—	Ta	—	RF	No decomposition. n ~1.6
Lanthanum Oxide	La_2O_3	2,307	—	6.51	—	—	1,400	G	W, Ta	—	—	—	RF	Loses O_2. n~1.73
Lead	Pb	328	—	11.34	342	427	497	Ex	W, Mo	W	W, Ta	Al_2O_3, Q	DC	—
Lead Bromide	$PbBr_2$	373	—	6.66	—	—	~300	—	—	—	—	—	—	—
Lead Chloride	$PbCl_2$	501	—	5.85	—	—	~325	—	Pt	—	—	Al_2O_3	RF	Little decomposition
Lead Fluoride	PbF_2	855	S	8.24	—	—	~400	—	W, Pt, Mo	—	—	BeO	RF	n 1.75
Lead Iodide	PbI_2	402	—	6.16	—	—	~500	—	Pt	—	—	Q	—	—
Lead Oxide	PbO	886	—	9.53	—	—	~550	—	Pt	—	—	Q, Al_2O_3	RF-R	No decomposition. n ~2.6
Lead Selenide	PbSe	1,065	S	8.10	—	—	~500	—	W, Mo	—	W	Gr, Al_2O_3	RF	—
Lead Stannate	$PbSnO_3$	1,115	—	8.1	670	780	905	P	Pt	—	Pt	Al_2O_3	RF	Decomposes
Lead Sulfide	PbS	1,114	S	7.5	—	—	500	—	W	—	W, Mo	Q, Al_2O_3	RF	Little decomposition. n 3.92
Lead Telluride	PbTe	917	—	8.16	780	910	1,050	—	Mo, Pt, Ta	—	—	Al_2O_3, Gr	RF	Film is Te rich. Sputter preferred; Co-evap OK.
Lead Titanate	$PbTiO_3$	—	—	7.52	—	—	—	—	Ta	—	—	—	RF	—
Lithium	Li	181	—	0.53	227	307	407	G	Ta, SS	—	—	Al_2O_3, BeO	—	Film reacts in air
Lithium Bromide	LiBr	550	—	3.46	—	—	~500	—	Ni	—	—	—	RF	n 1.78
Lithium Chloride	LiCl	605	—	2.07	—	—	400	—	Ni	—	—	—	RF	Preheat gently to outgas. n 1.66
Lithium Fluoride	LiF	845	—	2.64	875	1,020	1,180	G	Ni, Ta, Mo, W	—	—	Al_2O_3	RF	Optical films require rate control. Preheat gently to outgas. n 1.39
Lithium Iodide	LiI	449	—	4.08	—	—	400	—	Mo, W	—	—	—	RF	n 1.96
Lithium Oxide	Li_2O	>1,700	—	2.01	—	—	850	—	Pt, Ir	—	—	—	RF	n 1.64
Lutetium	Lu	1,663	—	9.84	—	—	1,300	Ex	Ta	—	—	Al_2O_3	RF, DC	—
Lutetium Oxide	Lu_2O_3	—	—	9.42	—	—	1,400	—	Ir	—	—	—	RF	Decomposes
Magnesium	Mg	649	S	1.74	185	247	327	G	W, Mo, Ta, Cb	W	W	Al_2O_3, VC	DC	Extremely high rates possible
Magnesium Aluminate	$MgAl_2O_4$	2,135	—	3.6	—	—	—	G	—	—	—	—	RF	(Natural spinel) n 1.72
Magnesium Bromide	$MgBr_2$	700	—	3.72	—	—	~450	—	Ni	—	—	—	RF	Decomposes
Magnesium Chloride	$MgCl_2$	714	—	2.32	—	—	400	—	Ni	—	—	—	RF	Decomposes . n 1.67
Magnesium Fluoride	MgF_2	1,261	—	2.9–3.2	—	—	1,000	Ex	Mo, Ta	—	—	Al_2O_3	RF	Substrate temp and rate control important. Reacts with W. Mo OK. n 1.38
Magnesium Iodide	MgI_2	<637	D	4.43	—	—	200	—	Ir	—	—	—	RF	—
Magnesium Oxide	MgO	2,852	—	3.58	—	—	1,300	G	—	—	—	C, Al_2O_3	RF, RF-R	R-Evap in 10^{-4} T O_2. W gives volatile oxides. n~1.7

Material	Symbol	MP (° C)	S/D	g/cm^3	Temp. (° C) for Given Vap. Press. (Torr)			Evaporation Techniques					Sputter	Comments
					10^{-8}	10^{-6}	10^{-4}	E-Beam	Thermal Sources: Boat	Coil	Basket	Crucible		
Manganese	Mn	1,244	S	7.20	507	572	647	G	W, Ta, Mo	W	W	Al_2O_3, BeO	DC	—
Manganese Bromide	$MnBr_2$	—	D	4.39	—	—	500	—	Incl	—	—	—	RF	—
Manganese Chloride	$MnCl_2$	650	—	2.98	—	—	450	—	Incl	—	—	—	RF	—
Manganese (III) Oxide	Mn_2O_3	1,080	—	4.50	—	—	—	—	—	—	—	—	—	—
Manganese (IV) Oxide	MnO_2	535	—	5.03	—	—	—	P	W	—	W	—	RF-R	Loses O_2 at 535° C
Manganese Sulfide	MnS	—	D	3.99	—	—	1,300	—	Mo	—	—	—	RF	Decomposes. n 2.70
Mercury	Hg	-39		13.55	-68	-42	-6	—	—	—	—	—	—	—
Mercury Sulfide	HgS	584	S	8.10	—	—	250	—	—	—	—	Al_2O_3	RF	Decomposes. n 2.85, 3.20
Molybdenum	Mo	2,617	—	10.2	1,592	1,822	2,117	Ex	—	—	—	—	DC	Films smooth, hard. Preheat gently to outgas.
Molybdenum Boride	MoB_2	2,100	—	7.12	—	—	—	P	—	—	—	—	RF	—
Molybdenum Carbide	Mo_2C	2,687	—	8.9	—	—	—	F	—	—	—	—	RF	Evaporation of $Mo(CO)_6$ yields Mo_2C.
Molybdenum Disulfide	MoS_2	1,185	—	4.80	—	—	~50	—	—	—	—	—	RF	—
Molybdenum Oxide	MoO_3	795	S	4.69	—	—	~900	—	Mo, Pt	—	Mo	Al_2O_3, BN	RF	Slight O_2 loss. n 1.9
Molybdenum Silicide	$MoSi_2$	2,050	—	6.31	—	—	—	—	W	—	—	—	RF	Decomposes
Neodymium	Nd	1,021	—	7.01	731	871	1,062	Ex	Ta	—	—	Al_2O_3	DC	Low W solubility
Neodymium Fluoride	NdF_3	1,410	—	6.5	—	—	~900	G	Mo, W	—	Mo, Ta	Al_2O_3	RF	Little decomposition. n 1.6
Neodymium Oxide	Nd_2O_3	~1,900	—	7.24	—	—	~1,400	G	Ta, W	—	—	ThO_2	RF, RF-R	Loses O_2; films clear. E-beam OK. n 1.79
Nichrome IV®	Ni/Cr	1,395	—	8.50	847	987	1,217	Ex	***	W	W, Ta	Al_2O_3, VC, BeO	DC	Alloys with W/Ta/Mo
Nickel®	Ni	1,453	—	8.90	927	1,072	1,262	Ex	W	W	W	Al_2O_3, BeO, VC	DC	Alloys with W/Ta/Mo. Smooth adherent films
Nickel Bromide	$NiBr_2$	963	S	5.10	—	—	362	—	Incl	—	—	—	RF	—
Nickel Chloride	$NiCl_2$	1,001	S	3.55	—	—	444	—	Incl	—	—	—	RF	—
Nickel Oxide	NiO	1,984	—	6.67	—	—	~1,470	—	—	—	—	Al_2O_3	RF-R	Decomposes on heating. n 2.18
Nimendium®	Ni3%Mn	1,425	—	8.8	—	—	—	—	—	—	—	—	DC	
Niobium	Nb	2,468	—	8.57	1,728	1,977	2,287	Ex	W	—	—	—	DC	Attacks W. n 1.80
Niobium Boride	NbB_2	2,900	—	6.97	—	—	—	—	—	—	—	—	RF	—
Niobium Carbide	NbC	3,500	—	7.6	—	—	—	F	—	—	—	—	RF	—
Niobium Nitride	NbN	2,573	—	8.4	—	—	—	—	—	—	—	—	RF, RF-R	R-evap Nb in 10^{-3} T N_2
Niobium (II) Oxide	NbO	—	—	7.30	—	—	1,100	—	Pt	—	—	—	RF	—
Niobium (III) Oxide	Nb_2O_3	1,780	—	7.5	—	—	—	—	W	—	W	—	RF, RF-R	—
Niobium (V) Oxide	Nb_2O_5	1,485	—	4.47	—	—	—	—	W	—	W	—	RF, RF-R	n 1.95
Niobium Telluride	NbTeX	—	—	7.6	—	—	—	—	—	—	—	—	RF	Composition variable
Niobium-Tin	Nb_3Sn	—	—	—	—	—	—	Ex	—	—	—	—	DC	Co-evap OK
Osmium	Os	3,045	—	22.48	2,170	2,430	2,760	F	—	—	—	—	DC	—
Osmium Oxide	OsO_2	—	D	—	—	—	—	—	—	—	—	—	—	—
Palladium	Pd	1,554	S	12.02	842	992	1,192	Ex	W	W	W	Al_2O_3, BeO	DC	Alloys W/Ta/Mo. Rapid evap suggested.
Palladium Oxide	PdO	870	—	9.70	—	—	575	—	—	—	—	Al_2O_3	RF-R	Decomposes
Parylene	C_8H_8	300–400	—	1.1	—	—	—	—	—	—	—	—	—	(Vapor-depositable plastic)
Permalloy®	Ni/Fe	1,395	—	8.7	947	1,047	1,307	G	W	—	—	Al_2O_3, VC	DC	Film low in Ni
Phosphorus	P	44.1	—	1.82	327	361	402	—	—	—	—	Al_2O_3	—	Film ignites in air. n 2.14
Phosphorus Nitride	P_3N_5	—	—	2.51	—	—	—	—	—	—	—	—	RF, RF-R	—
Platinum	Pt	1,772	—	21.45	1,292	1,492	1,747	Ex	W	W	W	C, ThO_2	DC	Alloys W/Ta/Mo. Films soft, poor adhesion.

Material	Symbol	MP (° C)	S/D	g/cm³	Temp. (° C) for Given Vap. Press. (Torr) 10^{-8}	10^{-6}	10^{-4}	Evaporation Techniques E-Beam	Thermal Sources Boat	Coil	Basket	Crucible	Sputter	Comments
Platinum Oxide	PtO_2	450	—	10.2	—	—	—	—	—	—	—	—	RF-R	—
Plutonium	Pu	641	—	19.84	—	—	—	—	W	—	—	—	—	—
Polonium	Po	254	—	9.4	117	170	244	—	—	—	—	Q	—	—
Potassium	K	63	—	0.86	23	60	125	—	Mo	—	—	Q	—	Film reacts in air. Preheat gently to outgas.
Potassium Bromide	KBr	734	—	2.75	—	—	~450	—	Ta, Mo	—	—	Q	RF	Preheat gently to outgas. n 1.559
Potassium Chloride	KCl	770	S	1.98	—	—	510	G	Ta, Ni	—	—	—	RF	Preheat gently to outgas. n 1.49
Potassium Fluoride	KF	858	—	2.48	—	—	~500	—	—	—	—	Q	RF	Preheat gently to outgas. n 1.363
Potassium Hydroxide	KOH	360	—	2.04	—	—	~400	—	Pt	—	—	—	—	Preheat gently to outgas
Potassium Iodide	KI	681	—	3.13	—	—	~500	—	Ta	—	—	—	RF	Preheat gently to outgas. n 1.677
Praseodymium	Pr	931	—	6.77	800	950	1,150	G	Ta	—	—	—	DC	—
Praseodymium Oxide	Pr_2O_3	—	D	7.07	—	—	1,400	G	Ir	—	—	ThO_2	RF, RF-R	Loses O_2
Radium	Ra	700	—	5 (?)	246	320	416	—	—	—	—	—	—	—
Rhenium	Re	3,180	—	20.53	1,928	2,207	2,571	P	—	—	—	—	DC	—
Rhenium Oxide	ReO_3	—	D	~7	—	—	—	—	—	—	—	—	RF	R-evap in 10^{-3} T O_2
Rhodium	Rh	1,966	—	12.4	1,277	1,472	1,707	G	W	W	W	ThO_2, VC	DC	E-beam OK
Rubidium	Rb	39	—	1.48	-3	37	111	—	—	—	—	Q	—	—
Rubidium Chloride	RbCl	718	—	2.09	—	—	~550	—	—	—	—	Q	RF	n 1.493
Rubidium Iodide	RbI	647	—	3.55	—	—	~400	—	—	—	—	Q	RF	n 1.647
Ruthenium	Ru	2,310	—	12.3	1,780	1,990	2,260	P	W	—	—	—	DC	—
Samarium	Sm	1,074	—	7.52	373	460	573	G	Ta	—	—	Al_2O_3	DC	—
Samarium Oxide	Sm_2O_3	2,350	—	8.35	—	—	—	G	Ir	—	—	ThO_2	RF, RF-R	Loses O_2. Films smooth, clear.
Samarium Sulfide	Sm_2S_3	1,900	—	5.73	—	—	—	G	—	—	—	—	—	—
Scandium	Sc	1,541	—	2.99	714	837	1,002	Ex	W	—	—	Al_2O_3, BeO	RF	Alloys with Ta.
Scandium Oxide	Sc_2O_3	2,300	—	3.86	—	—	~400	F	—	—	—	—	RF, RF-R	—
Selenium	Se	217	—	4.81	89	125	170	G	W, Mo	W, Mo	W, Mo	A_2O_3, VC	—	Dedicated vacuum system. High V.P.
Silicon	Si	1,410	—	2.32	992	1,147	1,337	F	W, Ta	—	—	BeO, Ta, VC	DC, RF	Alloys with W; use thick boat. E-beam OK
Silicon Boride	SiB_6	—	—	—	—	—	—	P	—	—	—	—	RF	—
Silicon Carbide	SiC	~2,700	S, D	3.22	—	—	1,000	—	—	—	—	—	RF	Sputter preferred. n 2.654, 2.697
Silicon Nitride	Si_3N_4	1,900	—	3.44	—	—	~800	—	—	—	—	—	RF, RF-R	—
Silicon (II) Oxide	SiO	>1,702	S	2.13	—	—	850	F	Ta	W	W	Ta	RF, RF-R	Use baffle box and low evap rate. n 1.6
Silicon (IV) Oxide	SiO_2	1,610	—	~2.65	*	*	1,025*	Ex	—	—	—	Al_2O_3	RF	Quartz excellent in E-beam. n 1.544, 1.553
Silicon Selenide	SiSe	—	—	—	—	—	550	—	—	—	—	Q	RF	—
Silicon Sulfide	SiS	940	S	1.85	—	—	450	—	—	—	—	Q	RF	n 1.853

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Silicon Telluride	$SiTe_2$	—	—	4.39	—	—	550	—	—	—	—	Q	RF	—
Silver	Ag	962	—	10.5	580	690	820	Ex	W	Mo	Ta, Mo	Al_2O_3, W	DC	Adhesion poor. Use Cr interlayer
Silver Bromide	AgBr	432	D	6.47	—	—	~380	—	Ta	—	—	Q	RF	n 2.253
Silver Chloride	AgCl	455	—	5.56	—	—	~520	—	Mo, Pt	—	Mo	Q	RF	n 2.07
Silver Iodide	AgI	558	—	6.01	—	—	~500	—	Ta	—	—	—	RF	n 2.21
Sodium	Na	98	—	0.97	74	124	192	—	Ta, SS	—	—	Q	—	Preheat gently to outgas. Film reacts in air. n 4.22
Sodium Bromide	NaBr	747	—	3.20	—	—	~400	—	—	—	—	Q	RF	Preheat gently to outgas. n 1.641
Sodium Chloride	NaCl	801	—	2.17	—	—	530	G	Ta, W, Mo	—	—	Q	RF	Copper oven; little decomposition Preheat gently to outgas. n 1.544
Sodium Cyanide	NaCN	564	—	—	—	—	~550	—	Ag	—	—	—	RF	Preheat gently to outgas. n 1.452
Sodium Fluoride	NaF	993	—	2.56	—	—	~1,000	G	Mo, Ta, W	—	—	BeO	RF	Preheat gently to outgas. No decomposition. n 1.336
Sodium Hydroxide	NaOH	318	—	2.13	—	—	~470	—	Pt	—	—	—	—	Preheat gently to outgas. n 1.358
Spinel	$MgAl_2O_4$	—	—	8.0	—	—	—	G	—	—	—	—	RF	n 1.72
Strontium	Sr	769	—	2.6	239	309	403	P	W, Ta, Mo	W	W	VC	RF	Wets but no alloy with W/Ta/Mo. Film reacts in air.
Strontium Chloride	$SrCl_2$	875	—	3.05	—	—	—	—	—	—	—	—	—	n 1.650
Strontium Fluoride	SrF_2	1,473	—	4.24	—	—	~1,000	—	—	—	—	Al_2O_3	RF	n 1.442
Strontium Oxide	SrO	2,430	S	4.7	—	—	1,500	—	Mo	—	—	Al_2O_3	RF	Reacts with W/Mo. n 1.810
Strontium Sulfide	SrS	>2,000	—	3.70	—	—	—	—	Mo	—	—	—	RF	Decomposes. n 2.107
Sulfur	S	113	—	2.07	13	19	57	P	W	—	W	Q	—	Dedicated vacuum system. High VP. n 1.957
Supermalloy®	Ni/Fe/Mo	1,410	—	8.9	—	—	—	G	—	—	—	—	DC	Sputter preferred; Co-evap Ni/Fe and Mo
Tantalum	Ta	2,996	—	16.6	1,960	2,240	2,590	Ex	—	—	—	—	DC	Forms good films
Tantalum Boride	TaB_2	3,000(?)	—	11.15	—	—	—	—	—	—	—	—	RF	—
Tantalum Carbide	TaC	3,880	—	13.9	—	—	~2,500	—	—	—	—	—	RF	—
Tantalum Nitride	TaN	3,360	—	16.30	—	—	—	—	—	—	—	—	RF, RF-R	Evap Ta in 10^{-3} T N_2
Tantalum Pentoxide	Ta_2O_5	1,872	—	8.2	1,550	1,780	1,920	G	Ta	W	W	VC	RF, RF-R	Slight decomposition. Evap Ta in 10^{-3} T O_2. n 2.6
Tantalum Sulfide	TaS_2	>1,300	—	—	—	—	—	—	—	—	—	—	RF	—
Technetium	Tc	2,200	—	11.5	1,570	1,800	2,090	—	—	—	—	—	—	—
Teflon®	PTFE	330	—	2.9	—	—	—	—	W	—	—	—	RF	Baffled source. Film structure doubtful.
Tellurium	Te	449	—	6.25	157	207	277	P	W, Ta	W	W, Ta	Al_2O_3, Q	RF	Wets W/Ta without alloying. n1.002
Terbium	Tb	1,356	—	8.23	800	950	1,150	Ex	Ta	—	—	Al_2O_3	RF	—
Terbium Fluoride	TbF_3	1,172	—	—	—	—	~800	—	—	—	—	—	RF	—
Terbium Oxide	Tb_2O_3	2,387	—	7.87	—	—	1,300	—	Ir	—	—	—	RF	Partially decomposes
Terbium Peroxide	Tb_4O_7	—	D	—	—	—	—	—	Ta	—	—	—	RF	Loses O_2. Films are mostly TbO
Thallium	Tl	304	—	11.85	280	360	470	P	W, Ta	—	W	Al_2O_3, Q	DC	Wets freely
Thallium Bromide	TlBr	480	S	7.56	—	—	~250	—	Ta	—	—	Q	RF	n 2.4 - 2.8
Thallium Chloride	TlCl	430	S	7.00	—	—	~150	—	Ta	—	—	Q	RF	n 2.247
Thallium Iodide	TlI	440	S	7.1	—	—	~250	—	—	—	—	Q	RF	n 2.78
Thallium Oxide	Tl_2O_2	717	—	10.19	—	—	350	—	—	—	—	—	RF	Decomposes at 850° C to Tl_2O
Thorium	Th	1,750	—	11.7	1,430	1,660	1,925	Ex	W, Ta, Mo	W	W	—	—	—
Thorium Bromide	$ThBr_4$	610	S	5.67	—	—	—	—	Mo	—	—	—	—	n 2.47
Thorium Carbide	ThC_2	2,655	—	8.96	—	—	~2,300	—	—	—	—	C	RF	—
Thorium Fluoride	ThF_4	>900	—	6.32	—	—	~750	F	Mo	—	W	VC	RF	—
Thorium Oxide	ThO_2	3,220	—	9.86	—	—	~2,100	G	W	—	—	—	RF, RF-R	—
Thorium Oxyfluoride	$ThOF_2$	900	—	9.1	—	—	—	—	Mo, Ta	—	—	—	—	n 1.52
Thorium Sulfide	ThS_2	1,925	—	7.30	—	—	—	—	—	—	—	—	RF	Sputter preferred; Co-evap OK
Thulium	Tm	1,545	S	9.32	461	554	680	G	Ta	—	—	Al_2O_3	DC	—
Thulium Oxide	Tm_2O_3	—	—	8.90	—	—	1,500	—	Ir	—	—	—	RF	Decomposes
Tin	Sn	232	—	7.28	682	807	997	Ex	Mo	W	W	Al_2O_3	DC	Wets Mo. Low sputter power. Ta liner for E-beam.
Tin Oxide	SnO_2	1,630	S	6.95	—	—	~1,000	Ex	W	W	W	Q, Al_2O_3	RF, RF-R	Using W, films low in O; Oxidize in air. n 2.0
Tin Selenide	SnSe	861	—	6.18	—	—	~400	G	—	—	—	Q	RF	—
Tin Sulfide	SnS	882	—	5.22	—	—	~450	—	—	—	—	Q	RF	—
Tin Telluride	SnTe	780	D	6.48	—	—	~450	—	—	—	—	Q	RF	—
Titanium	Ti	1,660	—	4.5	1,067	1,235	1,453	Ex	W	—	—	TiC	DC	Alloys with W/Ta/Mo; Outgas is high on first heating
Titanium Boride	TiB_2	2,900	—	4.50	—	—	—	P	—	—	—	—	RF	—
Titanium Carbide	TiC	3,140	—	4.93	—	—	~2,300	—	—	—	—	—	RF	—
Titanium Nitride	TiN	2,930	—	5.22	—	—	—	G	Mo	—	—	—	RF, RF-R	Sputter preferred. Decomposes with thermal evap.
Titanium (II) Oxide	TiO	1,750	—	4.93	—	—	~1,500	G	W, Mo	—	—	VC	RF	Preheat gently to outgas. n 2.2
Titanium (III) Oxide	Ti_2O_3	2,130	D	4.6	—	—	—	G	W	—	—	—	RF	Decomposes
Titanium (IV) Oxide	TiO_2	1,830	—	4.26	—	—	~1,300	F	W, Mo	—	W	—	RF, RF-R	Loses O_2. Oxides in air. Ta gives films TiO/Ti. n 2.616, 2.903
Tungsten	W	3,410	—	19.35	2,117	2,407	2,757	G	—	—	—	—	DC	Films hard and adherent.

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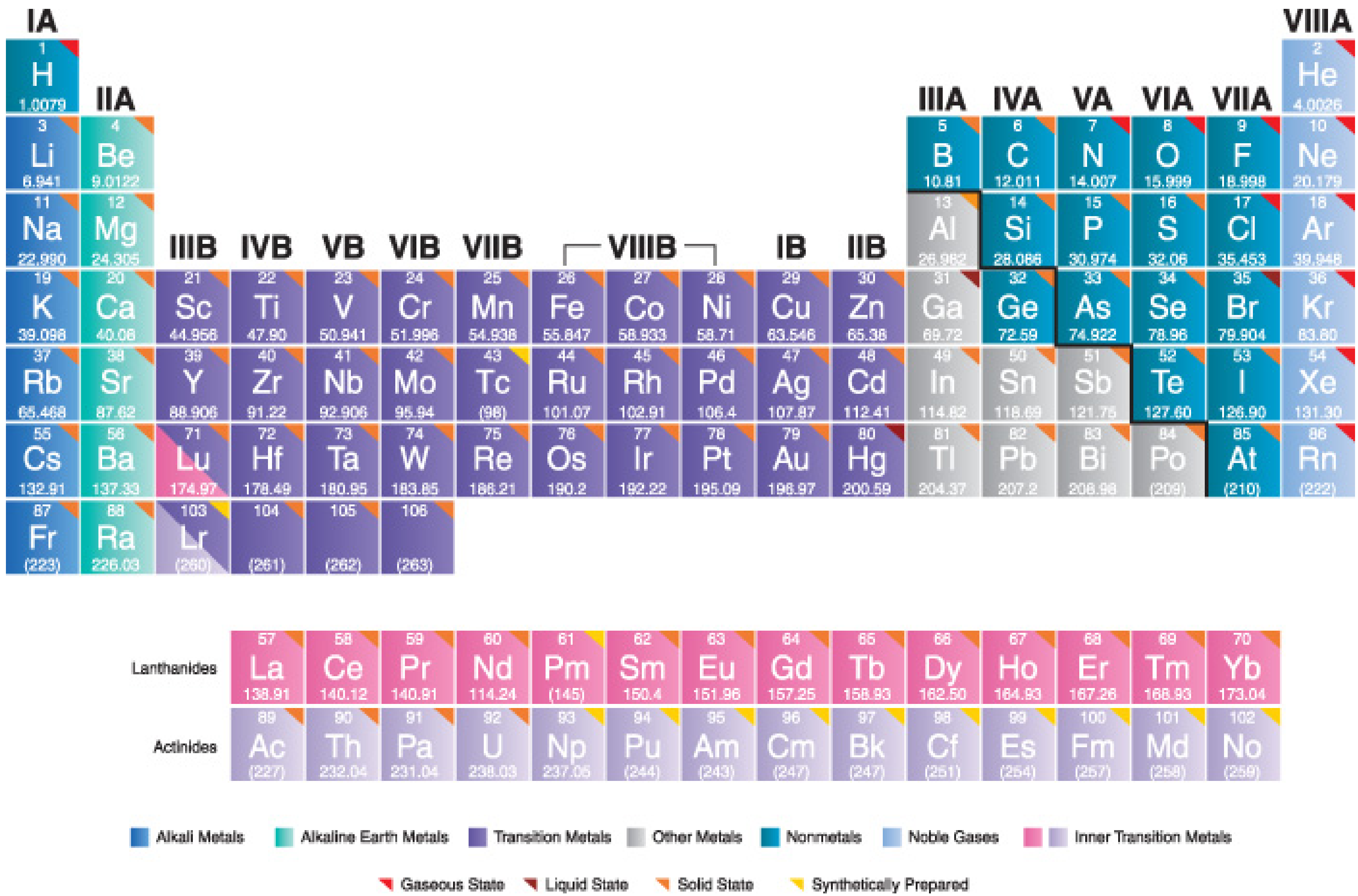
Tungsten Boride	WB_2	~2,900	—	10.77	—	—	—	P	—	—	—	—	RF	—
Tungsten Carbide	W_2C	2,860	—	17.15	1,480	1,720	2,120	Ex	C	—	—	—	RF	—
Tungsten Disulfide	WS_2	1,250	D	7.5	—	—	—	—	—	—	—	—	RF	—
Tungsten Oxide	WO_3	1,473	S	7.16	—	—	980	G	W, Pt	—	—	—	RF-R	Preheat gently to outgas. W gives O_2 loss. n 1.68
Tungsten Selenide	WSe_2	—	—	9.0	—	—	—	—	—	—	—	—	RF	—
Tungsten Silicide	WSi_2	>900	—	9.4	—	—	—	—	—	—	—	—	RF	—
Tungsten Telluride	WTe_2	—	—	9.49	—	—	—	—	—	—	—	Q	RF	—
Uranium	U	1,132	—	19.05	1,132	1,327	1,582	G	Mo, W	W	W	—	—	Films reacts in air
Uranium Carbide	UC_2	2,350	—	11.28	—	—	2,100	—	—	—	—	C	RF	Decomposes
Uranium Fluoride	UF_4	960	—	6.70	—	—	300	—	Ni	—	—	—	RF	—
Uranium (III) Oxide	U_2O_3	1,300	D	8.30	—	—	—	—	W	—	W	—	RF-R	Decomposes at 1,300° C to UO_2
Uranium (IV) Oxide	UO_2	2,878	—	10.96	—	—	—	—	W	—	W	—	RF	Ta causes decomposition
Uranium Phosphide	UP_2	—	—	8.57	—	—	1,200	—	Ta	—	—	—	RF	Decomposes
Uranium (II) Sulfide	US	>2,000	—	10.87	—	—	—	—	—	—	—	—	—	—
Uranium (IV) Sulfide	US_2	>1,100	—	7.96	—	—	—	—	W	—	—	—	RF	Slight decomposition
Vanadium	V	1,890	—	5.96	1,162	1,332	1,547	Ex	W, Mo	—	—	—	DC	Wets Mo. E-beam preferred. n 3.03
Vanadium Boride	VB_2	2,400	—	5.10	—	—	—	—	—	—	—	—	RF	—
Vanadium Carbide	VC	2,810	—	5.77	—	—	~1,800	—	—	—	—	—	RF	—
Vanadium Nitride	VN	2,320	—	6.13	—	—	—	—	—	—	—	—	RF, RF-R	—
Vanadium (IV) Oxide	VO_2	1,967	S	4.34	—	—	~575	—	—	—	—	—	RF, RF-R	Sputter preferred.
Vanadium (V) Oxide	V_2O_5	690	D	3.36	—	—	~500	—	—	—	—	Q	RF	n 1.46, 1.52, 1.76
Vanadium Silicide	VSi_2	1,700	—	4.42	—	—	—	—	—	—	—	—	RF	—
Ytterbium	Yb	819	S	6.96	520	590	690	G	Ta	—	—	—	—	—
Ytterbium Fluoride	YbF_3	1,157	—	—	—	—	~800	—	Mo	—	—	—	RF	—
Ytterbium Oxide	Yb_2O_3	2,346	S	9.17	—	—	~1,500	—	Ir	—	—	—	RF, RF-R	Loses O_2
Yttrium	Y	1,522	—	4.47	830	973	1,157	Ex	W, Ta	W	W	Al_2O_3	RF, DC	High Ta solubility
Yttrium Alum Oxide	$Y_3Al_5O_{12}$	1,990	—	—	—	—	—	G	—	W	W	—	RF	Films not ferroelectric
Yttrium Fluoride	YF_3	1,387	—	4.01	—	—	—	—	—	—	—	—	RF	—
Yttrium Oxide	Y_2O_3	2,410	—	5.01	—	—	~2,000	G	W	—	—	C	RF, RF-R	Loses O_2; films smooth and clear. n 1.79
Zinc	Zn	420	—	7.14	127	177	250	Ex	Mo, W, Ta	W	W	Al_2O_3 Q	DC	Evaporates well, over wide range of conditions
Zinc Antimonide	Zn_3Sb_2	570	—	6.33	—	—	—	—	—	—	—	—	RF	—
Zinc Bromide	$ZnBr_2$	394	—	4.20	—	—	~300	—	W	—	—	C	RF	Decomposes. n 1.545
Zinc Fluoride	ZnF_2	872	—	4.95	—	—	~800	—	Pt, Ta	—	—	Q	RF	—
Zinc Nitride	Zn_3N_2	—	—	6.22	—	—	—	—	Mo	—	—	—	RF	Decomposes
Zinc Oxide	ZnO	1,975	—	5.61	—	—	~1,800	F	—	—	—	—	RF-R	n 2.008, 2.029
Zinc Selenide	ZnSe	>1,100	—	5.42	—	—	660	—	Ta, W, Mo	W, Mo	W, Mo	Q	RF	Dedicated vacuum system. Preheat gently to outgas. Evaporates well. n 2.89
Zinc Sulfide	ZnS	1,700	S	3.98	—	—	~800	G	Ta, Mo	—	—	—	RF	Dedicated vacuum system. Preheat gently to outgas. Films partially decompose. Substrate temp affects sticking coeff. n 2.356
Zinc Telluride	ZnTe	1,239	—	6.34	—	—	~600	—	Mo, Ta	—	—	—	RF	Preheat gently to outgas. n 3.56
Zirconium	Zr	1,852	—	6.49	1,477	1,702	1,987	Ex	W	—	—	—	DC	Alloys W. Films react in air.
Zirconium Boride	ZrB_2	~3,200	—	6.09	—	—	—	G	—	—	—	—	RF	—
Zirconium Carbide	ZrC	3,540	—	6.73	—	—	~2,500	—	—	—	—	—	RF	—
Zirconium Nitride	ZrN	2,980	—	7.09	—	—	—	—	—	—	—	—	RF, RF-R	R-evap in 10^{-3} T N_2.
Zirconium Oxide	ZrO_2	~2,700	—	5.89	—	—	~2,200	G	W	—	—	—	RF, RF-R	Loses O_2. Films clear and hard. n 2.13, 2.19, 2.20
Zirconium Silicate	$ZrSiO_4$	2,550	—	4.56	—	—	—	—	—	—	—	—	RF	n 1.92–1.96; 1.97–2.02
Zirconium Silicide	$ZrSi_2$	1,700	—	4.88	—	—	—	—	—	—	—	—	RF	—

Periodic Table of the Elements



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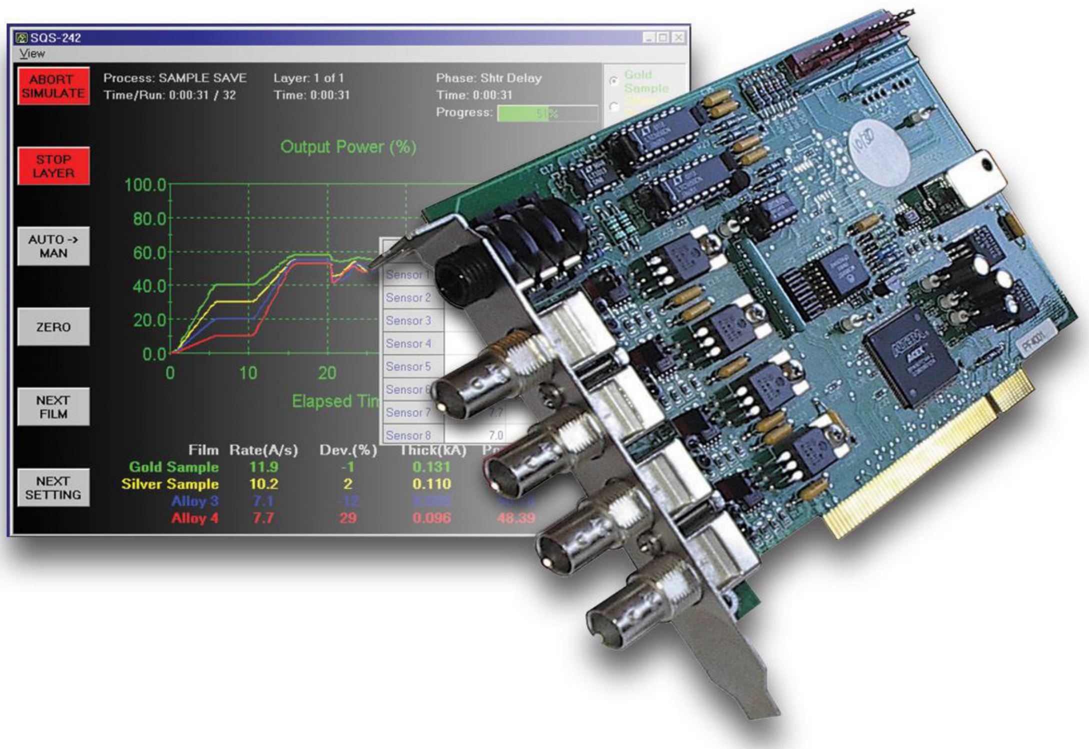
O P E R A T I N G   M A N U A L



SQS-242™

Deposition Control Software

IPN 074-551-P1A

INFICON

O P E R A T I N G M A N U A L

SQS-242

Deposition Control Software

IPN 074-551-P1A

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Communications

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Loop Tuning

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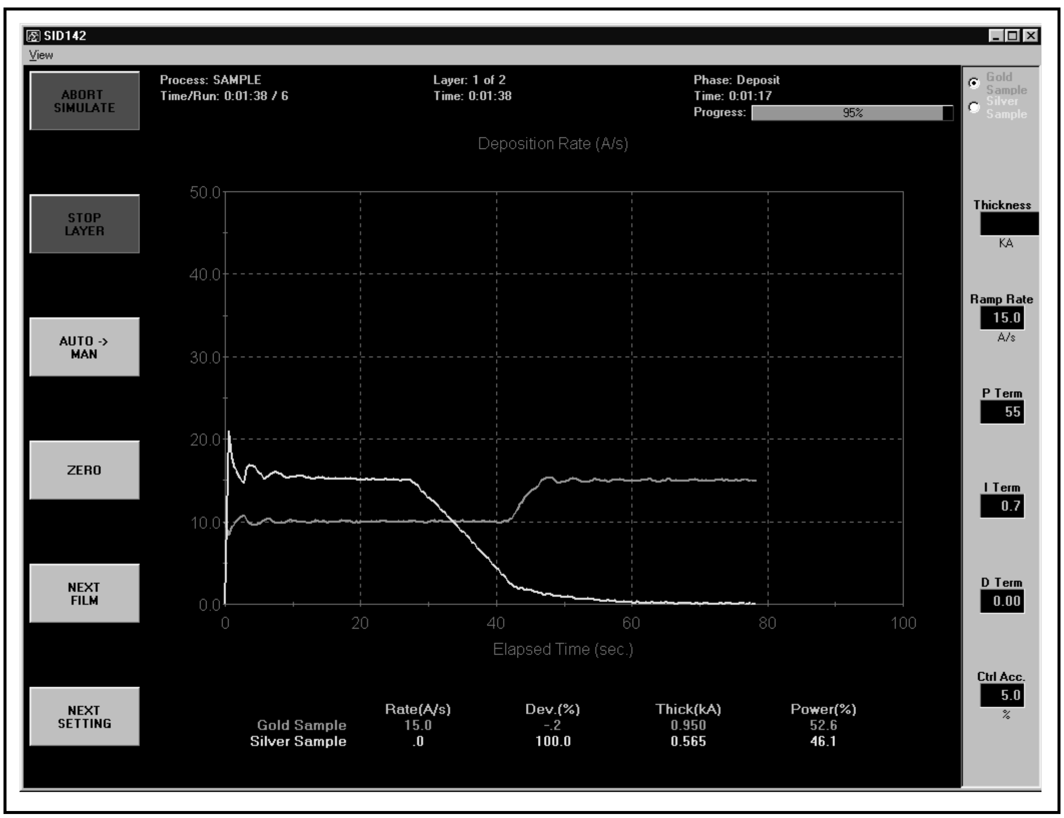
Chapter 1
Introduction

1.1 Introduction

The SQS-242 Deposition Control Software, see Figure 1-1, works with the INFICON SQM-242 card to provide a powerful, PC based thin film deposition controller that can:

- Measure up to eight quartz crystal sensors simultaneously.
- Control up to six deposition source supplies simultaneously (CoDeposition).
- Provide PreConditioning, multiple rate ramps, and feed/idle phases.
- Graph deposition rate, rate deviation, or power output.
- Store process, film and material parameters in Microsoft Access® database
- Provide flexible and reliable digital I/O using an inexpensive PLC (PLC not provided by INFICON).

Figure 1-1 SQS-242 Software



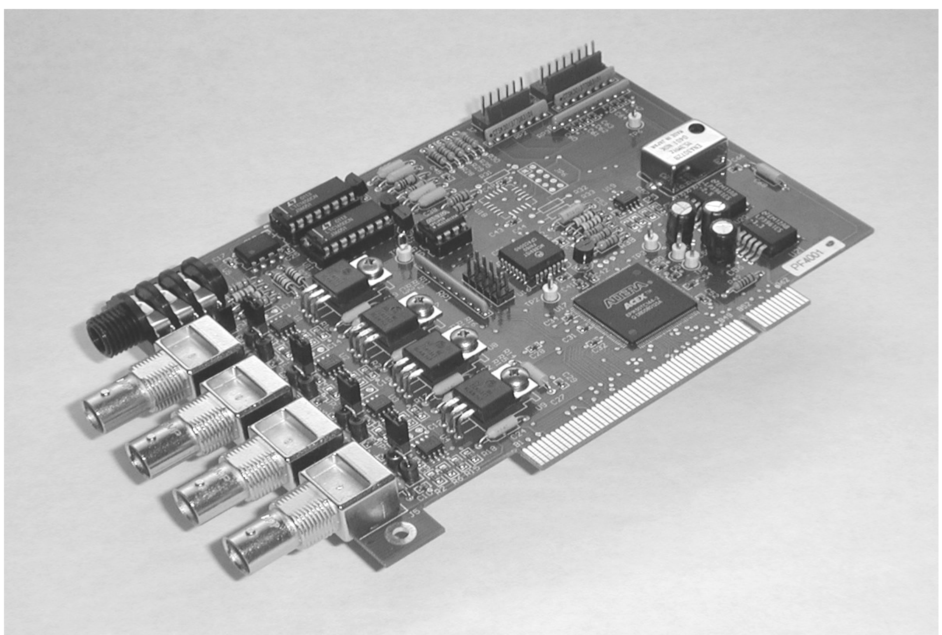
The six Soft Keys provide easy access to the common operating functions. A single tabbed dialog box provides all of the settings required for a thin film process. Material parameters, sensor/source setup, pre/post conditioning, and error conditions are all visible on a single dialog box. Process settings, numeric data, and graphical displays are displayed during all phases of deposition.

The SQS-242 software stores process parameters in a Microsoft Access compatible database. The SQS-242 software can be controlled from another computer using the RS-232 or Ethernet command protocol.

1.2 SQM-242 Deposition Control Card

The SQM-242 is a PCI expansion card for use in computers running the Microsoft® Windows® operating system. See Figure 1-2. Each card measures up to four quartz sensors via BNC inputs, and supplies the control signal for two evaporation sources via a ¼” stereo phone plug. Up to six SQM-242 cards can be installed in a computer. A single SAM-242 piggyback card with four analog inputs and two control outputs can also be installed.

Figure 1-2 SQM-242 Card



Consult the separate SQM-242 card Operating Manual for detailed information on installing and using the SQM-242 and the SAM-242 cards.

1.3 Digital I/O

Digital I/O for the SQS-242 software can be provided through an inexpensive, external, programmable logic controller (PLC), see Figure 1-3. This allows the PLC, and the associated I/O wiring, to be placed in a convenient location in a wiring cabinet. A single, serial communications cable runs to the computer. The PLC provides electrical isolation, fail-safe operation, and extensive I/O processing capabilities through its ladder logic programming.

Figure 1-3 Programmable Logic Controller (PLC)

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Chapter 2
Quick Start

2.1 Introduction

This chapter will provide a general overview on how to setup the SQS-242 deposition control program.

1. Power On the Computer.
2. Start the SQS-242 software from: Start Menu >> Programs >> INFICON >> SQS-242 Codep.
3. User Login Dialog Box

   The SQS-242 displays a progress bar during program startup, then a User Login dialog box. Select a User Name from the drop down box, enter the Password, then click OK. See section 3.5.5 on page 3-30 for more information on users, passwords, access levels, and registration.

   NOTE: The SQS-242 software has one pre-assigned user by default. The user name is Super, with no Password.

4. Process Database

   The SQS-242 normally starts with the last active process displayed. If that process is not found, a Database Open dialog is displayed.

5. Main Display

   As you operate the SQS-242, the six SoftKey labels along the left of the dialog box will change to display appropriate functions.

   Along the top of the display is a menu of less commonly used functions. This menu is available only when the SQS-242 is stopped (i.e., not running a deposition process).

6. Simulate Mode

   Simulate mode allows you to familiarize yourself with SQS-242 operation and test process recipes. Simulate Mode will be used for the remainder of this chapter.

   If the first SoftKey is labeled **START SIMULATE** then the Simulate mode is active. Otherwise, click the **Edit** menu selection along the top of the display, then click **System**. On the **Card** tab, click the **Simulate** button. Select the **Close** SoftKey to activate Simulate mode.

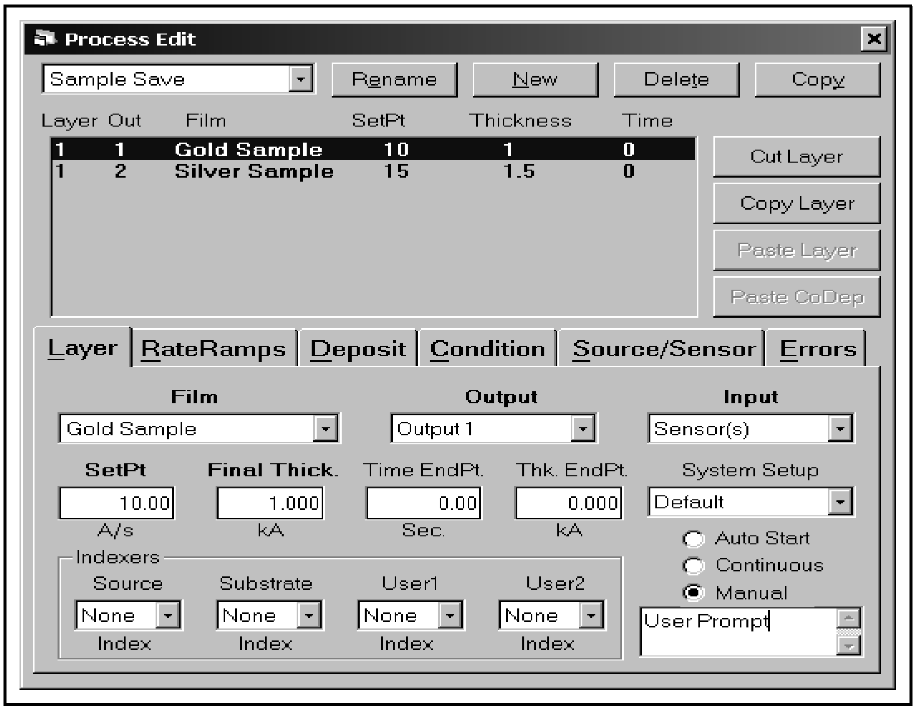
2.2 Single-Layer Process Setup

We will build a simple single-layer process as an introduction.

2.2.1 Create a New Process

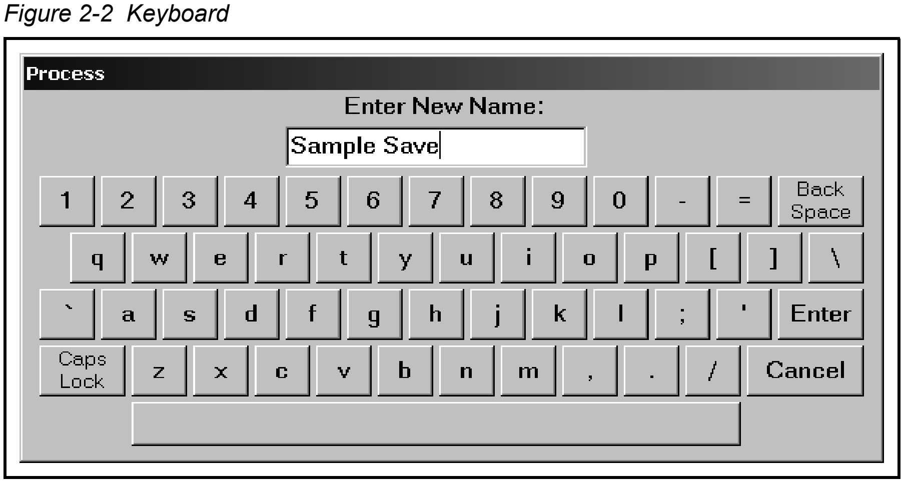
1. Click **Edit >> Process**.
2. The **Process Edit** dialog box will display the setup data for the active process. Click **New**.. See Figure 2-1.

Figure 2-1 Process Edit dialog box



3. Type a new process name using your keyboard, or the on-screen keyboard. Click **Enter** to save the new process name. See Figure 2-2.

Figure 2-2 Keyboard



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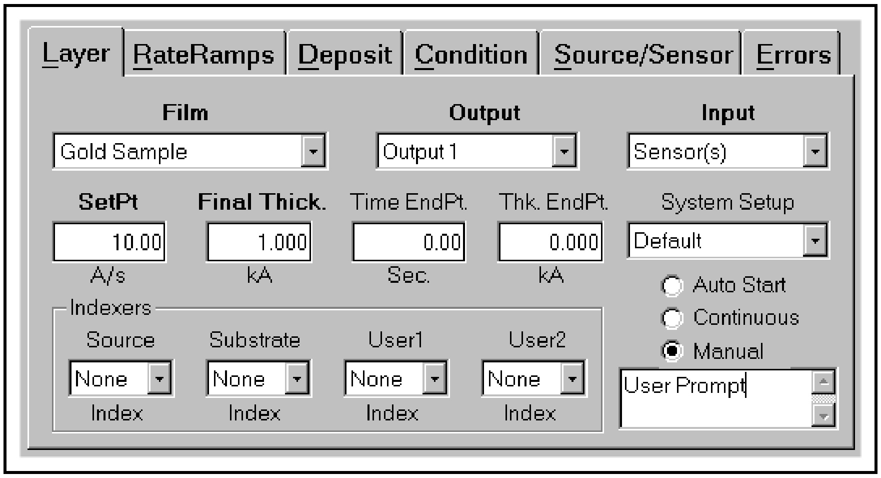
2.2.2 Edit Layer Parameters

4 Click **Layer** to display the layer parameters. See Figure 2-3.

Figure 2-3 Layer tab



5 A Film is basically a material, plus the settings that will control its deposition. Select **Film >> Gold Sample**.

6 We will be simulating a quartz sensor input that is controlling the deposition rate of Output 1. Select **Output >> Output 1**.

7 Select **Input >> Sensor(s)**.

8 Click **SetPt**, then adjust the rate setpoint to **10** Å/s.

9 Adjust **Final Thickness** to **1.000** kÅ.

NOTE: Time and Thickness Endpoints won't be used for this example.

10 **System Setup** determines the physical inputs and outputs that are used and displayed on the dialog box. For now use the **Default** system setup.

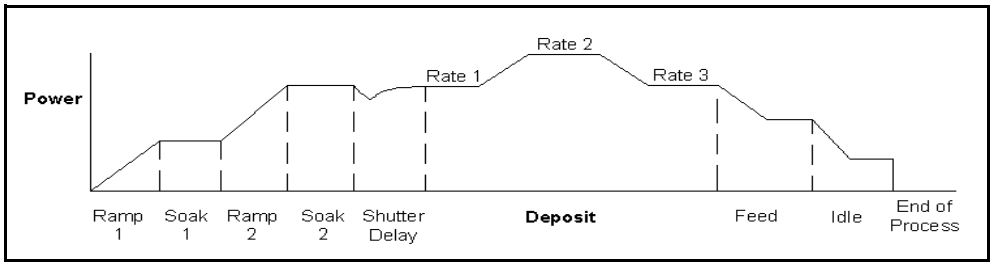
11 **Manual Start** causes this layer to wait for user input before beginning. An optional user prompt is possible.

12 We won't use any indexers for this example, so select **None**.

2.2.3 Edit Rate Ramps

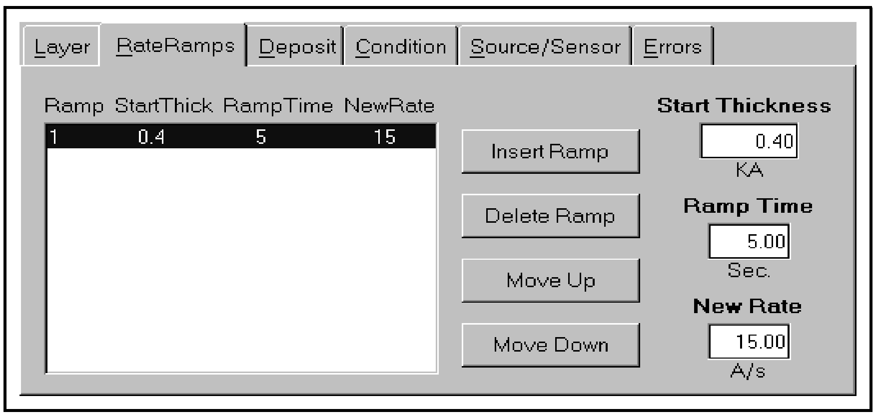
A thin-film deposition process consists of one or more layers of material evaporated onto a substrate. Figure 2-4 illustrates a complete deposition cycle for a single layer. Refer to this diagram as we set the remaining parameters.It may be desirable to vary the deposition rate during a layer. For example, to deposit slowly at first, then more quickly once the initial material is deposited.

Figure 2-4 Complete Deposition Cycle for a Single Layer



13 Click **Rate Ramps**. See Figure 2-5.

Figure 2-5 Rate Ramps tab



14 Click **Insert Ramp**.

15 Set **Start Thickness** to **0.400** kÅ.

16 Set **Ramp Time** to **5** seconds.

17 Set **New Rate** to **15** Å/s.

NOTE: Settings on the **Layer** and **Rate Ramp** tabs must be set for each layer in a process. Settings on the remaining four tabs (**Deposit**, **Condition**, **Source/Sensor**, and **Errors**) correspond to the Film that was selected on the **Layer** tab. This allows a Film's settings to be used in a number of layers, without the need to individually adjust each layer.

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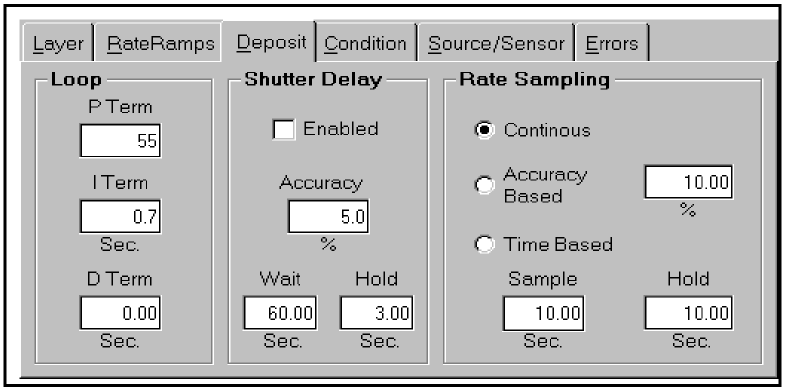
2.2.4 Edit Deposition

18 Select the **Deposit** tab. See Figure 2-6.

Figure 2-6 Deposit tab



19 Set gain (**P Term**) to **55**.

20 Set time constant (**I Term**) to **0.7**.

21 Set dead time (**D Term**) to **0**.

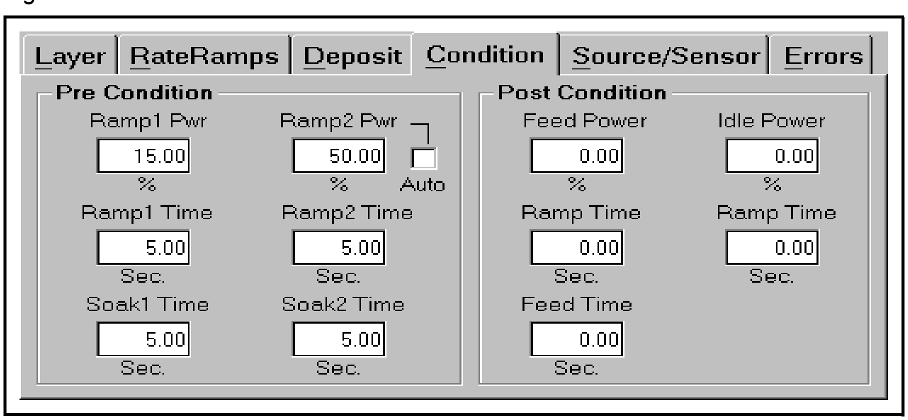
22 Be sure **Shutter Delay Enabled** is <u>not</u> selected.

23 Set **Rate Sampling** to **Continuous**.

2.2.5 Edit Pre/Post Conditioning

24 Before deposition begins, the source material is often brought to a ready state by slowly raising the evaporation source power. Select the **Condition** tab and set each parameter to the values shown in Figure 2-7.

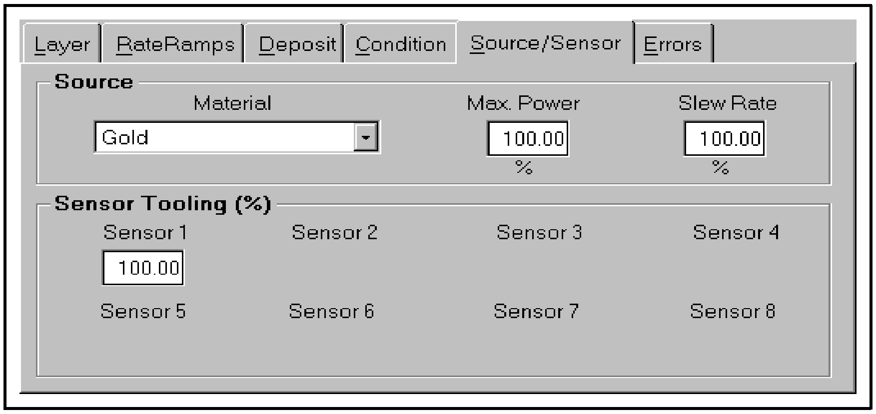
Figure 2-7 Condition tab



2.2.6 Edit Source/Sensor

25 Select the **Source/Sensor** tab. See Figure 2-8

Figure 2-8 Source/Sensor tab



26 Select the proper material for this film, **Gold**.

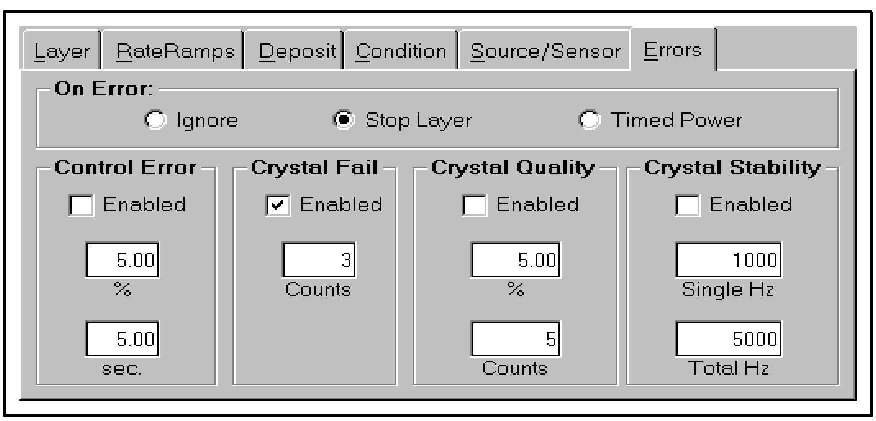
27 Set the maximum power and slew rate that should be used for the selected material.

28 **Sensor Tooling** adjusts for differences in the substrate deposition and that measured by each sensor. Select **100**% for now.

2.2.7 Edit Errors

29 Select the **Errors** tab, see Figure 2-9, to control the actions taken when a sensor or deposition control error occurs. You can elect to ignore errors (unlikely), stop deposition for this layer, or continue deposition at a fixed power level. Select **Stop Layer** for this example.

Figure 2-9 Errors tab



30 Until a process is well established, it is best to enable only the **Crystal Fail** error checking. Uncheck the remaining error conditions.

2.2.8 Save Edits

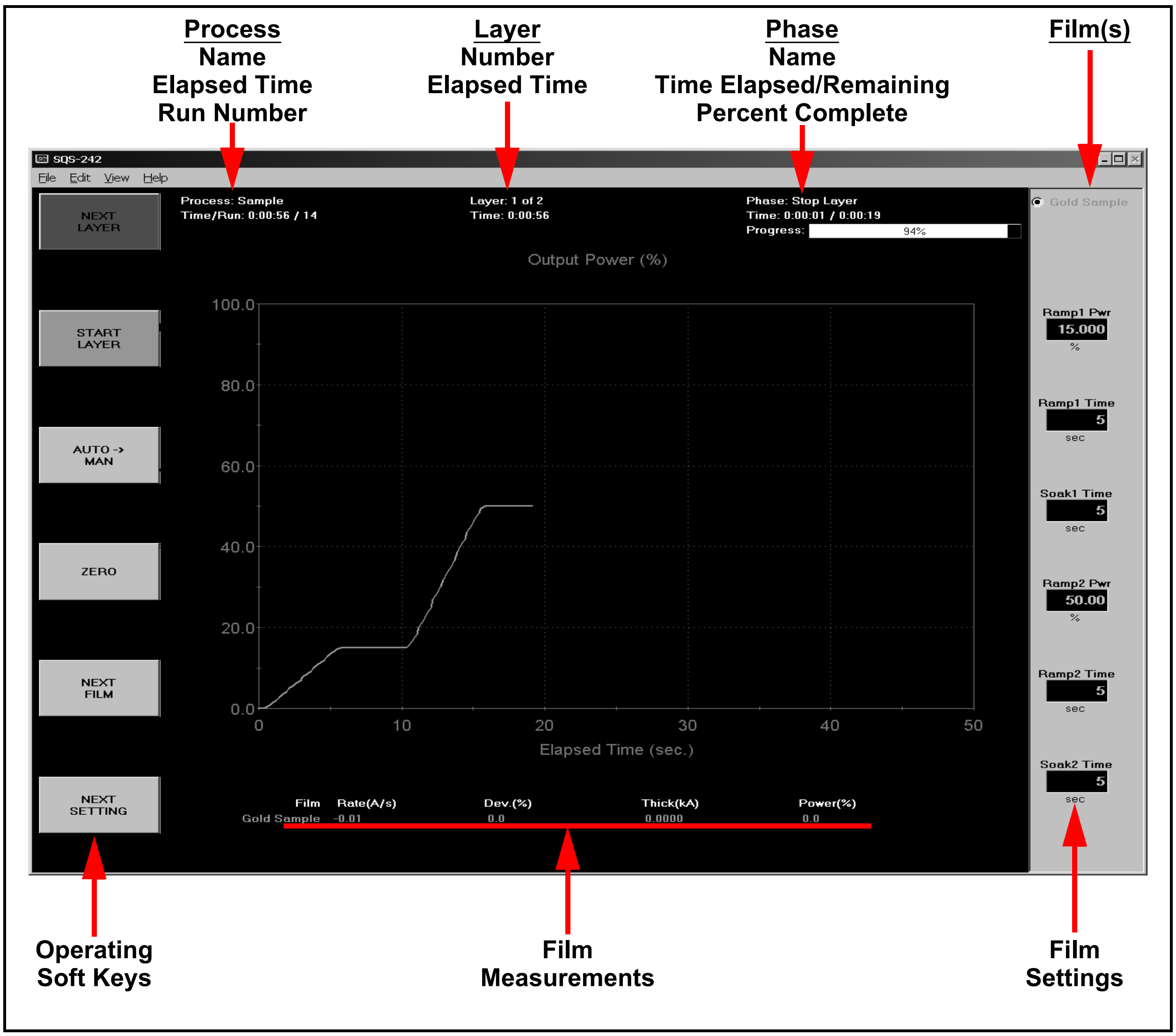
31 Select the **Close Form** SoftKey to save this one-layer process. If you are prompted **Do you want to change….** answer **Yes** to make this the current process.

32 Your new single-layer process is now the active process in the main window. Notice the process, layer, and time information above the graph.

2.3 Single Layer Process Simulation

If you have followed this chapter, you are ready to simulate a deposition process. First, take a look at the information provided on the main dialog box. See Figure 2-10.

Figure 2-10 Information on Main Dialog Box



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2.3.1 Setup Displays

Click the **View** menu and make sure that these options are selected:

- **Film Settings**
- **Film Readings**
- **Automatic**

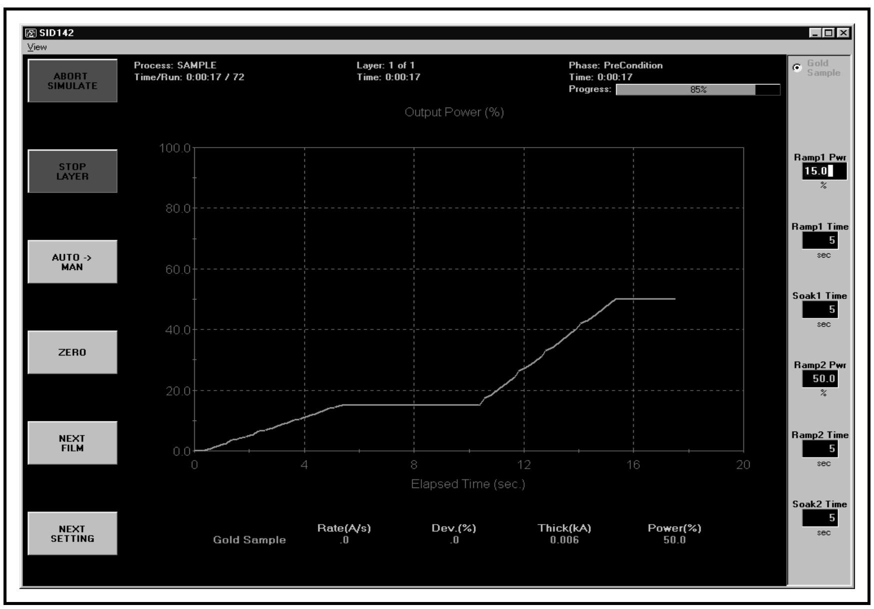
Note that the settings “ribbon” along the right side of the dialog box displays the pre-conditioning parameters you entered in the previous section.

2.3.2 Start Process

Verify that the top SoftKey label displays **START SIMULATE**. If **START PROCESS** is displayed, follow the instructions at the end of section 2.1 to enable simulate mode. Press the **START SIMULATE** SoftKey to start the process.

The process will start with preconditioning (i.e., **Ramp1**, **Soak1**, **Ramp2**, **Soak2**) as shown in Figure 2-11. Once preconditioning is complete, the process will enter the Deposit phase.

Figure 2-11 Preconditioning



You may want to select **ABORT SIMULATE**, then **START SIMULATE** several times to familiarize yourself with the on-screen displays during preconditioning. You may also want to use the settings ribbon to adjust parameters while the process is running.

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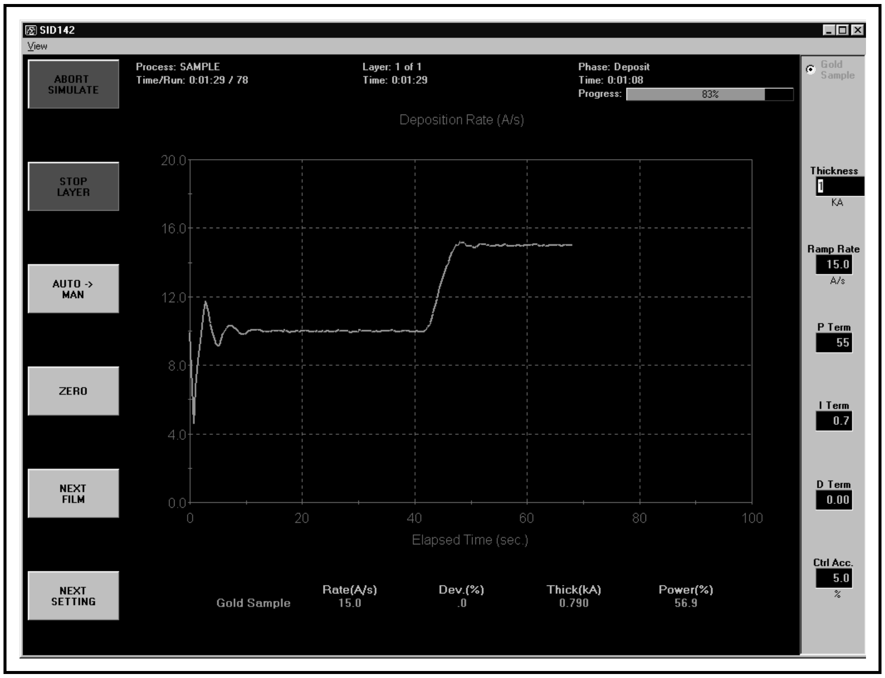
2.3.3 Preconditioning Phases

Because we selected **Automatic** in the **View** menu, the graph displays **Output Power** during preconditioning, then switches to **Rate** during the deposition phase.

As shown in Figure 2-12, the initial deposition rate was 10 Å/s until a thickness of .400 kÅ. Then the deposition rate was ramped up to 15 Å/s, and held until the desired final thickness of 1.000 kÅ was achieved. At this point, this single-layer process is finished.

Figure 2-12 Deposition Rate



2.3.4 Deposition Phase with one Rate Ramp

You should adjust the PID parameters on the setting ribbon, then Start/Stop the process several times to become familiar with their effect on control loop response.

NOTE: In Simulate Mode, a deposition rate is not "measured" until the output power exceeds 50%.

2.4 SoftKey Functions

As you have seen, the SoftKey functions remain constant during deposition. Spend a few minutes to become familiar with each of these SoftKey functions.

START PROCESS

Starts the first layer of a process when **START** is pushed. If **AUTO→MAN** is shown on the third SoftKey (AUTO mode) the process starts PreConditioning. If **MAN→AUTO** is shown on the third SoftKey (**MANUAL** mode) the process immediately starts in the Deposition phase.

ABORT PROCESS

Aborts the process. The process can only restart at the first layer.

START LAYER

Starts a stopped layer, or a layer that has been designated Manual Start in the process database. Starts the layer based on the state of the AUTO >> MAN SoftKey as described above.

STOP LAYER

Stops the current layer. Also changes the function of the first SoftKey to **NEXT LAYER**.

NEXT LAYER

Abandons the current layer and moves to the next layer in the process. If it is the last layer of a process, the same as pushing **ABORT PROCESS**.

AUTO→MAN

When **AUTO→MAN** is pushed, the source output is set to manual control. You may adjust the output using the settings ribbon. Because the PID loop is not running, you can manually set the output power to different levels and observe the associated deposition rate.

MAN→AUTO

Returns the output to PID loop control. If the process is running (**ABORT PROCESS** and **STOP LAYER** shown on the first two SoftKeys) deposition continues. If the process is stopped, sets the output to zero and awaits a start command.

ZERO

Resets the thickness reading to zero.

NEXT FILM

Sequences the setting ribbon through each Film in a codeposition layer.

NEXT SETTING

When the settings ribbon is shown, sequences the setting knob action through each of the displayed parameters.

2.5 Multi-Layer CoDeposition Process

Our final example builds on the previous sections. If you have modified the setup of your process, return to section 2.2, Single-Layer Process Setup, on page 2-2 and adjust the process to those values. When your single-layer process matches section 2.2, complete these steps:

1 Duplicate a Layer

Open the Edit Process dialog box. Click on Layer 1, click the **Layer** tab, then click **Copy Layer**. Now click **Paste Layer**. A duplicate Gold Sample film will be added as Layer 2. Click **Paste Layer** again to add a third Gold Sample layer.

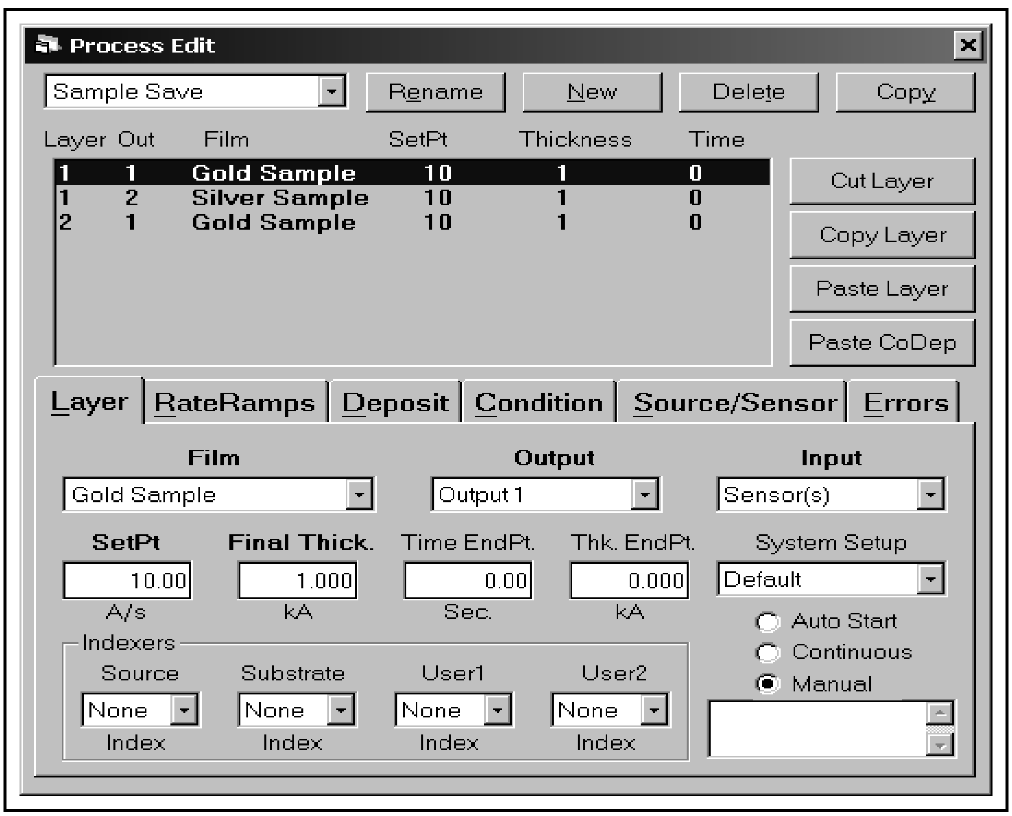
2 Select a CoDep Film

Select **Layer 3** in the layers list. Select **Films >> Silver Sample**. Select **Output >> Output 2**. The layers list will update to show the new Silver Sample film assigned to Layer 3.

3 Add a CoDep Layer

Select **Layer 3** in the layers list, then click **Cut Layer**. Now select **Layer 1**. Click **Paste CoDep**. The Silver Sample film will be added below Gold Sample as a codeposition layer. Your setup should match Figure 2-13.

Figure 2-13 Added CoDep Layer



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We now have two layers in our process. Layer 1 has Gold being deposited from source Output 1 and Silver is being codeposited on Output 2. Layer 2 is Gold alone.

HINT: It's easiest to copy a layer, then paste several temporary layers of that type as additional layers. Next, assign the films and outputs that you want to each of these additional layers. Now use **Cut Layer** on the temporary layers, and **Paste CoDep** to assign the film to the desired codeposition layers. Remember that each film in a codeposited layer must be assigned to a different source output! Review this example until you are comfortable with these concepts.

4 Edit Layer 1 Rate & Thickness

Click **Silver Sample** in the list of layers. Set **Initial Rate** to **15** Å/s, **Final Thickness** to **1.500** kÅ. Click the **Rate Ramps** tab and set **Start Thickness** to **0.400** kÅ, **Ramp Time** to **15** seconds, and **New Rate** to **0** Å/s.

5 Edit Layer 2 Rate & Thickness

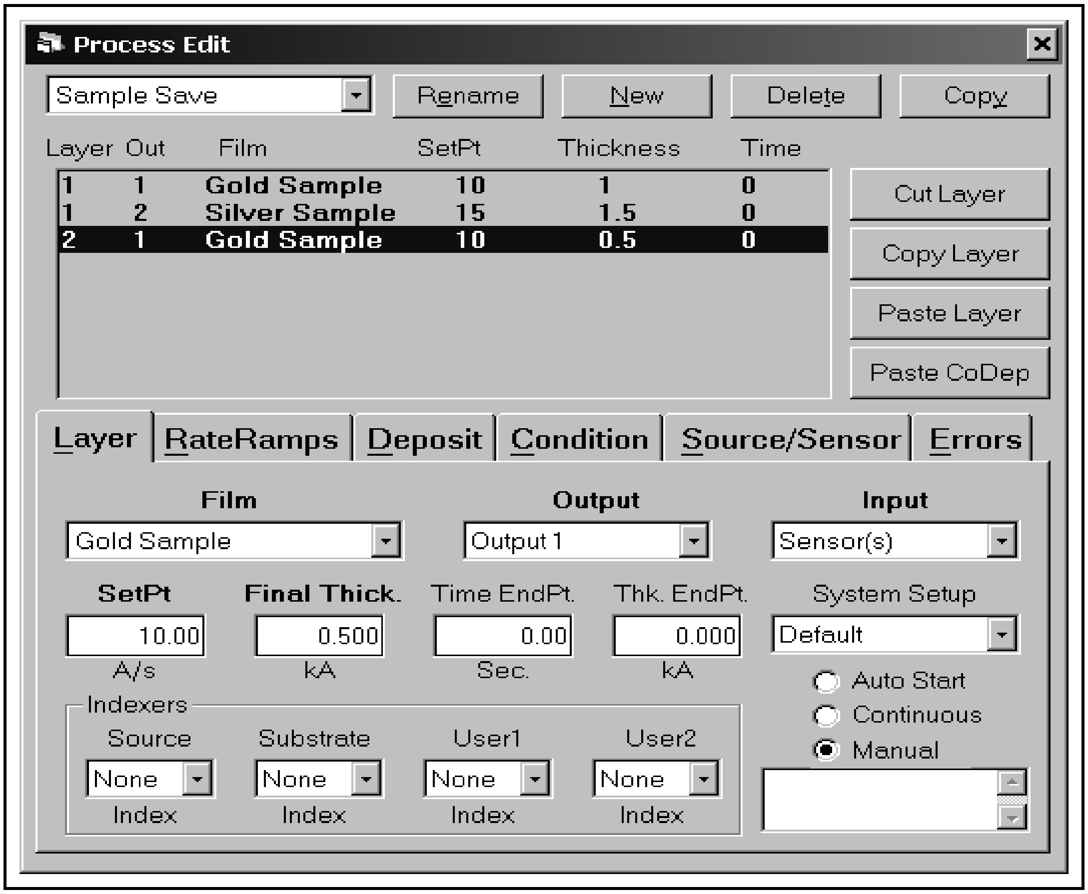
Click the **Layer** tab, then click **Layer 2 Gold Sample**. Set **Final Thickness** to **0.5000** kÅ.

6 Set Layers to Auto Start

At the end of deposition, you may choose to have the next layer wait for a Start Layer command, or to start automatically. Select each Layer in the layers list, then click **Auto** to set that layer to start automatically.

Verify that your process matches the one shown in Figure 2-14.

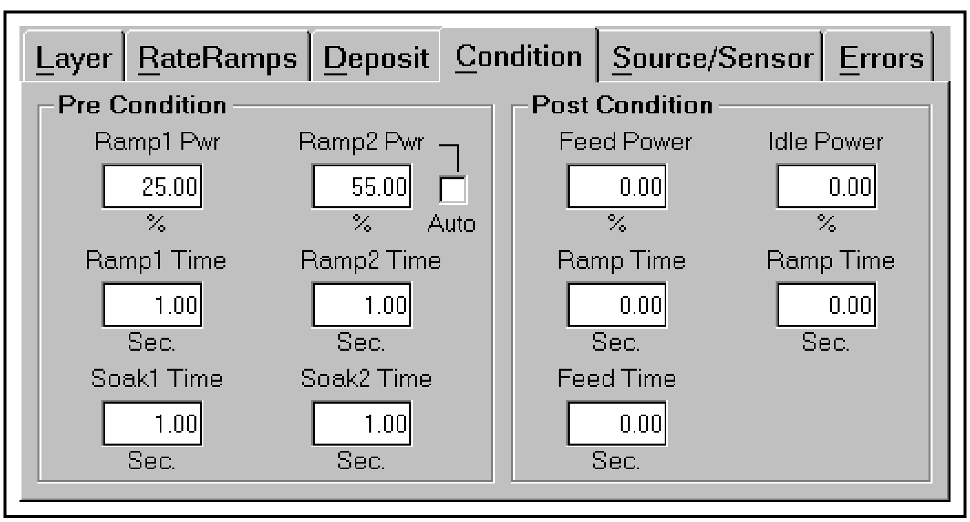
Figure 2-14 Process Edit Dialog Box



7 Edit Silver Conditioning

Select the **Condition** tab and the **Silver Sample** layer. Set each parameter to the values shown in Figure 2-15.

Figure 2-15 Condition Tab for Silver Sample Layer



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8 Save Edits

Click **Close Form** or press the first SoftKey to save this two-layer codeposition process. Answer **Yes** if it displays the **Do you want to change….** message box to make this the current process.

9 Start Process

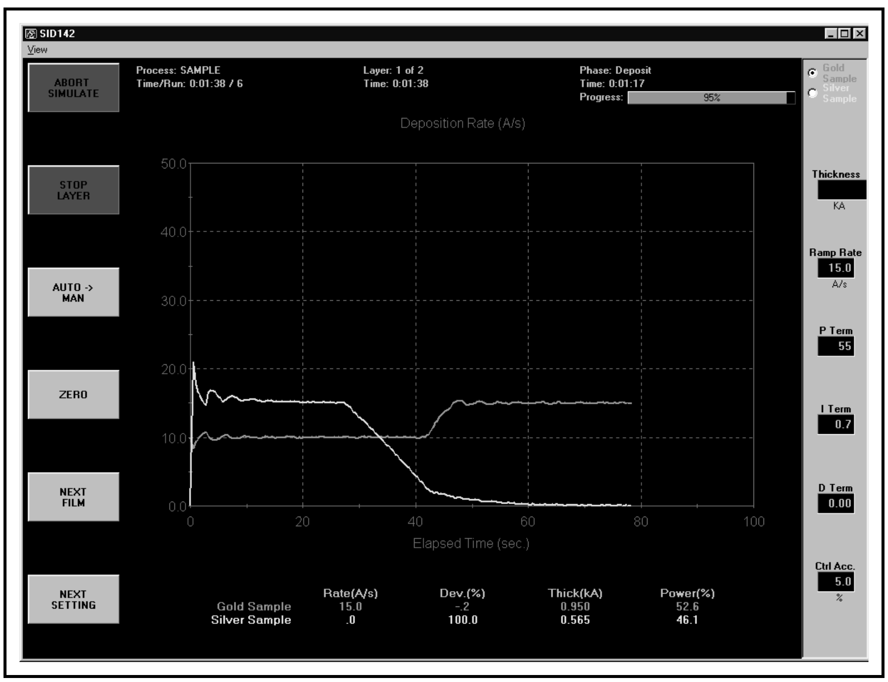
Press the **START SIMULATE** SoftKey to start the first layer preconditioning phases. Note that two outputs are displayed for this codeposition layer.

Preconditioning of the two materials is entirely independent. If the preconditioning of one layer takes longer than the other, the start times are adjusted so that the end times coincide.

When preconditioning ends, codeposition of the two materials begins.

Your response should be similar to the graph shown in Figure 2-16 (your vertical scale may be slightly different). The slight ringing on the waveforms indicates some further tuning may be desired. However, this is an example of a reasonably well tuned loop.

Figure 2-16 Start Process Response



At 0.400 kÅ thickness, the Silver Sample deposition rate ramps down from 15 Å/s to 0. Similarly, at 0.400 kÅ thickness the Gold Sample film ramps to a higher deposition rate of 15 Å/s. Because the initial rate for Gold was set lower than the initial rate for Silver, Gold reached its 0.400 kÅ thickness rate ramp trigger later in the deposition cycle.

Try a P Term in the 25-30 range (less gain) for both Gold and Silver to decrease the loop susceptibility to noise. Increasing the I Term a little, say toward 1.0, will lessen overshoot during rate changes. The D term can be thought of as a “dead band” term. Most systems require little or no D term.

2.6 Conclusion

Spend some time with this process to become familiar with its setup and the effect of changes on deposition performance.

Because we selected Simulate Mode at the beginning of this Quick Start session, the SQM-242 card is “faking” an actual process. You can use the Simulate feature at any time to become familiar with SQS-242 operation and the effect of various settings on process performance. It is also a very useful feature for pre-testing your process setups. Return to the **Edit** menu, then select **System** and set the **Mode** to **Normal** to begin running your real process with the SQS-242 software.

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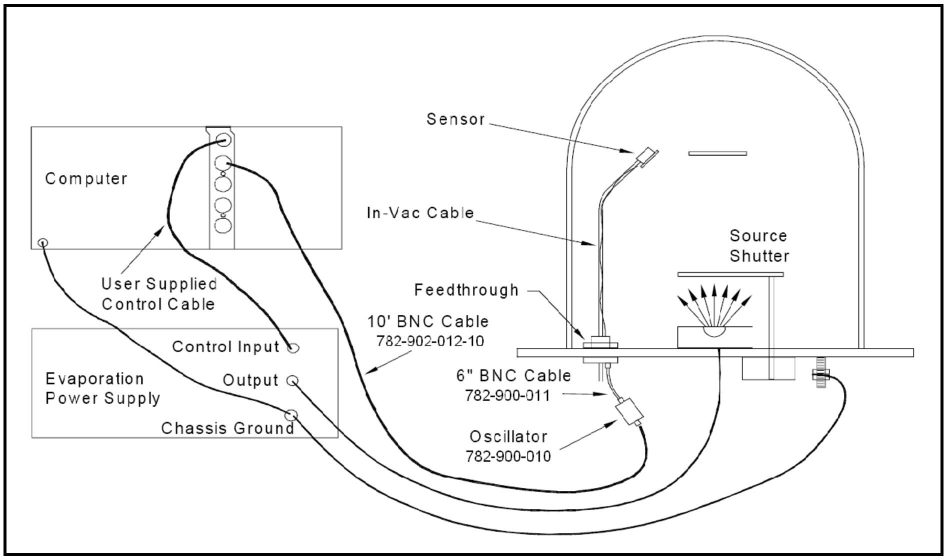
Chapter 3
SQS-242 Software

3.1 Introduction

This chapter covers the minimum system connections and initial setup required to run the SQS-242 software. Consult the SQM-242 operating manual for more detailed instructions. See Figure 3-1.

Figure 3-1 SQM-242 Setup



1 Sensor Input Connections

Connect the BNC cables and oscillators from your vacuum chamber feedthrough to the desired SQM-242 Card Input(s). Refer to Chapter 2 of the SQM-242 manual for detailed instructions on system hookup to the SQM-242 card(s).

2 Source Output Connections

Connect the dual phone plug from the SQM-242 output jack to your evaporation supply control input. Refer to Chapter 2 in the SQM-242 manual for detailed instructions on wiring the SQM-242 output phone plug.

3 Digital I/O Connections

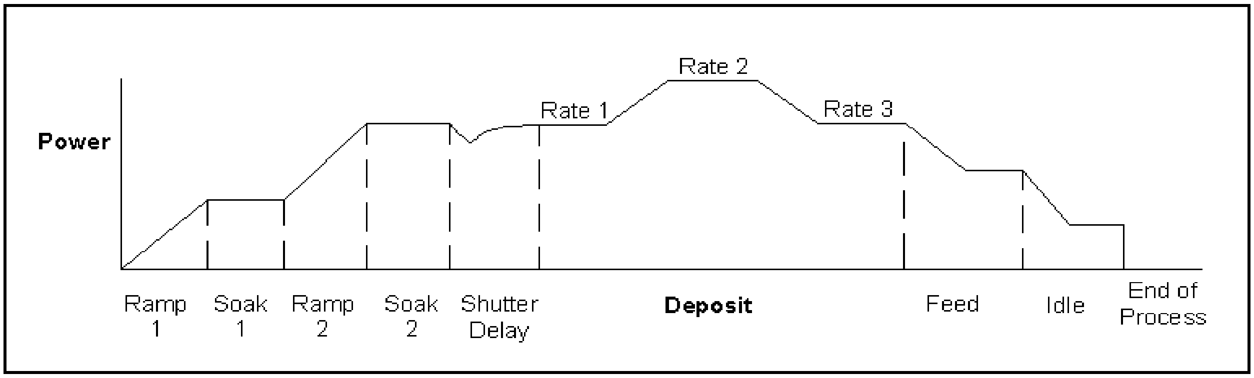
Digital I/O is not required for initial operation of the SQS-242 software. Perform initial setup and checkout of the SQS-242 before connecting your digital I/O. See Chapter 4 for detailed information on wiring the SQS-242 for digital I/O.

WARNING

Care should be exercised to route cables as far as practical from other cables that carry high voltages or generate noise. This includes other line voltage cables, wires to heaters that are SCR-controlled, and cables to source power supplies that may conduct high transient currents during arc down conditions

A typical deposition cycle for a thin film is shown in Figure 3-2. The cycle can be broken into three distinct phases: pre-conditioning (ramp/soak), deposition, and post-conditioning (feed/idle)

Figure 3-2 Typical Deposition Cycle



During pre-conditioning, power is applied to prepare the source material for deposition. The first ramp/soak preconditioning phase is used to bring the material to a uniform molten state. The second ramp/soak phase is typically set to a power that is near the desired deposition rate.

When pre-conditioning ends, PID rate control of deposition begins. Initially, the substrate material may remain shuttered until the desired deposition rate is achieved (shutter delay). Once the control loop achieves the desired rate, the shutter opens and deposition begins. Multiple deposition rates (rate ramps) can be programmed.

When the desired thickness is reached, the evaporation source is set to feed or idle power. At this point the process may be complete, or deposition of another film layer may begin. Up to six separate films can be codeposited within a single layer. There is no practical limit to the total number of processes, layers, or materials that can be stored in the process database.

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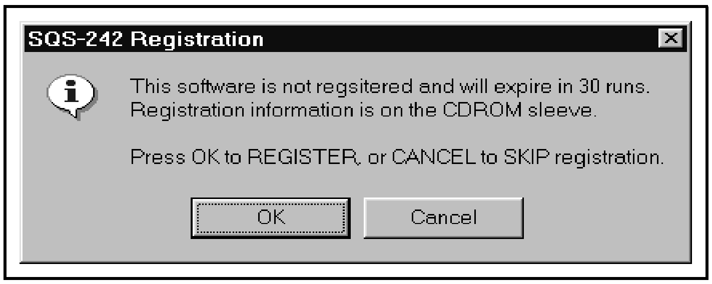
3.2 Installation and Registration

The SQM-242 card can be installed before or after the SQS-242 software. Consult the separate SQM-242 card User's Guide for installation information. To install the program, insert the disk or CD-ROM. Click Start, then Run, then type <d>:Setup (where <d> is the drive you are using). Click OK to begin installation, and follow the on-screen prompts. When installation is complete, you may be prompted to restart the computer.

To start the SQS-242 program, click Start >> Programs >> INFICON >> SQS-242. If you see this Registration dialog box appear (see Figure 3-3.), you have a older version of the SQS-242 software. contact INFICON for the latest version which removes this registration requirement.

Figure 3-3 Registration Dialog Box

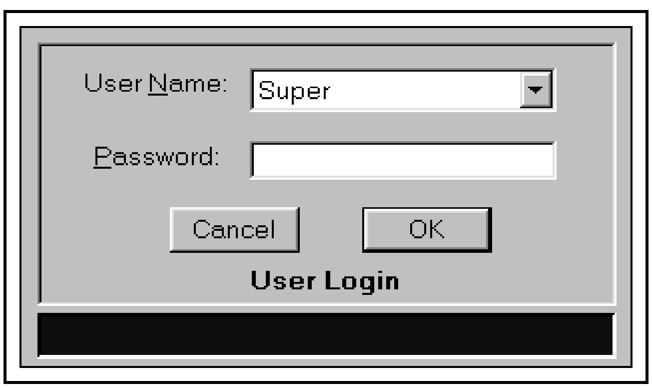


3.3 Operation

When the program is first started, it displays a progress bar during startup, then a User Login dialog box (see Figure 3-4).

NOTE: The SQS-242 software ships with one pre-assigned user. The user name is Super, with no Password.

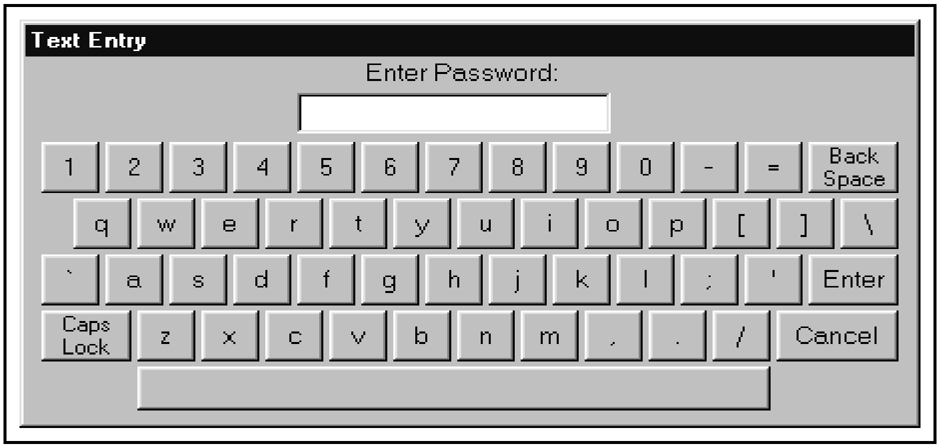
Figure 3-4 User Name



Select a User Name from the drop down box, type in the Password, then click OK to start the program.

If your software is configured for keyboardless operation, an on-screen keyboard will appear as shown below. You can use your normal keyboard or mouse to “type” the password, then click Enter. See System Setup, SQM-242 Setup later in this chapter to enable or disable the on-screen keyboard (see Figure 3-5).

Figure 3-5 On-screen Keyboard



An Access Level is associated with each User Name. The Access Level controls which software functions are available to each user. For example, only users with an Access Level of Supervisor can add new users. See the Security section of this chapter for information on setting up users.

The remainder of this chapter covers the purpose and operation of each software function, arranged by menu selections. For a more “operational” approach, consult the previous Quick Start chapter.

Menus: The menus along the top of the main dialog box provide access to functions for building deposition processes, configuring the hardware for your vacuum system, and data display.

SoftKeys: The six switches to the left of the display are used for the normal operation of the instrument, and to navigate the setup programs (see below for the individual switch functions). Just move the cursor over the key label on dialog box and single click the mouse. You can also use the keyboard F1 to F6 function keys to simulate the front panel function switches. The SoftKeys change during operation to address different user input requirements.

3.4 Menu

NOTE: The current process must be stopped for the File menu to be available.

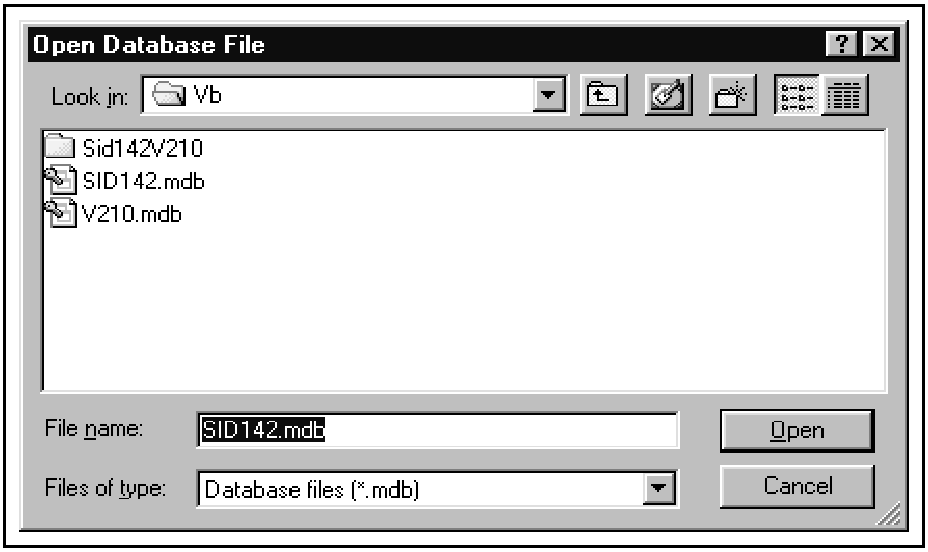
3.4.1 File: Process

Used to select a process from a list of all processes in the current database. If the process selected is different than the current process, you are prompted to confirm the change.

3.4.2 File: Open and Save Database

Open Database: Selects a process database to be used for deposition. Remember, a single process database may contain an unlimited number of processes, films, and materials. See Figure 3-6.

Figure 3-6 Open Database File dialog



Save Database As: Saves the current process database to disk under a different name. This is useful for saving the process database to floppy disk (for backup!), or for making trial changes without affecting your working database. Process databases are saved in Microsoft Access® format.

Once again, a pop-up keyboard may appear. If you want to browse, just select Cancel from the pop-up keyboard.

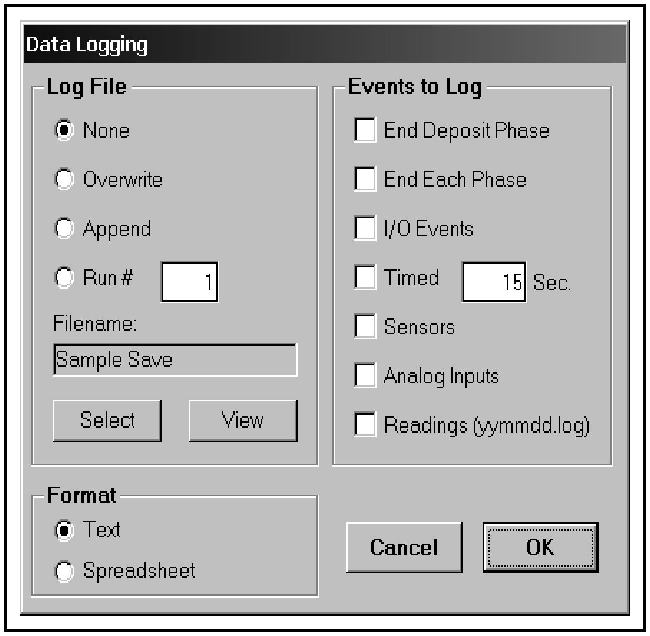
3.4.3 File: Data Logging

Logs data from a deposition process to a disk .LOG file. There are four options for file naming and logging. See Figure 3-7.

Log File: Select None to disable data logging. If Overwrite is selected, the last run of the process is saved as FileName.LOG (where FileName is the name shown in the FileName text box). Subsequent runs overwrite the log file. If Append is selected, each run is appended to FileName.LOG. If Run# is selected, each run of the process is saved as a separate file under the format FileName_Run#.LOG.

Changing Run# on this dialog box will also change the Run# displayed at the top of the main program dialog box.

Figure 3-7 Data Logging



Normally, the log file is saved to the folder where the program is installed. If desired, you can click Select and navigate to a different folder. Log files can be viewed in Notepad by clicking the View button.

NOTE: To avoid delays in data acquisition DO NOT log data to a floppy disk file. Instead, save to the hard disk, and transfer the files to a floppy disk later.

Events to Log: A number of “events” can trigger a data entry in the log file. End Deposit Phase records process data (rate, thickness, time, etc.) at the end of each layer’s deposit phase. Similarly, End Each Phase logs data at the end of each phase (conditioning, depositing, etc.). I/O Events logs data each time an external digital input or output changes.

Timed logging records data at the selected time intervals throughout the process. Click the Sensors box to include individual sensor data in addition to the normal film based data. Click Analog Inputs to also log that data.

Finally, click Readings to log every reading from the SQM-242 card(s). The file will be saved in the application directory with a name in yymmdd.log format. That is, readings logged on January 15, 2011 will be saved as 110115.log.

NOTE: This file can grow quite large and cause Windows to slow significantly. Typically, the Timed option is a better choice unless you must record every reading. When Readings is selected, a reminder dialog box appears each time the SQS-242 program is started.

Format: There are two formats for writing data. If Spreadsheet is selected, each entry is a comma-delimited line of data. If Text is selected, the data is formatted for easy reading. The first few lines of the LOG file is a heading that illustrates the file format and content.

NOTE: To use a different delimiter than a comma, change the SQS242.INI file so that under the [DataLog] section, the LogDelimit= entry shows the character you want to use. To use a <TAB> character, type the word Tab. See section 3.8 on page 3-37.

3.4.4 File: Print

Print Process: Prints the parameters for the current process to the system printer. Select Print to File in the Printer Setup Menu to print the data to a file.

Print Setup: Selects and modifies the current system printer.

3.4.5 File: User Login

Displays the User Login dialog box so that a different user may log in. The existing user is logged off automatically. The user Access Level changes immediately to that of the new user. See the Edit, Security section for more information on Users, Passwords, and Access levels.

3.4.6 File: Exit

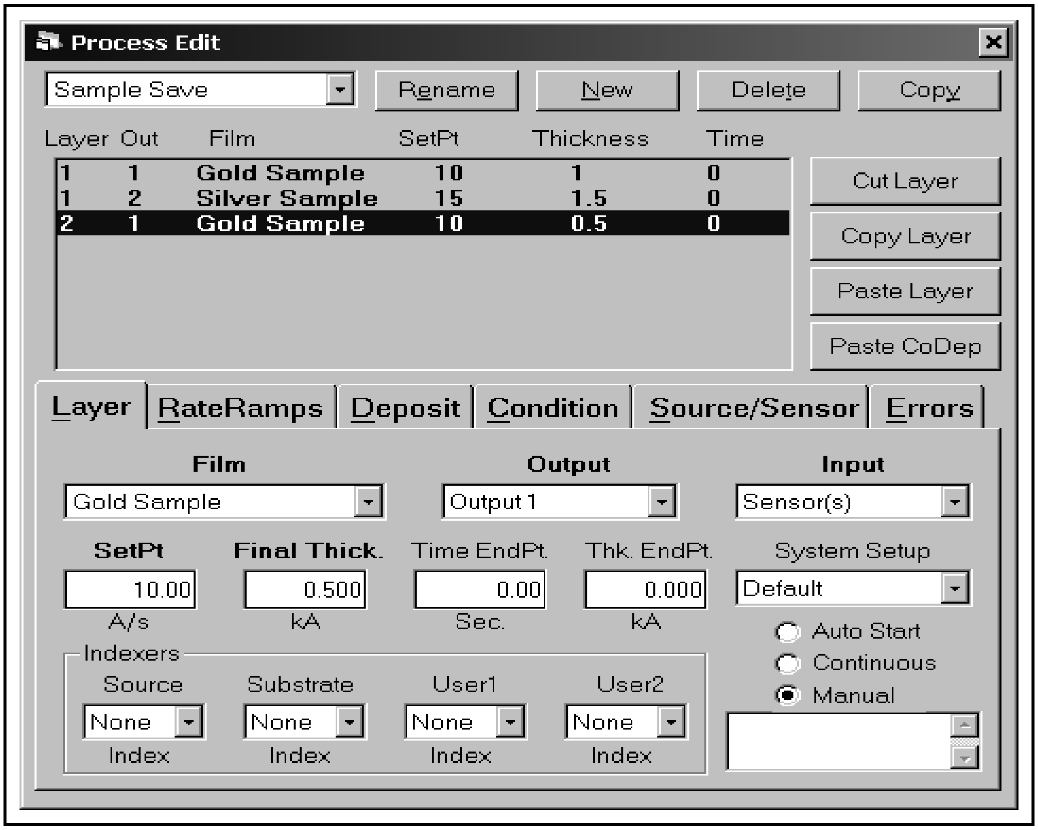
Exits the SQS-242 deposition control program and saves the current data.

3.5 Edit Menu

3.5.1 Edit: Process

A process is a sequence of thin film layers. Multiple films deposited in the same layer are known as CoDeposition. The Process Edit dialog box, see Figure 3-8, provides the functions needed to develop a thin film deposition process from the database of existing films and materials.

Figure 3-8 Process Edit dialog



Controls along the top of the Process Edit dialog box apply to the entire process:

Process: A dropdown box that selects the process to be edited. Defaults to the current process. Below the process dropdown, a listing of each layer assigned to the Process. CoDeposition layers are listed with the same layer number, but a different output.

Rename: Edits the name of the selected process.

New: Creates a new process. Since every process must have at least one film, the first film of the currently selected process is used.

Delete: Deletes the selected process from the database. *There is no undelete!*

Copy: Creates a duplicate of the currently selected process.

Layers List: To select a process layer, click on it in the Layers list.

Cut/Copy/Paste the selected layer as described below:

Cut Layer: Removes the selected layer from the process and places the layer on the clipboard.

Copy Layer: Places the layer selected in the Layers list box on the clipboard, without removing it from the process.

Paste Layer: Inserts the clipboard layer above the currently selected layer in the Layers list box. Existing layers are shifted down.

Paste CoDep: Pastes the clipboard layer as a CoDeposition layer at the currently selected layer number. Attempting to paste a layer that uses an output already assigned to the selected layer generates an error message.

HINT: To add layers to a process, it is easiest to select an existing layer in the layers list, then click Copy. Click Paste repeatedly to insert several temporary layers. Next, assign the proper film and layers parameters to each of these temporary layers.

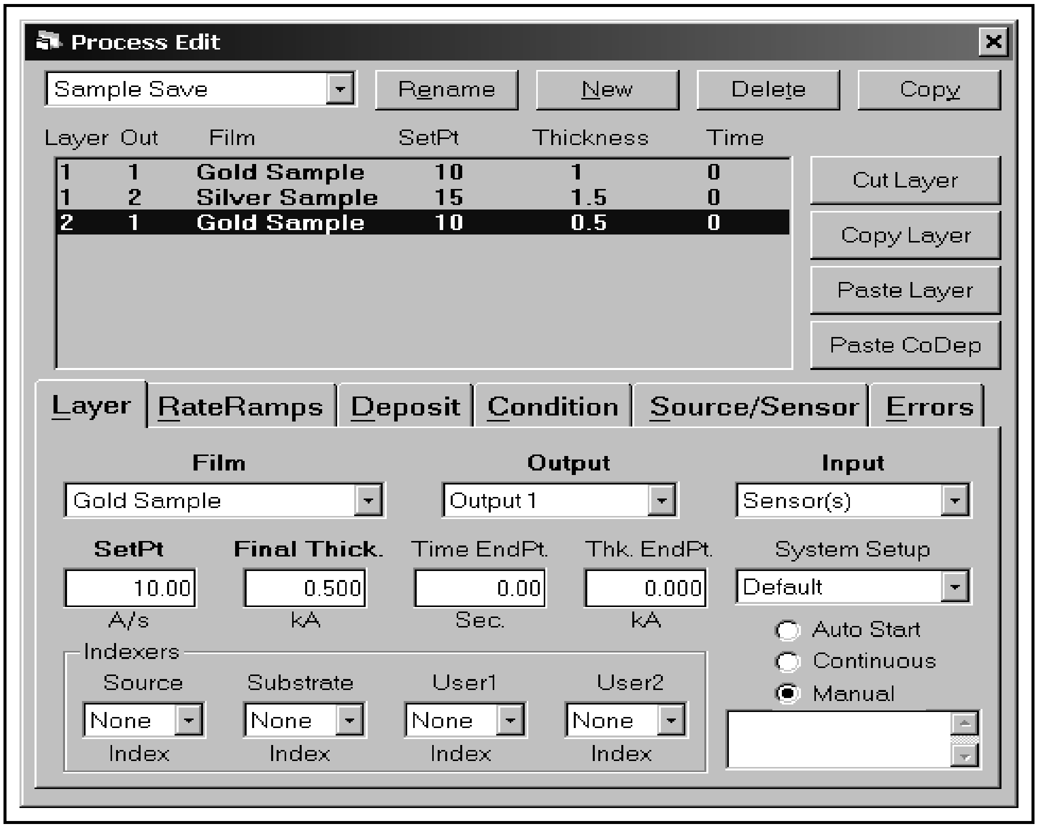
To change one of the temporary layers to a CoDep layer, highlight the temporary layer and click Cut Layer. Next click the layer desired for CoDep and click Paste CoDep to assign the selected layer.

Controls in the tabbed control apply to the layer selected above, in the Layers list. The Layer and Rate Ramp tabs assign layer-specific parameters to the selected layer. Note that captions on the Layer tab may change, depending on the input and output selections. The remaining tabs provide access to the film assigned to the selected layer.

NOTE: Edits to the Deposition, Condition, Source/Sensor, and Error tabs will affect all processes and layers that use the selected film!

3.5.1.1 Layer Tab

Figure 3-9 Layer Tab



Film DropDown Box: Assigns a film to the selected layer. A film is basically a Material, plus the other settings shown on the Deposit, Condition, Source/Sensor, and Error tabs.

Output DropDown Box: Selects the output that is used for deposition of the selected layer's film. A particular film often uses the same output (i.e., a thermal boat or E-Beam pocket).

NOTE: Due to the way outputs are stored in the process database, the physical output number (not its name) is listed in the layers listing. Outputs 1 and 2 refer to the first SQM-242 card outputs. Outputs 3 and 4 refer to the second SQM-242 card outputs (if installed). Outputs 13 and 14 are the SAM-242 card outputs (if installed).

Input DropDown Box: Selects the input used to measure and control deposition of the selected layer. The combination of an output and its input defines the deposition "control loop" for the selected layer. The Input selection can significantly alter operation of the deposition phase, as described in the following discussion on the SetPt parameter.

SetPt: The function of the setpoint parameter depends on the Input dropdown. If Sensor(s) are used as the input, the setpoint is Rate (in Å/s). This sets the initial Rate setpoint for the selected layer. Rate is controlled by the PID parameters for the film assigned to the layer. If no rate ramps are defined for the layer, this is the rate setpoint for the entire layer.

If the Input selected is Timed Power, the setpoint is shown as % Power. This sets a fixed % output Power during deposition. In Timed Power the Time Endpoint establishes the length of time for the deposition cycle. The layer will end when either the time endpoint is reached, or when the Final Thickness is reached, whichever occurs first.

If one of the SAM-242 analog inputs are selected, the setpoint is in volts (or the analog input's corresponding user-defined units). The layer will end when either Time Endpoint or Final Thickness is reached, whichever occurs first. See the Analog Inputs section later in this chapter for a discussion of programming for analog inputs.

Final Thickness: Sets the endpoint thickness for the layer. When final thickness is reached, deposition is stopped for that layer and the feed/hold phase is entered.

Time EndPoint: Sets an arbitrary time, after deposition begins, when the time setpoint relay is activated. During % Power and Analog Input deposition, it also sets the length of the deposition cycle.

Thickness EndPoint: Sets an arbitrary thickness that activates the thickness limit relay.

Auto/Manual/Continuous Start: Auto Start begins the next layer automatically upon completion of the previous layer. Continuous ignores Conditioning phases and controls continuously at rate setpoint (see Analog Inputs). If Manual Start is selected, the previous layer ends at its idle power and waits for the user to push the Start Layer switch. An optional User prompt can be entered for Manual Start layers. (This feature can be disabled by editing ShowPrompts in the SQS242.INI file).

NOTE: The following parameters are common to all of the films in a layer. In the previous dialog box shot for this section, both layer 1.1 and 1.2 would share common values for the following parameters. Layer 2.1 could have different values.

System Setup: System setup assigns outputs to their controlling sensors (called sensor mapping). It also determines which physical sensor and output connections are displayed on the main dialog box. See section 3.5.4 Edit: System for detailed system setup information.

Source Index: Assigns each film to a specific source indexer pocket (one of 16 values). Each of the six possible outputs is associated with a unique source indexer. These values are sent to the digital I/O (PLC) at the beginning of each layer.

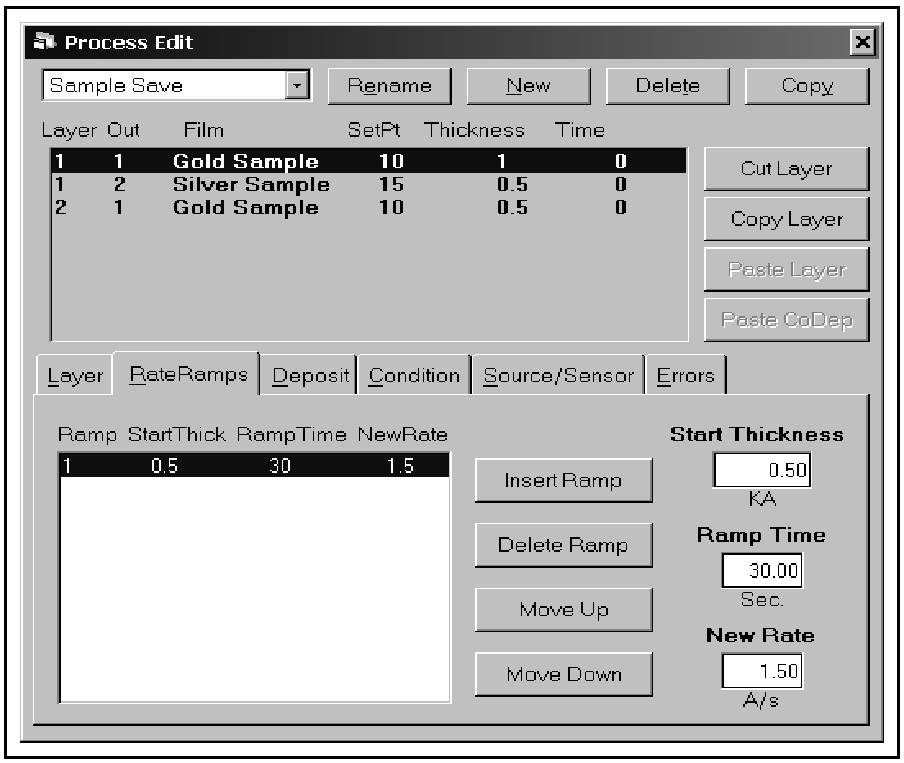
Substrate Index: If using a substrate indexer, assigns the substrate to one of 16 possible values. These values are set at the beginning of each layer.

User1/User2 Index: These additional values are output to the PLC for use as needed. Common applications are to select external equipment configurations. (The Index names, the range of values (0 to 15, or 1 to 16), and the first entry can be customized by editing entries in the SQS242.INI file - See section 3.8).

3.5.1.2 Rate Ramps Tab

Rate ramps cause changes to the deposition rate over time under PID control. Each rate ramp has a starting thickness, an elapsed time to ramp to the new rate, and a new rate setpoint. Each process layer can have an unlimited number of rate ramps. See Figure 3-10.

Figure 3-10 Rate Ramps tab



Insert Ramp: Inserts a new rate ramp for the selected layer, at the selected position in the rate ramps list. Existing rate ramps are shifted down.

Delete Ramp: Deletes the selected rate ramp.

Move Up: Shifts the selected rate ramp up one position.

Move Down: Shifts the selected rate ramp down one position.

Start Thickness: The thickness that triggers a timed ramp to a new rate. (Start thickness should be greater for each subsequent ramp, and less than the final layer thickness, otherwise the rate ramp is ignored.)

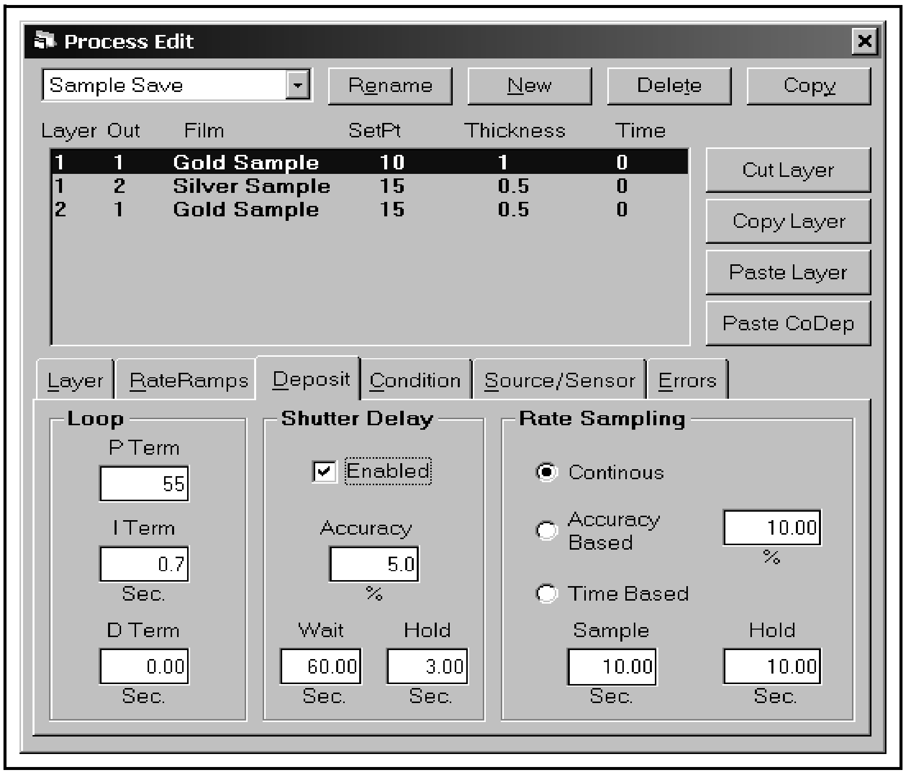
Ramp Time: The time (in seconds) to ramp to the new rate. If the rate ramp is too fast, a PID control error may be generated.

New Rate: The new deposition rate setpoint for the selected layer.

3.5.1.3 Deposit Tab

The **Deposit** tab contains parameters that directly affect the deposition phase of the process cycle. See Figure 3-11.

Figure 3-11 Deposit tab



P Term: Sets the gain of the control loop. High gains yield more responsive, but potentially unstable loops. Try a value of 25, then gradually increase/decrease the value to respond to step changes in rate setpoint.

I Term: The integral term controls the time constant of the loop response. A small I term, say 1 to 3 seconds, will smooth the response of most loops.

D Term: The differential term causes the loop to respond quickly to changes. Use 0 or a very small value (.1 x I Term) to avoid oscillations.

Shutter Delay: It is often desirable to assure stable process control before the substrate shutter opens. Enabling shutter delay requires that the system reach the programmed shutter delay Accuracy, and maintain that accuracy before deposition begins. If the accuracy is not reached within Wait seconds, the process halts. If accuracy is achieved, and maintained for Hold seconds, then the substrate shutter opens and deposition begins. The Thickness reading is zeroed at the end of the shutter delay period.

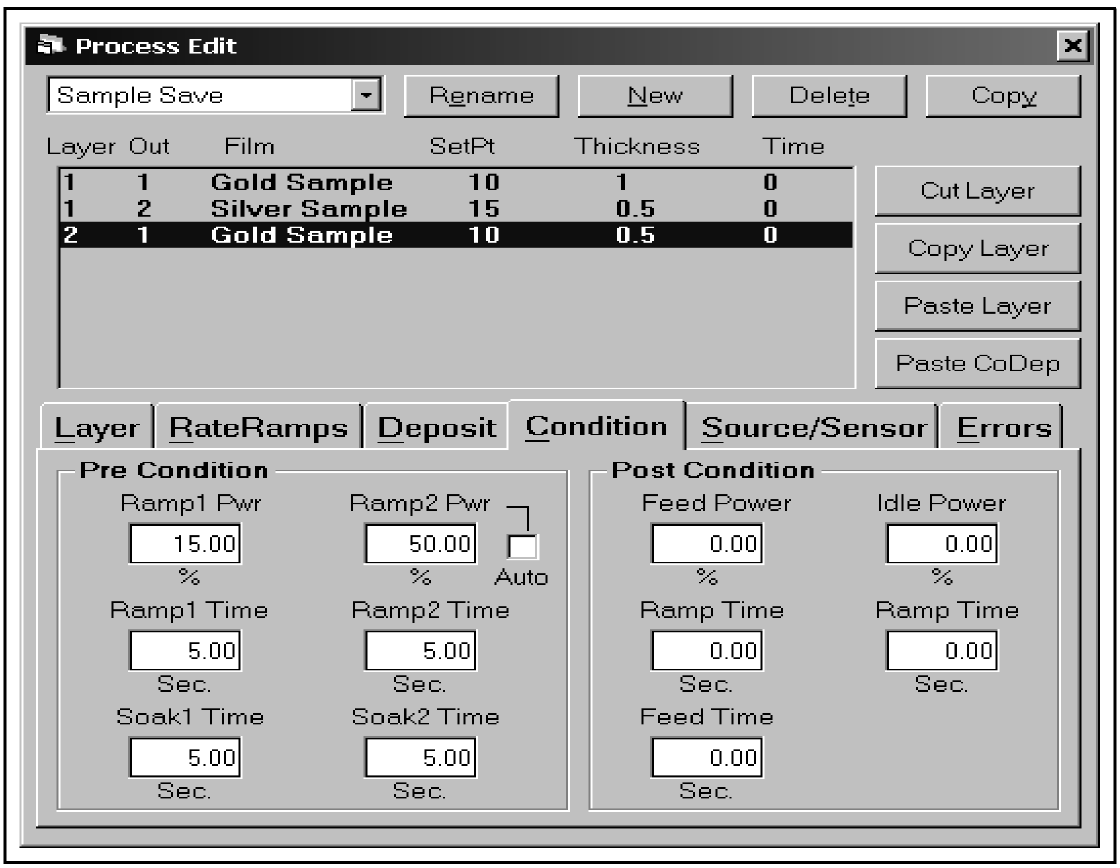
Rate Sampling: Rate sampling can extend the life of crystals. With rate sampling, the deposition rate is sampled for a period of time, then the sensor shutter is closed. Power is then held at the same level as the final power setting during the sample period.

Continuous selects no sampling; the sensor shutter remains open during deposition. Accuracy Based sampling opens the shutter until the desired accuracy is reached, leaves the shutter open for Sample time, then closes the shutter and holds power constant for Hold time. Time Based sampling opens the shutter for a fixed period of time then closes it for a fixed time.

3.5.1.4 Condition Tab

Before the deposition begins, it is often necessary to PreCondition the source material. This places the system at the proper power level to achieve rapid PID control when deposition begins. See Figure 3-12.

Figure 3-12 Condition tab



Ramp 1: Ramp power sets the power level that is desired at the end of the ramp phase, in % of full scale. Ramp time sets the time to ramp with a linear rate from the initial power to the Ramp power. Soak time sets the time the output remains at the ramp power level.

Ramp 2: Ramp 2 functions are the same as Ramp 1. Typically, Ramp 2 power is set near the power level required to match the desired initial deposition rate. Selecting the Ramp2 Power Auto checkbox stores the power over the last few seconds of the deposit phase for this film. That value is used as the Ramp2 power for the next run of the selected film.

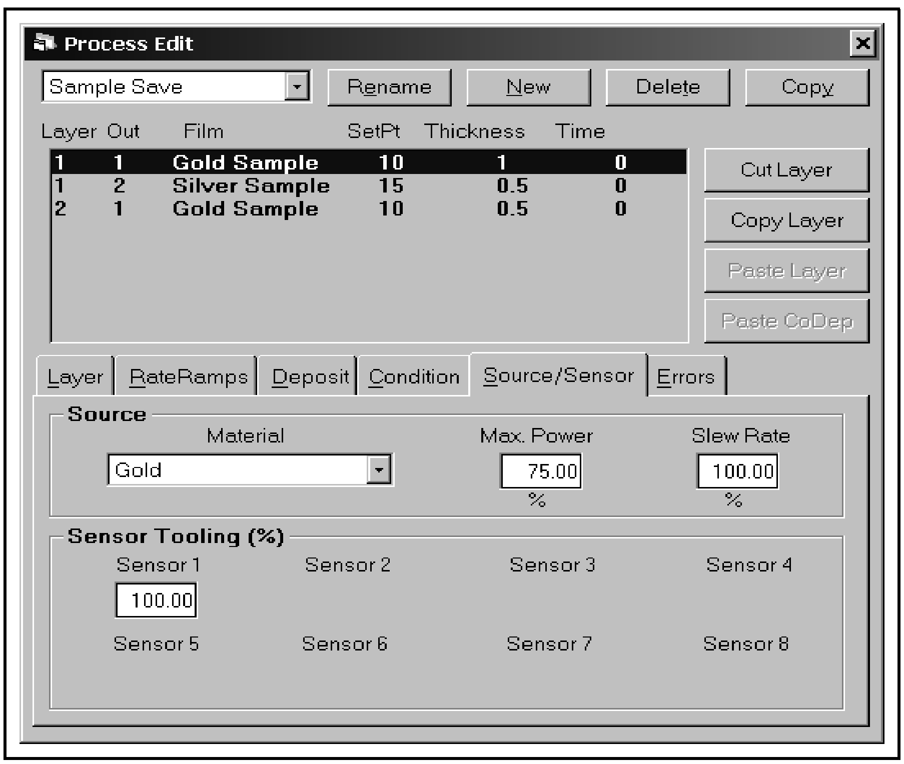
Feed: The feed phase begins immediately after deposition is complete. It holds output power at the level and time required to wire feed new material.

Idle: The Idle phase follows the Feed phase.

3.5.1.5 Source/Sensor Tab

The Source/Sensor tab controls the physical setup of the deposition system. See Figure 3-13.

Figure 3-13 Source/Sensor tab



Material: Selects the physical deposition material for the film selected on the Layers tab. Selecting a material sets the Density and Z Factor, as defined in the Edit Materials dialog box.

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Max Power: The maximum output power allowed for the selected output. The full scale output voltage is a function of the deposition power supply input specifications, and is set in the Edit System menu, Outputs tab. Max Power controls the maximum % of the full scale power that can be used by this film in all phases (PreConditioning, Deposition, and Feed/Idle).

Slew Rate: The maximum power change allowed on an output, per second. If rate ramps or PID power requirements exceed this value, an error will occur.

Sensor Tooling: Adjusts for sensor measured deposition rates that differ from the substrate deposition rate. For example, if the sensor sees only 50% of the substrate rate, set the value to 200%. Setting Tooling to 0% causes a sensor to be ignored for this film.

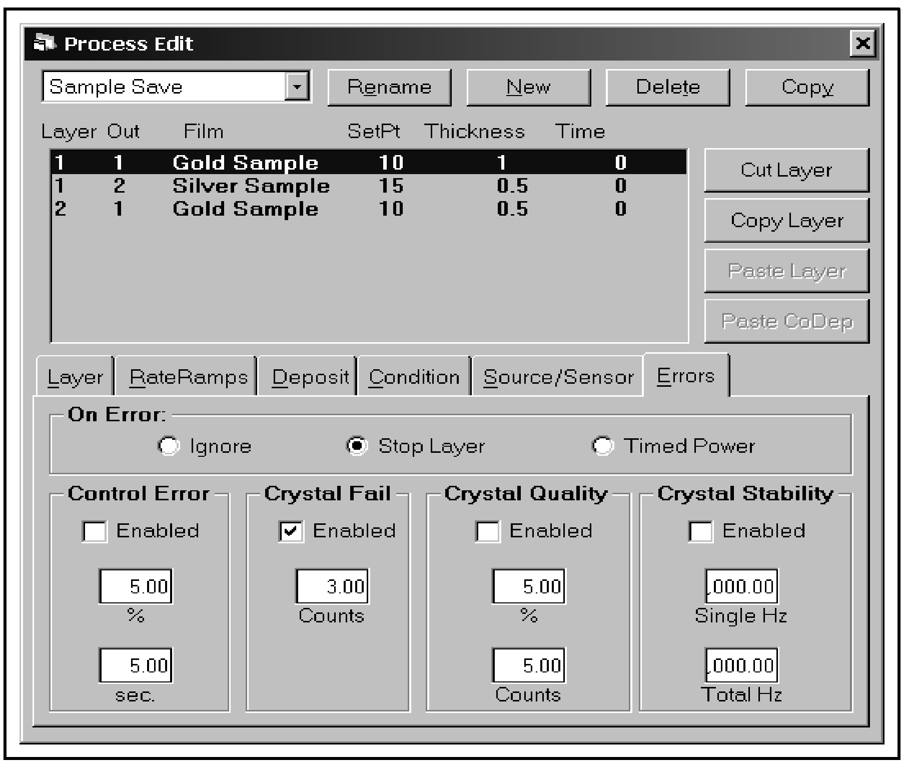
The System Setup selection on the Layer tab establishes which sensor(s) are visible. Only those sensors “mapped” to the layer’s output are visible.

3.5.1.6 Errors Tab

Several source or sensor error conditions are possible during deposition. This tab establishes the program's response to errors. See Figure 3-14.

NOTE: It is best to leave all error settings, except **Crystal Fail**, disabled until you are confident of the stability and repeatability of your process.

Figure 3-14 Errors tab



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Control Error: If the control loop cannot maintain the desired deposition rate (due to loss of source material, excessively high rate ramps, or equipment malfunction) a control error occurs. Control error % is the accuracy that must be exceeded for the specified time (in seconds) to trigger a control error. Use shutter delay accuracy to assure adequate process control before entering the deposition phase.

Crystal Fail: Establishes the number of bad readings (i.e., 0 Hz) from a sensor that generates a Crystal Fail condition. If a crystal fails, the PID loop will send the source supply to max power. Therefore, it is unlikely you will ever want to disable this error.

Crystal Quality: Each time the rate deviation for this film exceeds the % value, a counter is incremented. Each time the rate deviation is within the % value, the counter is decremented (to zero minimum). If the counter exceeds the Counts value during the entire layer deposition, an error occurs.

Crystal Stability: When material is being deposited, a crystal's frequency normally drops. At the end of crystal life, sensor frequency may briefly "mode hop" to higher frequencies. Single Hz is the largest single positive frequency shift allowed. Total Hz is the sum of positive shifts allowed during a film's deposition.

On Error: When an error condition occurs, three actions are possible. Ignore the error and let the PID loop attempt to maintain rate control. Stop the layer and allow the user to fix or manually control deposition. The last choice, Timed Power, uses the last good Rate/Power settings to "estimate" rate and thickness.

In Timed Power, the output is set to the power level that last yielded a rate reading within the Control Error % deviation setting (10% deviation if Control Error is disabled). The program then calculates the estimated thickness based on that rate and the deposition elapsed time. When the calculated thickness reaches thickness setpoint, deposition stops.

3.5.1.7 Analog Inputs

Normally the SQS-242 software uses SQM-242 card quartz sensor inputs to measure or control rate and thickness. The SAM-242 Analog Input Card extends this capability to allow measurement and control on DC voltage-based process variables such as temperature transmitters, pressure/flow controllers.

Analog input based control is treated, for the most part, identically to quartz sensor based control. Considerations for using an analog input are discussed below.

Layers Tab: In the Inputs dropdown, select one of the Analog inputs. In the Outputs dropdown, select the output that is to be controlled. Enter the desired setpoint. Normally this setpoint is in Volts, but can be converted to other units (e.g., degrees or PSI) in the Edit, System, Analog dialog box.

Use Time Endpoint to stop the analog layer after a set time. Otherwise, a Sensor input, programmed as a Codep layer, can control the layer endpoint. Final Thickness and Thickness Endpoint settings have no effect for an analog input.

If Continuous Start is selected the analog input controls to its programmed Layer Setpoint through all of the Ramp/Soak/Feed phases. This allows temperature or pressure control (for example) to be maintained through all phases of the layer. If Stop Layer is selected, control is still maintained at setpoint. Pressing Abort Process will set the output to zero.

Rate Ramps Tab: Setpoint ramps can also be programmed for an analog signal.

Deposition Tab: The PID and Shutter Delay controls operate the same as a Sensor input. Rate sampling is not possible for analog inputs.

Condition Tab: Conditioning is identical to that of a Sensor input.

Source/Sensor Tab: Only Max Power and Slew Rate are functional.

Errors: Only Control Error applies.

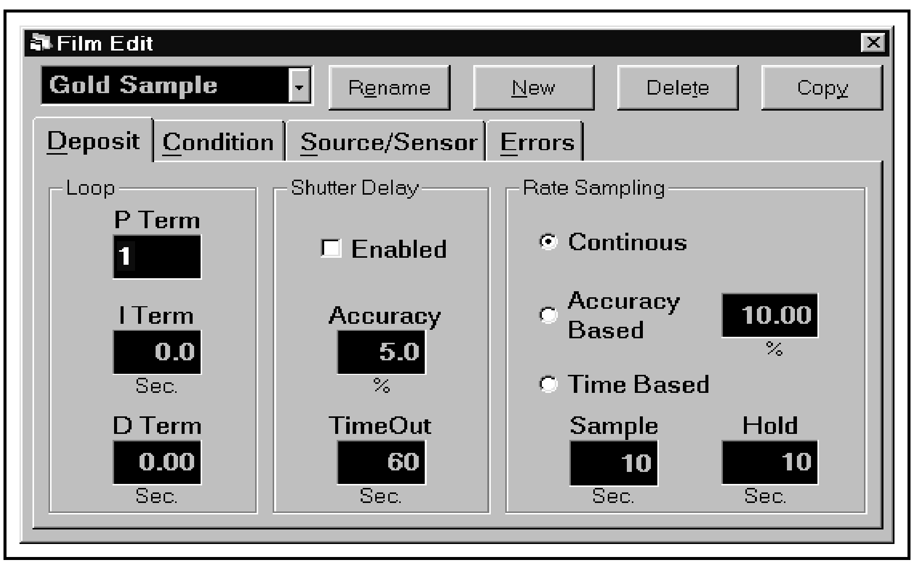
The Analog Input's measured value (converted to the defined units) and deviation from setpoint are shown below the graph. The analog input values are NOT shown on the normal Rate graph (the values could lead to poor rate resolution on the graph). Instead the analog input voltages are shown on the View, Analog graph. Volts are displayed on this graph, rather than the scaled units (again, to maintain adequate graph resolution).

3.5.2 Edit: Films

The Edit Films dialog, see Figure 3-15, allows you to rename, delete, and copy films. The functions in the tabbed control are identical to those for this film on the Edit Processes dialog.

NOTE: Edits to a Film will affect all processes and layers that use that film!

Figure 3-15 Film Edit dialog



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Film: A dropdown box that selects the film parameters displayed in the edit film dialog box.

Rename: Edits the name of the selected film.

New: Creates a new film.

Delete: Deletes the currently selected film from the database. A film cannot be deleted if it is used in ANY process! To delete a film, you must first delete the film from each process where it is used.

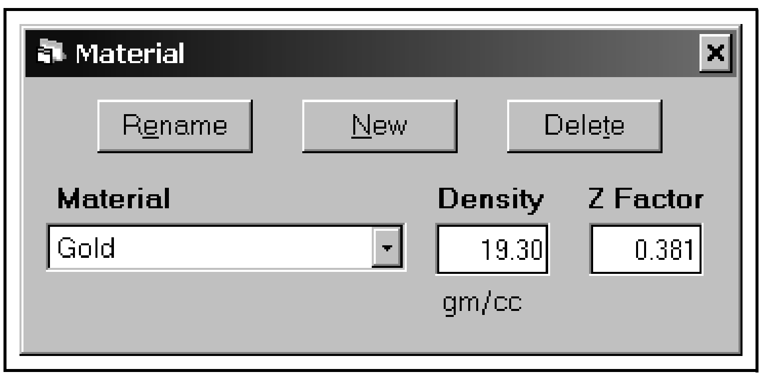
Copy: Creates a duplicate of the currently selected film.

The function of each Edit Films tab, and its associated controls, are identical to those detailed in the Edit Processes section. Please consult section 3.5.1 on page 3-8 for that information.

3.5.3 Edit: Materials

The Edit Material dialog, see Figure 3-16, provides the functions needed to build a materials database. In addition to the functions listed below, the main dialog box SoftKeys provide capabilities to add/edit/delete materials.

Figure 3-16 Material dialog



Rename: Edits the name of the selected material.

New: Creates a new material.

Delete: Deletes the currently selected material from the database. A material cannot be deleted if it is used in ANY process! To delete a material, you must first delete each film where it is used.

Material: Selects a material to edit.

Density: Sets the density for this material. Material density has a significant impact on deposition calculations.

Z-Factor: Sets the Z-Ratio, a measure of a material's effect on quartz crystal frequency change. Z-Ratio has no effect on measurements when using a new crystal. If the Z-Ratio for your material is not known, using crystals with >80% life will eliminate the effect of the Z-Ratio term.

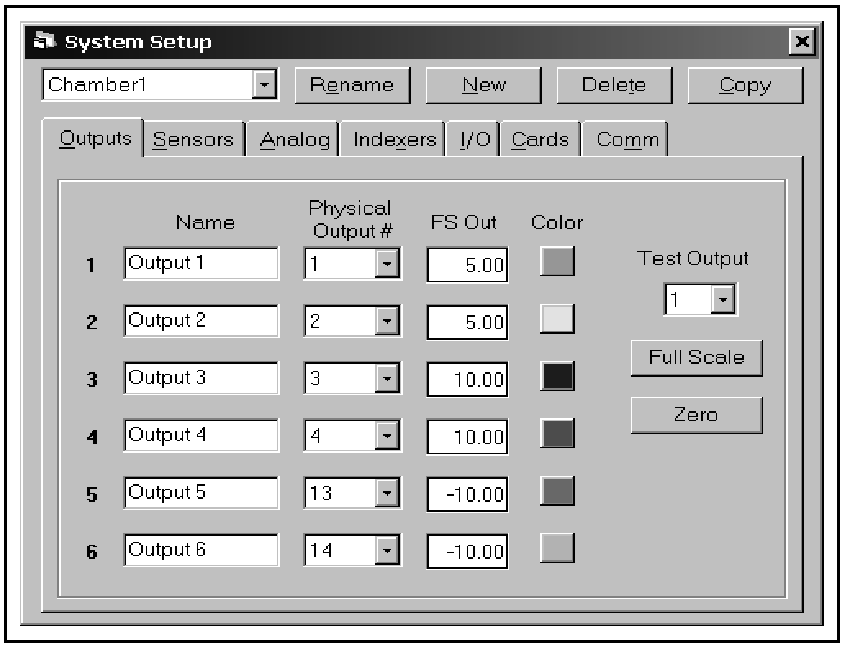
3.5.4 Edit: System

The System Setup dialog, Figure 3-17, configures the SQS-242 software to the physical setup of your deposition system. Several settings that control the overall operation of the program are also accessed in System Setup.

The combination of sensor input and control output assignments, known as a System Setup, are stored in the SQS-242 database. Most systems will have a single setup that applies to all processes. However, complex systems may use several different system setups within a single process.

NOTE: Settings on the Outputs, Sensors, Analog, and Cards tabs are unique for each System Setup. Settings on the Indexers, I/O, and Comm tabs apply to all System Setups. Output colors are also common to all setups.

Figure 3-17 System Setup dialog



Controls along the top of the System Setup dialog box apply to the selected system setup:

System Setup: A dropdown box that selects the setup to be edited. Defaults to the current setup.

Rename: Edits the name of the selected setup.

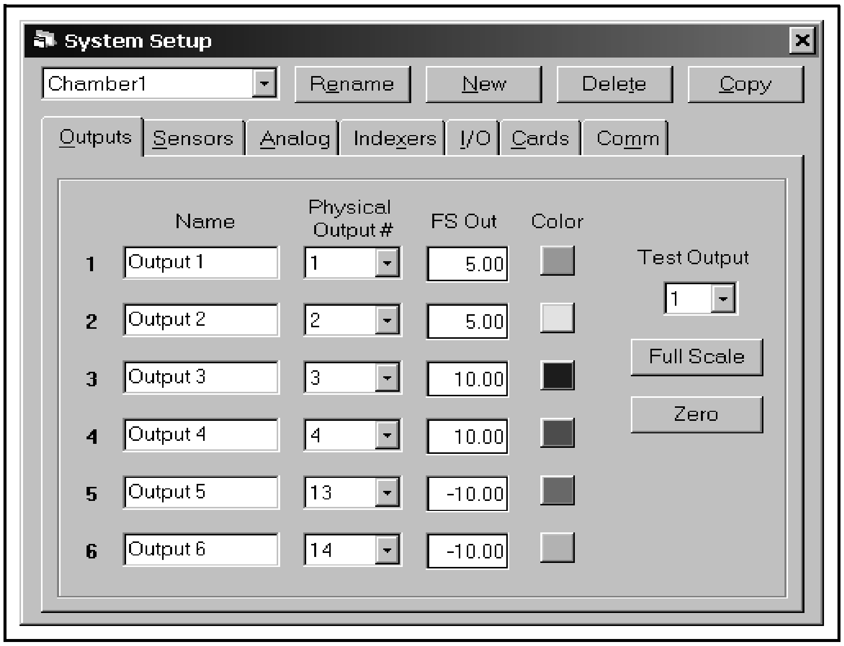
New: Creates a new system setup, based on the existing default setup.

Delete: Deletes the currently selected setup from the database. If the setup is used in a process, an error message is displayed.

Copy: Creates a duplicate of the currently selected system setup.

3.5.4.1 Outputs Tab

Figure 3-18 Outputs tab



Name: Assigns a name to each displayed output. For clear display, keep the name to less than 8 characters.

Physical Output: Up to six SQM-242 cards (physical outputs 1 to 12) and a single SAM-242 card (physical outputs 13 and 14) may be installed in a computer. However, the SQS-242 software can display and control a maximum of 6 outputs simultaneously. Use this dropdown to assign a “physical” output to a “display” output.

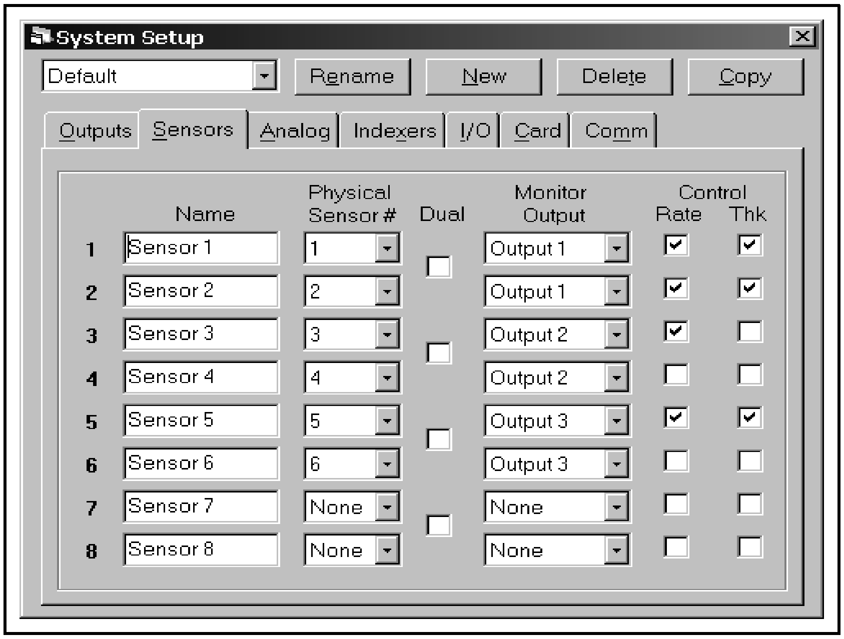
FS Out: The input voltage required by the deposition source power supply to produce 100% output power. Positive or negative full scale values are possible.

Color: Selects the color used to graph and display output data.

Test Output: Useful for testing output wiring and Full Scale voltage settings. Select an output, then click Full Scale to set the SQM-242 card output to its Full Scale voltage. Click Zero to return the selected output to 0 volts.

3.5.4.2 Sensors Tab

Figure 3-19 Sensors tab



Name: A meaningful name assigned to each sensor. For clear display, keep the name to less than 8 characters.

Physical Sensor: Up to six SQM-242 cards (physical sensors 1 to 24) may be installed in a computer. However, the SQS-242 software can display a maximum of 8 sensors simultaneously. Use this dropdown to assign a “physical” sensor to a “display” sensor.

Dual: Indicates that a pair of sensors is set up as primary/secondary duals. When a primary sensor fails, the SQS-242 switches to the secondary sensor.

Monitor Output: Select the output that each sensor is positioned to measure. The rate and thickness displayed by the sensor will be calculated based on the material assigned to the selected output.

Control Checkboxes: Click Rate to assign the sensor to the PID rate control loop for the assigned output during deposition. Click Thk to use the sensor for Thickness endpoint detection. Typically you will check both boxes so that the sensor controls to rate setpoint and detects the thickness endpoint. If multiple sensors are assigned to control the same output, the sensor readings are averaged when calculating rate and thickness.

Uncheck both boxes to have a sensor monitor an output, without controlling deposition rate or stopping when final thickness is reached.

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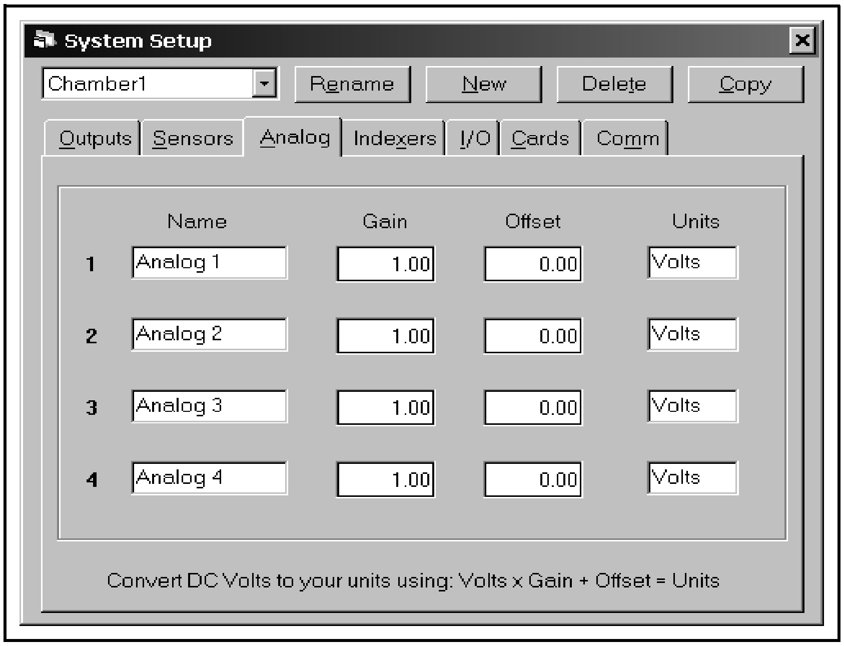
3.5.4.3 Analog Tab

Figure 3-20 Analog tab



The SAM-242 analog input card measures DC voltages in the +/-10 volt range. These voltages may represent temperature, flow, or any other process variable. The analog tab allows you to modify the display to show values in the desired units, using a linear (y = mx + b) transformation.

For example, assume you have a temperature transmitter that sends 0V at 0°C and 1V at 100°C. To display temperature in °F, set the Gain to 180, Offset to 32, and Units to DegF. The SQM-242 will display setpoints and measurements associated with the analog input in degrees F.

To leave the analog input display in Volts, set Gain = 1 and Offset = 0.

Name: A meaningful name assigned to each analog input. For clear display, keep the name to less than 8 characters.

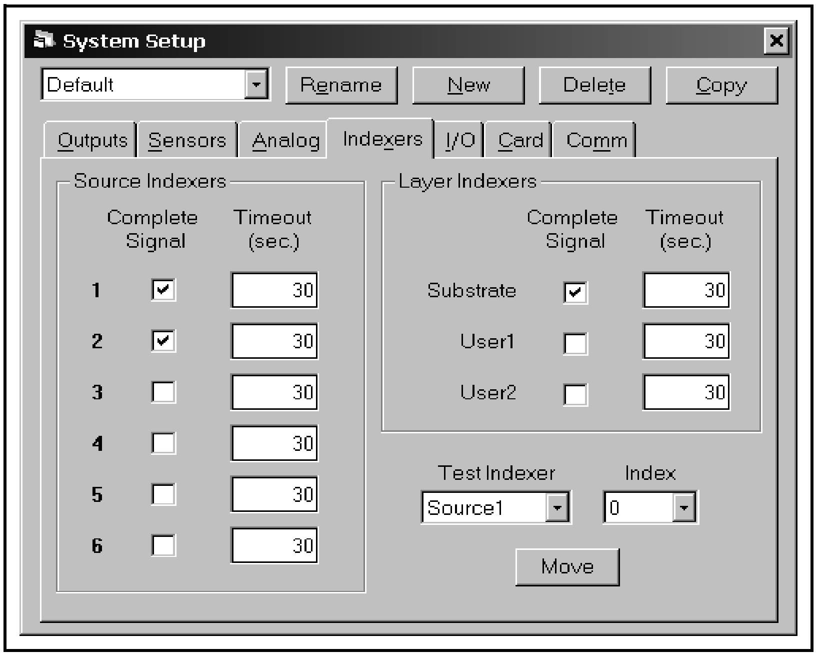
Gain: The gain term for transforming voltage to measured units. This is the m term in y = mx + b.

Offset: The offset term for transforming voltage to measured units. This is the b term in y = mx + b.

Units: The units that you wish to display for the analog input.

3.5.4.4 Indexers Tab

Figure 3-21 Indexers tab



Source Indexers: A unique source indexer (pocket rotator) is available for each output used. The source indexer moves at the beginning of each layer.

Layer Indexers: Three “layer indexers” are also available. Layer indexers also move at the beginning of each layer. Layer indexer values are useful for control of substrate indexers or other external process equipment.

NOTE: The Layer Indexer names, the range of values, and the first entry can be customized by editing entries in the SQS242.INI file (see section 3.8).

Complete Signal: Check this box if your indexer sends a signal indicating that the move is complete.

Timeout: If Complete Signal is checked, the process will halt if a move complete signal is not received within this timeout period. If Complete Signal is not checked, the process waits for this fixed time period before starting a layer.

Move: Useful for testing indexer functions manually. Select an indexer, then an index (pocket). Click Move to move to the selected index. Layer indexers are typically named Substrate, User 1, and User 2. Layer indexer names can be edited in the SQS242.INI file (see section 3.8).

3.5.4.5 I/O Tab

A PLC must be used to provide digital I/O capabilities. The I/O tab assigns deposition events (i.e., open shutter, start deposit, final thickness, etc.) to the physical relays and inputs on the PLC.

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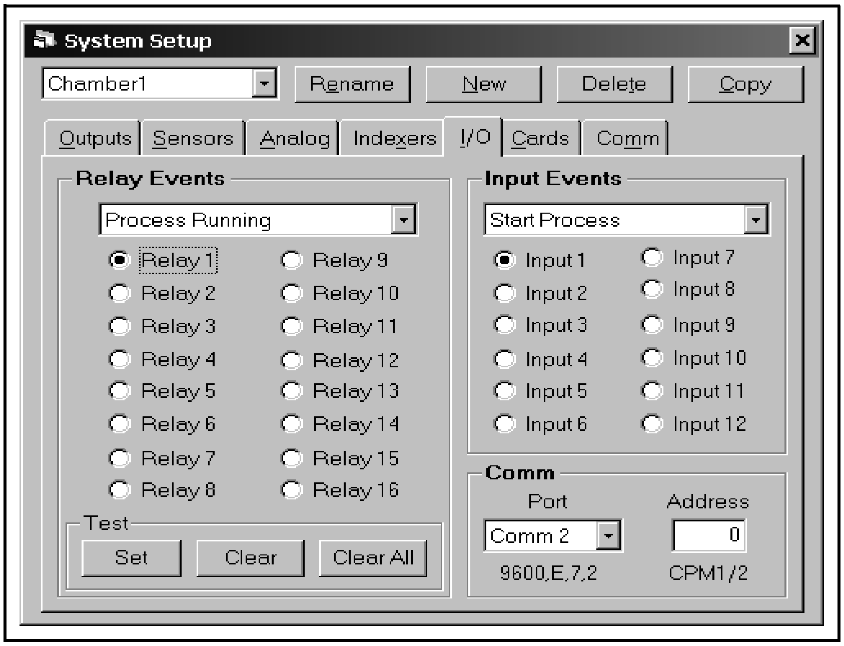
NOTE: Omron CPM series PLCs number relays from 10.00 to 10.07, then 11.00 to 11.07. These correspond to Relays 1 to 16 on the I/O tab. Similarly, inputs 0.00 to 0.11 on the Omron PLC correspond to inputs 1 to 12 on this dialog box. See Figure 3-22.

Figure 3-22 I/O tab



Relay Events: The relay events dropdown box lists the deposition events that can cause a relay output to be activated. To assign a deposition event to a relay, click the Relay #, then select the desired event from the dropdown box. As you click each Relay#, the dropdown will change to show its currently assigned event. A description of each relay (output) event follows:

Source Shutter 1 to 6

These relays control the Shutter that covers your deposition source. At the beginning of the deposit phase the relay will close its contacts. When the deposit phase finishes the shutter relay contacts open.

Sensor Relays 1 to 8

These relays control sensor shutters. Their function depends on whether you have single or dual sensors.

If Dual Sensor is not selected (i.e., a single sensor), the relay contacts close when Shutter Delay phase is entered on a layer with the sensor enabled. As an example, let’s say you have sensors 1 and 3 enabled for Film 1 and sensors 2 and 4 enabled for Film 2. When you start Film 1 Shutter Delay phase, the contacts for Sensor Relays 1 and 3 will close. When you start Film 2, these contacts open and the contacts for Sensor Relays 2 and 4 will close when Shutter Delay is entered.

If the software is configured for dual sensors, the relay operation is considerably different. Dual sensors use pairs of sensors (i.e., Sensor 1 and 2, or Sensor 3 and 4). With Sensors 1 or 3 selected, the associated relay contacts are open. If a Crystal Fail is detected, the relay contacts for the failed sensor will close to select the second sensor in the Dual Sensor assembly for the duration of the film.

Xtal All Good and Xtal All Fail Relays

These two relays provide an indication of the general health of your sensors. If the Xtal All Good Relay is closed, then all enabled sensors are returning a valid reading. If the Xtal All Fail Relay is closed, none of the enabled sensors are returning a valid reading.

Process Stopped and Running Relays

These relays indicate the overall status of the process. The Process Running relay closes as soon as Start Process is selected (by front panel or digital input), and opens when Abort Process is selected. Even if a layer is stopped within a process, the Process Running relay remains closed until the last film of a process has finished. The Process Stopped relay contacts behave in the inverse manner.

Layer Stopped and Running Relays

The Layer Running relay closes as soon as Start Layer is selected (by front panel or digital input), and opens when Stop Process is selected. The Layer Stopped relay contacts behave in the inverse manner.

Deposit Phase Relay

This relay indicates that you are in the deposit phase of a film. It is like having the two Source Shutter Relays connected in parallel. If you have shutter delay enabled, this relay will wait until the end of the shutter delay before going active.

Pre-Cond Phase Relay

This relay closes for the preconditioning phases (Ramp1, Soak1, Ramp2, Soak2) of a film.

Soak Hold Phase Relay

This relay closes for the Soak and Hold phases after deposition.

Process Active Relay

This relay action is similar to the Process Running relay, except it will open if the process is temporarily halted for any reason, e.g. a Manual Start layer.

Manual Mode Relay

Closes when the program is placed in Manual mode.

Max Power Relay

Closes when any control voltage output is at the programmed maximum power level.

Thickness Setpoint Relay

This relay will become active when the Thickness Setpoint is reached. This is a programmable process parameter.

Time Setpoint Relay

This relay will become active when the Time Setpoint has been reached. This is measured from the beginning of the deposit phase, and is a programmable parameter.

Test: The Test section provides a simple means of testing I/O wiring. To close a relay, select the desired relay button, then click Set. Click Clear to open the relay contacts.

Input Events: The input events dropdown box lists the deposition events that can be caused by an external digital input. To assign a deposition event to an input, click the Input #, then select the desired event from the dropdown box. As you click each Input #, the dropdown will change to show its currently assigned event. A brief description of each input event follows:

Start Process Input

Triggering this input is the same as pushing the Start Process button.

Abort Process Input

Triggering this input will abort the process.

Start Layer Input

Triggering this input will start or restart the current layer.

Stop Layer Input

Triggering this input will stop the current layer.

Start Next Layer Input

Triggering this input will skip the current layer and start the next layer.

Zero Thickness Input

This will zero the thickness. It is identical to pressing the Zero button.

Force Final Thickness Input

Triggering this input has the same effect as reaching Final Thickness setpoint.

Comm Port: Selects the serial port used to communicate with the PLC. The Comm Port dropdown lists available ports. However, some ports may be used by other devices (modem, mouse, etc.). Select Disabled to prevent I/O from using the PLC.

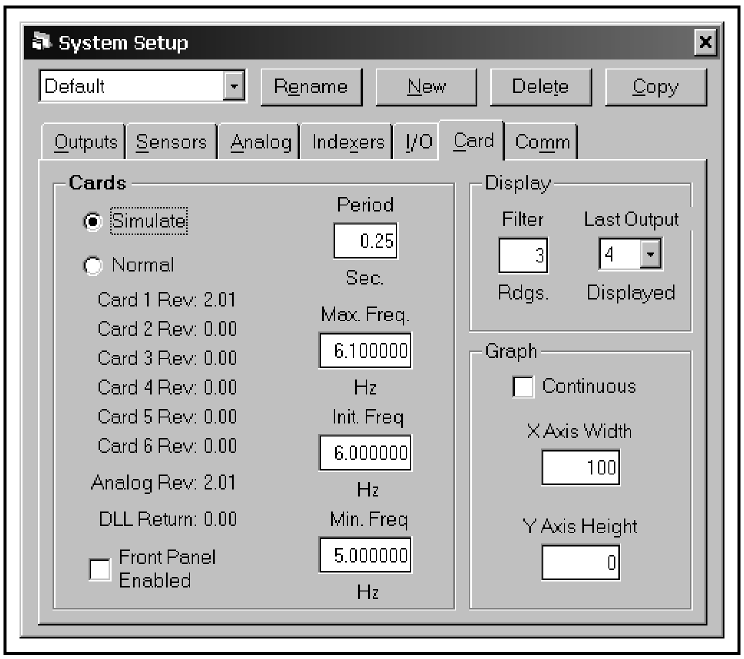
The communications parameters (baud, parity, bits, stop) are shown below the Comm Port dropdown. The baud rate can be changed in the SQS242.INI file (see section 3.8).

Address: Several PLCs can be controlled from a single computer Comm Port by connecting their expansion ports. The slave address of each such PLC is usually set by a rotary or dip switch, and must be unique. Single PLC systems usually use Address 0. Consult your PLC User Manual.

If the PLC is found at the selected Comm Port and Address, the COMM LED on the PLC will flash continuously. The PLC model is displayed below the address.

3.5.4.6 Card Tab

Figure 3-23 Card tab



Mode: In Normal mode, the SQS-242 gets readings from the SQM-242 card(s). In Simulate mode, the SQS-242 generates simulated readings even if a card is not installed. This is useful for testing new processes and learning the software.

The firmware revisions of the installed SQM-242 cards are listed below the mode buttons. A value of 0 indicates the card is not installed. Analog Rev refers to the revision of an SAM-242,card if installed. DLL Return is the status of the SQM-242 card's Windows drivers. DLL return values of 9XX indicate a card installation error.

Front Panel Enabled: When used with the SRC series computer, enables/disables the SQS-242 software to read the SoftKeys.

Period: Sets the measurement period between 0.2 seconds (5 readings per second) and 2 seconds. A longer period gives higher reading accuracy, especially at low rates.

Max/Init/Min Frequency: The frequency values for the quartz crystal sensors used as inputs to the SQM-242. Typical values are Max=6.1, Init=6.0, Min=5.0. Sensor readings outside the min/max values cause a Sensor Fail error.

Filter: Sets the number of readings used in the reading filter. A low setting gives rapid response to process changes, high settings give smoother graphs.

Last Output: Limits the maximum number of outputs shown on the main dialog box.

Continuous: Check this box to have the graph continuously display data for each phase of the deposition cycle. Uncheck this box to clear the graph at the end of the preconditioning, deposition, and post conditioning phases.

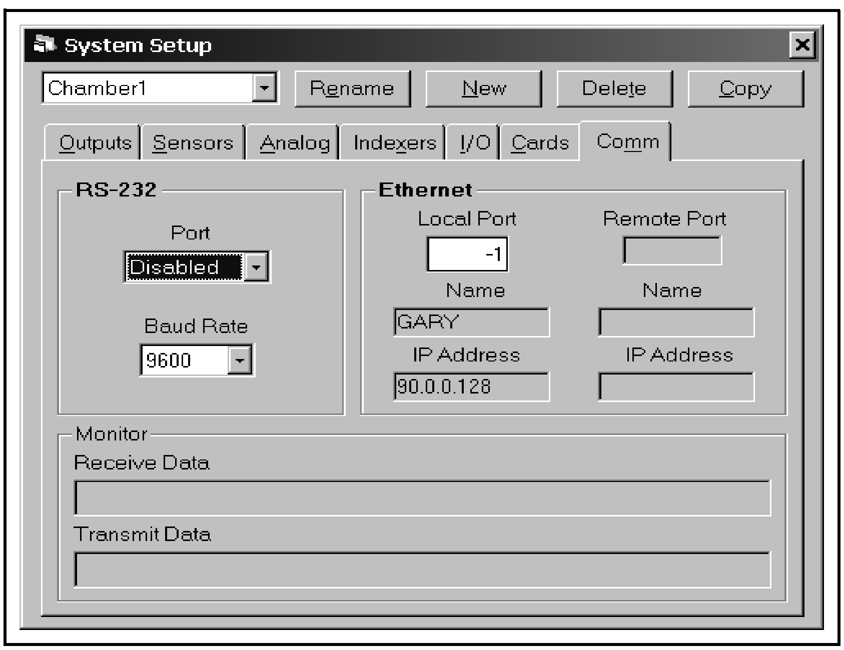
Graph X Axis: Sets the width of the X axis during deposition, normally 100 seconds. Whatever width is selected, the graph automatically scrolls the X axis as required. Due to screen resolution, setting a width of more than 10 minutes (600 seconds) may cause some data points to not be plotted.

Graph Y Axis: Sets the Y axis Rate graph maximum value during deposition. Setting the value to 0 causes the Y axis to automatically scale to the highest rate displayed.

3.5.4.7 Comm Tab

The SQS-242 software can be controlled by another computer through an RS-232 or Ethernet connection. See section 5.2 on page 5-1 for more details.

Figure 3-24 Comm tab



RS-232 Port: Selects the comm port used for serial communications with another computer. The Comm Port dropdown box lists available ports.

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Baud Rate: Sets the baud rate used for serial communications.

Ethernet Ports: Local Port sets the TCP/IP port used by the SQS-242 software for Ethernet communications (1001 is a typical value, -1 for no Ethernet). When communications is established, Remote Port displays theTCP/IP port of the remote computer communicating with the SQS-242 software.

Ethernet Name: Displays the name of the local and remote computers, as set in their Windows, My Computer dialog box.

Ethernet IP Address: Displays the IP address (xxx.xxx.xxx.xxx) of the local and remote computers.

Receive Data: Displays the Query and Update requests received from the Comm and Ethernet port. See section 5.6 on page 5-2 for a description of the serial communications protocol.

Transmit Data: Displays the response to Query and Update requests received from the Comm and Ethernet port.

NOTE: The Comm tab does not monitor communications with the PLC.

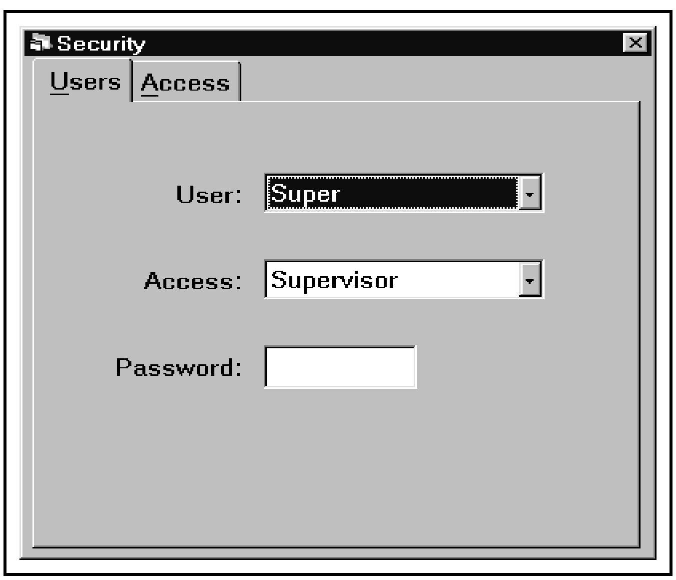
3.5.5 Edit: Security

The Security menu assigns Users, their Password, and their Access Level. It also provides a flexible way to assign program functions to different Access Levels.

NOTE: The Security dialog box is available only to users with Supervisor Access.

3.5.5.1 Users Tab

Figure 3-25 Users tab



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User: Dropdown box used to select an existing user, to edit their Access or Password. It is not possible to edit or add a user name in the User dropdown. Use the New SoftKey to create a new User. Use the Delete SoftKey to delete the selected user.

Access: Assigns a program access level to the selected user. Generally speaking, Supervisor (SUPV) provides access to all program functions. Technicians (TECH) have access to a subset of functions. While User level access (USER) has access to only those functions needed to run deposition processes. See the Access Tab section to assign SUPV, TECH, and USER program capabilities.

Password: Each user will typically have their own password. When a password is entered, a second box will appear for password confirmation. If the Password box is left blank, no Password is needed for that user to login.

NOTE: User names and passwords are limited to A-Z, 0-9, _, -, and space. Passwords are a maximum of 8 characters.

3.5.5.2 Access Tab

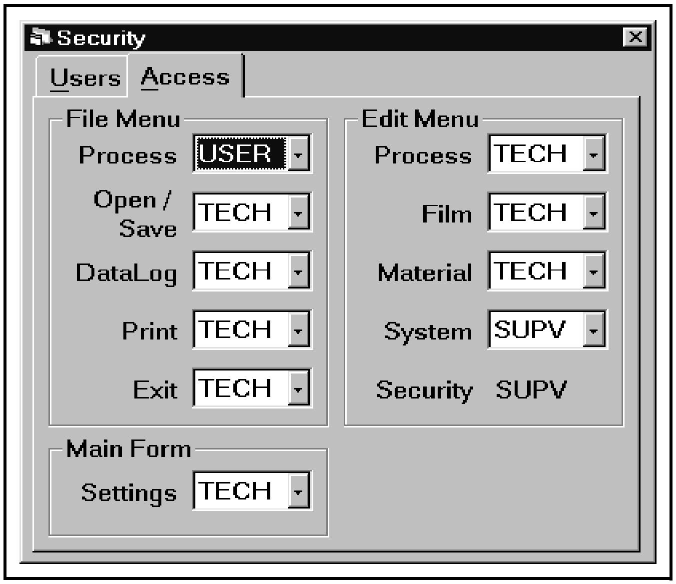
The Access tab allows Supervisors to assign which program functions are available to each of the three Access Levels. When a program function is assigned to a particular access level, it is automatically available to higher access levels.

In Figure 3-26, every user has access to the File Process menu and the File Exit menu. Only Supervisors have access to the Edit System and Edit Security menus. The remaining menus are assigned TECH access. They will be available to TECH and SUPV users, but not to USER access users.

The settings along the right side of the Main Form can be viewed by any user, but values can only be edited by TECH or higher access.

Those who login with USER access can select and run processes, but they cannot edit process parameters. TECHs can also select and run processes (because those functions are assigned to a lower level access). However, TECHs can also edit process parameters. Only Supervisors can change System Setup or Security assignments.

Figure 3-26 Access tab



3.6 View Menu

The View menu controls the appearance of the main display.

Film Settings: Displays/hides a ribbon of commonly accessed process settings along the right of the dialog box. Additional process parameters are available in the Edit menu. When displayed, the settings ribbon allows the user to easily modify process settings during deposition without leaving the main dialog box. Changes are made to the current process and the process database immediately. In CoDeposition, first click on the desired film to display its parameters.

Film Readings: Displays/hides film deposition readings along the bottom of the dialog box. Readouts of Film, Rate, Deviation, Thickness, and Power are displayed simultaneously for each of the active outputs. The rate, deviation, and thickness readings displayed represent an average of the quartz sensors assigned to each film.

Sensor Readings: Displays/hides a pop-up window of sensor rate, thickness, remaining life, and frequency readings. Unlike the main dialog box's Film Readings, this display is the raw data coming from each sensor. In addition, the output (i.e., PID control loop) that each sensor is assigned to is displayed. Sensor assignments are established on the Sensor tab of System dialog box.

A (P) in the Control column indicates the sensor is the primary sensor of a dual sensor pair. (S) indicates a secondary sensor. An (R) in the Control column indicates that the sensor is being used only for rate control. A (T) indicates the sensor is used only for Final Thickness endpoint detection. An (M) indicates the sensor is being used to monitor, but not control, the output. These options are selected on the Sensor tab of System dialog box

NOTE: The Sensor Readings dialog box can be sized to also show SAM-242 card analog input readings and digital I/O information. The digital I/O information is useful for troubleshooting I/O problems during setup.

Rate Graph: Fixes the main graph to deposition rate. Deposition rate is useful during the shutter delay, rate ramp, and deposition phases. During other phases, the power output graph is usually more useful.

Deviation Graph: Fixes the main graph to display percent deviation from the rate setpoint. Rate deviation is useful for fine tuning the PID control loop.

Power Graph: Fixes the main graph to output power. Output power is directly adjusted during the PreConditioning, feed, and hold phases. Output power is also useful during the deposition phases to detect error conditions, which cause oscillations. Be sure the Full Scale voltage is set properly in the SQM-242 Setup menu.

Sensors Graph: Normally the graph displays output, or film-based information. The Sensors Graph selection displays the rate readings from each individual sensor assigned to a system setup. It is a graphical display of the Rate column of the Sensor Readings dialog box.

Analog Graph: If an SAM-242 analog input card is installed, this graph shows the voltage readings from each analog input assigned to a system setup.

Automatic: Changes the main graph to display the most pertinent information for each deposition phase. During preconditioning, output power is displayed. During shutter delay, rate ramps, and deposition, the main graph displays deposition rate. During feed and hold phases, the graph reverts to output power.

NOTE: To alter the appearance of a graph, right-click anywhere on the graph. Use the Graph Property Page dialog box to alter the graph to your preferences. To permanently save the changes, click the Control tab, the General tab, then the Save button. Save the graph setup to the appropriate .OC2 file for the graph you are modifying.

High Resolution: When this option is checked, rate is displayed to 0.01 Å/s, and thickness to 0.1kÅ. This can be useful for low rate applications, but annoying for moderate rates. The SQM-242 card resolution for PID control is unchanged.

3.7 Software Specifications

Display

Graphs . . . . Rate, Deviation, Power

Readouts . . . . Rate, Dev, Thick, Power

Process Parameters

Name . . . . 12 characters

Processes . . . . Unlimited

Layers . . . . Unlimited

Films . . . . Unlimited

Rate Ramps . . . . Unlimited

Sensors (Dual) . . . . 1 to 8 (4 Dual)

Sources . . . . 1 to 6

Layer Parameters

Film . . . . Any defined

Output . . . . 1 to 6

Input . . . . Sensor(s)
Timed Power
Analog Input

SetPoint . . . . 0.00 to 999.99 Å/s
0.00 to 100.00% Power
0.00 to10.00 V(dc)

Final Thickness . . . . 0.0 to 999.9 kÅ

Time EndPoint . . . . 0 to 30000 s

Thickness EndPoint . . . . 0.0 to 999.9 kÅ

Start Mode . . . . Auto/Manual

Source Indexers . . . . 6, Index 1-16

Layer Indexers . . . . 3, Index 1-16

Rate Ramp Start. . . . . 0.0 to 999.9 kÅ

Rate Ramp Time . . . . 0 to 1000 s

New Rate . . . . 0.00 to 999.99 Å/s

Film Parameters

Name . . . . 12 characters

Ramp Time (1,2) . . . . 0 to 30000 s

Soak Power (1,2) . . . . 0.0 to 100.0%

Soak Time (1,2) . . . . 0 to 30000 s

Shutter Delay Time. . . . . 0 to 200 s

Shutter Delay Error . . . . 0.0 to 30.0%

P Term . . . . 1 to 9999

I Term . . . . 0 to 999.9 s

D Term . . . . 0 to 99.9 s

Control Error. . . . . Ignore/Stop/Hold

Control Error Set . . . . 0 to 30.0%

Feed Ramp Time . . . . 0 to 30000 s

Feed Power . . . . 0.0 to 100.0%

Feed Time . . . . 0 to 30000 s

Idle Ramp Time . . . . 0 to 30000 s

Idle Power . . . . 0.0 to 100.0%

Tooling (Sensor 1 to 8) . . . . 10.0 to 999.0

Max Power . . . . 0.0 to 100.0%

Slew Rate . . . . 0.0 to 100.0%/s

Source Index (Pocket) . . . . 0 to 15

Material Parameters

Name . . . . 12 characters

Density . . . . .0.40 to 99.99 gm/cm^3

Z-Factor . . . . 0.100 to 9.900

Digital Inputs *(available only with PLC option)*

Start Process

Stop Process

Start Layer

Stop Layer

Start Next Layer

Zero Thickness

Force Final Thickness

Substrate Index Complete

Source Index Complete

Relay Outputs *(available only with PLC option)*

Source Shutter . . . . 1 to 6

Sensor Shutter . . . . 1 to 8

All Crystal Fail

All Crystal Good

Process Running

Process Stopped

Process Active

Deposit Phase

Pre-Cond Phase

Feed/Idle Phase

Manual Mode

Max Power

Thickness Setpoint

Time Setpoint

Final Thickness

Substrate Index Select . . . . 0 to 15

Source Index (Pocket) Select. . . . . . 0 to 15

Security

User Name . . . . 16 characters

Password . . . . 8 characters

Access . . . . 3 levels

Computer Interface

Type . . . . RS-232, Ethernet, ActiveX

3.8 INI File Parameters

Parameters that control operation of the SQS-242 program are stored in the SQS242.INI file. Most of these are easily altered within the program and updated automatically.

However, a few of the parameters cannot be changed within the program. Use a text editor to alter the parameters listed below.

CAUTION

Always make a backup of the INI file before editing!

MDISize = Left, Top, Width, Height (Screen size and location (in pixels))

Debug = True or False (Show SQM-242 card error messages)

Show = True or False (True loops continuously through a process)

KillErrLog = True or False (True clears error log each time application)

NumberFormat = 0 or 1 (0 uses Windows setting for number format)
(1 uses the U.S. format (i.e., 1,000.00))

BackColor = Color (Default is BLACK)

ForeColor = Color (Default is LIGHTGRAY)

HighLightColor = Color (Default is WHITE)

The next four parameters control setup of the 4 indexer values where:

Name is the Indexer label on the Process form

Start is the first index number, typically 0 or 1

End is the last index number, typically 15 or 16

First is the text displayed for the Start index number

SourceIndex = Name, Start, End, First

LayerIndex1= Name, Start, End, First

LayerIndex2= Name, Start, End, First

LayerIndex3= Name, Start, End, First

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Chapter 4
Digital I/O

4.1 Introduction

Digital I/O for the SQS-242 software can be handled by an inexpensive PLC. This section will cover interfacing a Omron CPM2 series PLC to the SQS-242 card and PC. It is not necessary, however, to use external I/O with the SQS-242 software.

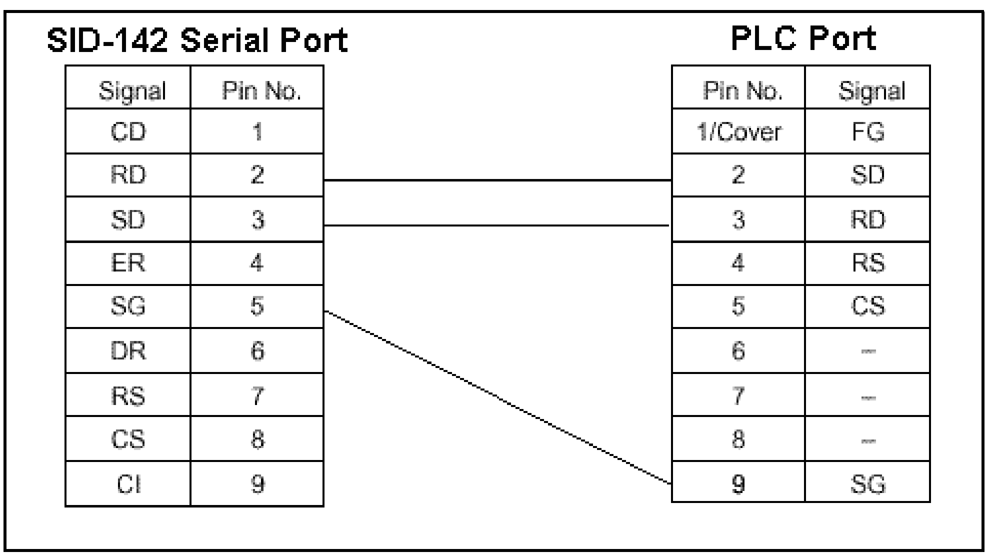
There are several benefits to using an external PLC for I/O. First, noisy high voltage wiring can be placed near the control sources, rather than routed into the controller's equipment rack. Only a single serial cable runs from the PLC to the controller. The PLC also provides electrical isolation for the process controller. And finally, the PLC's ladder logic programming provides fail-safe process protection and allows I/O to be easily tailored to each end user's installation.

4.2 PLC Installation

CAUTION

The Omron PLC uses a special RS-232 cable as shown in Figure 4-1. Do not use a standard serial cable. Damage to the PC or the PLC could result.

Figure 4-1 Omron PLC RS-232 Cable



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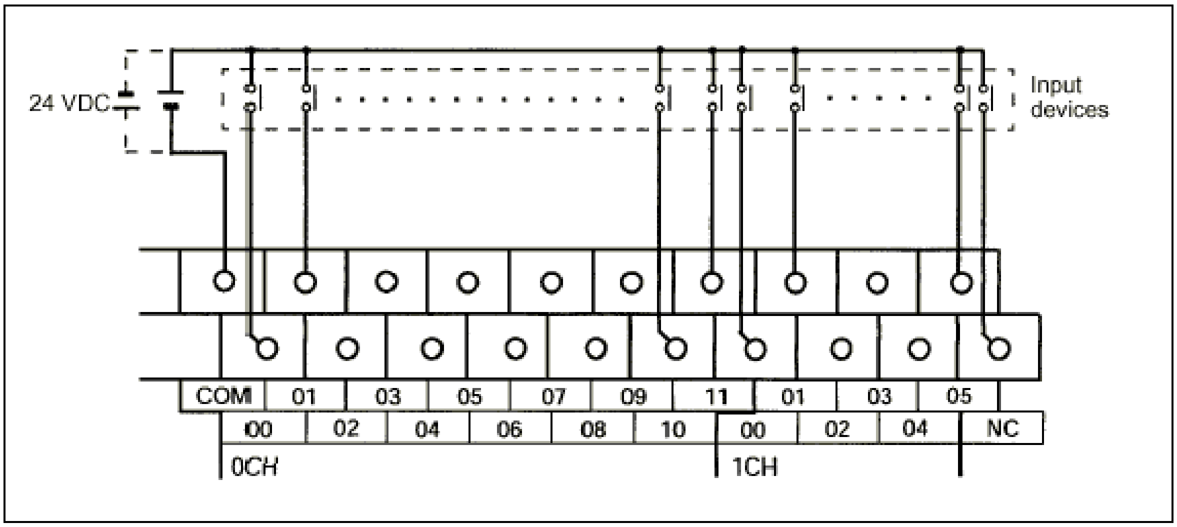
Mount the PLC controller near the devices it is controlling and sensing. Connect the PLC to a properly grounded power source. See the PLC User Manual for detailed PLC mounting and connection information. Connect the serial cable supplied from the PLC serial port to your computer serial port.

Input Wiring: The 0.0 to 0.11 inputs on Omron PLCs correspond to Inputs 1 to 12 in the SQS-242 software. Omron PLC input wiring is shown in Figure 4-2.

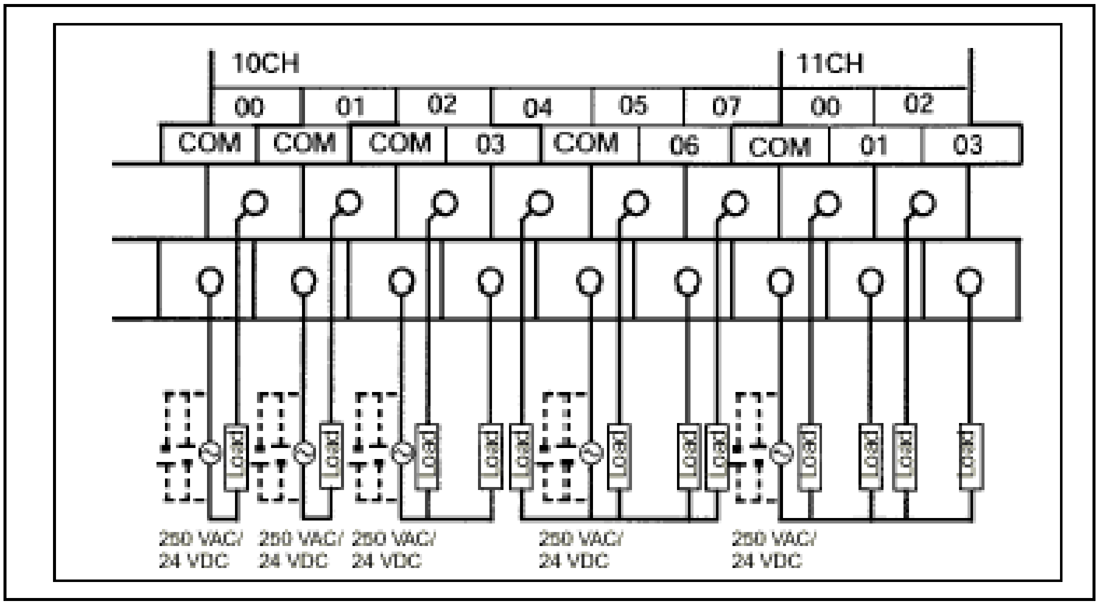
Figure 4-2 Omron PLC Input Wiring



Output Wiring: The PLC output relays are mapped to output events using the SQS-242 software's Edit, System dialog, I/O Events tab.

NOTE: Relays 1 to 8 in the SQS-242 software correspond to relays 10.00 to 10.07 on the PLC. Relays 9 to 12 correspond to Omron relays 11.00 to 11.03.

Figure 4-3 Omron PLC Output Wiring



Omron PLC output wiring is illustrated in Figure 4-3. Notice that some relays (i.e., 02/03 and 04/05/06/07) share a common terminal.

NOTE: The internal 24 V (dc), .3 A supply of the Omron PLC is NOT adequate to serve as the supply shown in the diagram above.

Indexer I/O: Indexers from different manufacturers use a variety of pocket decoding schemes. The PLC monitor program adapts information from the SQS-242 program to a specific indexer. The two most common indexer decoding schemes are illustrated below.

Binary Pocket Select: Each pocket requires a dedicated relay. That is 8 pockets require 8 relays. The CPM2A-Basic PLC monitor program assigns relays 11.00 to 11.03 to operate a 4 pocket indexer of this type.

Binary Coded Pocket Select: Pockets are selected by a value that is the binary representation of the pocket. That way fewer relays are required. For example, 16 pockets can be selected with only four relays. The CPM2A-BCD monitor program assigns relays 11.00 to 11.03 to this function.

Please contact INFICON for information on your indexer.

Other Digital I/O: Depending on the PLC model used, additional relay and input pins are available for other functions (i.e., source indexer operation). Please contact INFICON.

4.3 PLC Setup and Test

In the SQS-242 software select Edit, System, then the I/O tab. Set the Address to match the PLC Address (usually 0). Set the Comm Port to the serial port you are using. The COMM LED on the PLC should flash several times a second when the Address and Comm Port are set properly.

The Test section of the I/O tab provides a means of testing your PLC communications and digital I/O wiring. To set a relay on the PLC, go to the Digital I/O tab and find which I/O event is assigned to that relay. On the PLC tab, select the same event in the test dropdown, then click Set. The assigned Relay# should close. Click Clear to open the relay.

The Indexers tab of the Edit System dialog box allows you to move a source or substrate indexer. Select the index (i.e., pocket) to activate, then click the appropriate move button.

4.4 5.3 PLC Programming

The PLC runs a small ladder logic program that communicates with the SQS-242 software. This program transfers external relay and input states from the PLC connecting block to internal PLC registers. The SQS-242 software reads/writes to those registers.

The preset functions of the SQS-242 software will be adequate for most applications. If you need to perform additional logic functions, they can be programmed using Omron's CX-Programmer software. Contact INFICON for more information on programming your PLC.

The functions of the internal PLC registers used by the standard SQS-242 program are shown below.

PLC Register	SQS-242 Function
200	Layer/Phase Register Bits 0-9 are BCD layer number running Bits 10-15 are BCD Phase# as shown below

00	Application Startup	09	ShutterDelay Phase
01	Program Initializing	10	Deposit Phase
02	Not Used	11	Layer Stopped
03	Not Used	12	Layer Starting
04	Process Stopped	13	Not Used
05	Ramp1 Phase	14	Feed Ramp Phase
06	Soak1 Phase	15	Feed Hold Phase
07	Ramp2 Phase	16	Idle Ramp Phase
08	Soak2 Phase	17	Idle Phase
		18	Continuous Phase

PLC Register	SQS-242 Function
201	Sensors/Outputs 1-4 Register (updated each layer) Bits 0-7 are sensors used (1=used, 0=unused) Bits 12-15 are outputs used, 12 is Out1, 13 is Out2, etc.

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202	Analog/Outputs 5-6 Register (updated each layer) Bits 0-3 are analog inputs used (1=used, 0=unused) Bits 4-5 outputs used, 4 is Out5, 5 is Out6 Bits 8-11 are BCD of Output source index Bits 12-15 are BCD of Output 6 source index
220	Source Index Register (updated each layer) Bits 0-3 are BCD of Output 1 source index Bits 4-7 are BCD of Output 2 source index Bits 8-11 are BCD of Output 3 source index Bits 12-15 are BCD of Output 4 source index
221	Source Indexer Done Flag Bit 0 is Source Indexer 1 (1= Indexer Done, 0=Not Done) Bit 1 is Source Indexer 2 Bit 2 is Source Indexer 3 Bit 3 is Source Indexer 4 Bit 4 is Source Indexer 5 Bit 6 is Source Indexer 6
222	Relays 1-16 Bit 0 is Relay 1, etc.
224	Inputs 1-12 Bit 0 is Input 1, etc.
225	Layer Index Register Bits 0-3 are BCD of Layer Indexer 1 Bits 4-7 are BCD of Layer Indexer 2 Bits 8-15 are BCD of Layer Indexer 3
226	Layer Indexer Done Flag Bit 0 is Layer Indexer 1 (1= Indexer Done, 0=Not Done) Bit 1 is Layer Indexer 2 Bit 2 is Layer Indexer 3

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Chapter 5
Communications

5.1 Introduction

The computer interface capabilities of the SQS-242 program allow operation from an external computer via Ethernet or RS-232 serial communications and a simple ASCII command set. Programs running on the same computer, can also control the SQS-242 program using ActiveX® and the same ASCII command set.

Parameters may be read (Query commands) while the process is running, but can only be changed (Update commands) while the process is stopped. Changes to the “structure” of a process (e.g., add or delete layers) are not allowed from the computer interface.

5.2 Serial Interface

Connect a serial cable from the serial port of the computer the SQM card is installed on to another computer’s serial port. The cable required is a DB9 female to female with pins 2 and 3 crossed, commonly referred to as a null modem cable.

In the SQS-242 program select the Edit, System menu, then the Comm tab. Set the Comm Port to match the serial port the cable is connected to on the other computer. Set the baud rate to match between the host computer and the remote computer. Communications format is No Parity, 8 bits, 1 stop bit.

5.3 Ethernet Interface

Connect a cable from the Ethernet card to your Ethernet network. In the SQS-242 program select the Edit, System menu, then the Comm tab. Set the Ethernet Port to 1001, and the Ethernet name to the Network name, or IP Address of the computer you wish to communicate with. Enter a –1 for the Ethernet Port to disable the Ethernet functions.

5.4 ActiveX (COM) Interface

Any program that supports Microsoft’s COM (ActiveX) interface (i.e., LabVIEW®, etc.) can communicate with the SQS-242 program. A small ActiveX interface program, SQS242X.EXE, provides receive data and transmit data entry points to the global cComm242 class. Contact INFICON for examples in other languages, and detailed technical information.

5.5 SQS-242 Comm Program

SQS-242 Comm, found on the SQS-242 CD-ROM, is a simple Windows program to demonstrate SQS-242 communications concepts. With SQS-242 Comm you can easily send commands to, and read the responses returned by the SQS-242 program.

5.5.1 Setup for RS-232 or Ethernet

In the SQS-242 program, select Edit, System and set the RS-232 or Ethernet settings as detailed in the previous sections.

Load the Comm program on a computer (the host), and connect an Ethernet or RS-232 cable between the host and the computer running the SQS-242 program. Start the Comm program on the host computer, then select the Utility tab. Set the Comm Port and Baud Rate for the host computer, or select Ethernet and set the Ethernet Port (typically 1001).

5.5.2 Setup for Active X Control

Load the Comm program on the same computer that is running the SQS-242 program. Start the Comm program, then select Active X on the Utility tab. Start the SQS-242 program but minimize it, or bring the Comm program to the foreground.

5.5.3 Communicating with the SQS-242 Program

In the Comm program, Utility tab, click the Version button under the SID-242 Controller heading. Click Send to send the query to the computer running the SQS-242 program.

The response from the SQS-242 program should show in the Comm program Response window. A typical response is @QU;ACK;3.2.9;32, which indicates software version 3.29. The next section describes the Query/Update and Response strings in detail.

The transmissions to and from the Comm program will also show in the SQS-242 Edit, System, Comm, Receive Data and Transmit Data windows.

5.6 Protocol

SQS-242 commands fall into two categories:

- **Query** commands request data from the SQS-242 program.
- **Update** commands update a setting or instruct the program to take an action.

The SQS-242 responds to both Query and Update commands with a response that indicates the results of the command request. The SQS-242 program never initiates communications. It only responds to commands from the host.

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5.6.1 Query Command Format

```
@<command>;<param1>;…;<paramn>;<Chksum><CR>
```

5.6.1.1 Example: Software Version Query

```
@QU;11;44<CR>
where:
@     Message start character
;     Separator
QU    Query Utility command
;     Separator
11    Parameter 11 (SQS-242 Software Version)
;     Separator
44    Checksum (see section that follows on checksums)
<CR>  Carriage Return (ASCII 13)
```

5.6.1.2 Example: Response to Software Version Query

```
@QU;<ACQ>;2.1.6;??<CR>       (Response to Software Version query)
where:
@;QU;<ACQ>; Query Acknowledged (ASCII 06)
2.1.6       Message (Software Version)
;           Separator
0C          Checksum (actual checksum varies with different
                             versions)
<CR>        Carriage Return (ASCII 13)
```

5.6.2 Update Command Format

```
@<command>;<param1>;...;<paramn>;<data>;<Chksum><CR>
```

5.6.2.1 Example: Set Process Update

```
@UP;11;MyProcess;44<CR>
where:
@;UP;       Update Process command
;           Separator
01          Parameter 01 (Set Process)
;           Separator
MyProcess   Data
;           Separator
??          Checksum
<CR>        Carriage Return (ASCII 13)
```

5.6.2.2 Example Response: Set Process Update Succeeded

```
@UP;<ACQ>;??<CR>
```

5.6.2.3 Example Response: Set Process Update Failed

```
@UP;<NAK>;<ERR>;??<CR>
Where:
01    Illegal Command
02    Illegal Parameter
03    Illegal Format
04    Checksum Error
05    Request Denied
06    Unknown Error
```

5.7 Checksum Calculation

The sample code below calculates the FCS checksum of a string of characters.

In the code, Message is a string that has been stripped of terminator and checksum characters before being passed to this routine.

```
' XOR ASCII codes
For i = 1 To Len(Message)
    FCS = Asc(Mid$(Message, i, 1)) Xor FCS
Next i

' Convert FCS to two character hex string
If Len(Hex$(FCS)) = 1 Then
    CalcChkSum = "0" & Hex$(FCS)
Else
    CalcChkSum = Hex$(FCS)
```

NOTE: While checksums “may” be useful for RS-232 communications, they are not needed for Ethernet or ActiveX. If you don’t want to use a checksum, replace the checksum in each command with “00” (two ASCII zero (Hex 30) characters). The program response will contain two checksum characters, which you can just ignore.

5.8 Command Summary

NOTE: *Update commands (except UP02-UP10) are only valid in Stop Mode.*

5.8.1 Query Process

```
@QP;<param1>
where <param1> is:
01     Process Name
       Example Query: @QP;01
       Example Response: @QP;06;MyProc(Process is MyProc)
02     Process Time           (mm:ss)
03     Active Layer #
04     Layer Time             (mm:ss)
05     Phase # (where phase numbers returned are)
       00      Application Startup   09      ShutterDelay Phase
       01      Program Initialize    10      Deposit Phase
       02      Not Used              11      Layer Stopped
       03      Not Used              12      Layer Starting
       04      Process Stopped       13      Not Used
       05      Ramp1 Phase           14      Feed Ramp Phase
       06      Soak1 Phase           15      Feed Hold Phase
       07      Ramp2 Phase           16      Idle Ramp Phase
       08      Soak2 Phase           17      Idle Phase
06     Phase Time (mm:ss)
07     Run #
08     All Process Names      (comma delimited list)
1n     Source Shutter Status, n=1 to 6 (0=Open, 1=Close)
2n     Sensor Shutter Status , n=1 to 8 (0=Open, 1=Close)
30     All Crystal Good Status (0=False, 1=True)
3n     Crystal n Good, n=1 to 8 (0=False, 1=True)
39     All Crystal Fail (0=False, 1=True)
4n     Sensor to Output Map, n=1 to 8
50     DataLog Filename
51     DataLog Type (0=None, 1=Overwrite, 2=Append, 3=Run#)
52     DataLog Interval in seconds
```

5.8.2 Update Process

```
@UP;<param1>;<data>
where <param1> is:
01     Set Process
       Example Update @UP;01;MyProc(Select MyProc)
       Example Response: @UP;06;
02     Start Process
03     Stop Process
04     Start Layer
05     Stop Layer
06     Start Next Layer
07     Auto Mode (all films in layer)
08     Manual Mode (all films in layer)
09     Zero Thickness (all films in layer)
10     Set Run #
```

```
11     Set Active Layer #
2n     Output n (1 to 6) Power (Manual Mode Only)
4n     Map Sensor n to Output #
50     Set DataLog filename without extension (Stop mode only)
51     DataLog type (0=None, 1=Overwrite, 2=Append, 3=Run#)
52     DataLog Interval in seconds (set Bit 3 in Command 53 below)
53     DataLog Events (bit weighted integer)
       Bit 0 End Deposit Phase
       Bit 1 End Each Phase
       Bit 2 I/O Event
       Bit 3 Timed
       Bit 8 Every Reading
       Bit 9 Sensor Readings
       Bit 10Analog Readings
```

5.8.3 Query/Update Layer

@QL;<param1>;<layer>;<output>
@UL<param1>;<layer>;<output>

NOTE: A <layer> value of zero sets/returns data on the current layer.

```
where <param1> is:
01     Film Name
       Example: @UL;01;1MyFilm,New Film    (set Layer 1, MyFilm to
                                           NewFilm)
02     Setpoint                            Å/s, V, or % Power
03     Start Thickness                     kÅ
04     Time SP                             mm:ss
05     Thickness SP                        kÅ
06     Start Mode                          0/1
07     Substrate Index (obsolete)          0 to 15
08     # Layers in Process (query)
09     Start Prompt                        250 characters or less
10     Phase of the requested output (query)
1n     Ramp n Start Thickness, n=1 to 9    kÅ
2n     Ramp n Ramp Time, n=1 to 9          mm:ss
3n     Ramp n New Rate, n=1 to 9           Å/s
41     Layer Indexer 1 Index               0 to 15
42     Layer Indexer 2 Index               0 to 15
43     Layer Indexer 3 Index               0 to 15
44     Source Indexer Index                0 to 15
45     Input Type (Sensors=0, TimedPower=1, Analog1-4 = 2-5)
46     System Configuration
47     Source Indexer Done                 0/1
48     Layer Indexer 1 Done                0/1
49     Layer Indexer 2 Done                0/1
50     Layer Indexer 3 Done                0/1
```

5.8.4 Query/Update Film

```
@QF;<param1>;<layer>;<output>
@UF;<param1>;<layer>;<output>;<value>
Note: <layer>=0 is active layer
where <param1> is:
01    P Term
02    I Term
03    D Term
04    Shutter Delay Status (0/1)
05    Shutter Timeout
06    Shutter Accuracy
07    Control Error Status (0/1/2)
08    Control Error Accuracy
09    Rate Sampling Status (0/1/2)
10    Sample Accuracy
11    Sample Time
12    Sample Hold
13    Ramp 1 Power
14    Ramp 1 Time
15    Soak 1 Time
16    Ramp 2 Power
17    Ramp 2 Time
18    Soak 2 Time
19    Feed Power
20    Feed Ramp Time
21    Feed Time
22    Idle Power
23    Idle Ramp Time
24    Output (1-6)
25    Source Index (obsolete)
26    Max Power
27    Slew Rate
28    Material
3n    Tooling n (n=1 to 8)
40    AutoSoak2 (0/1)
```


5.8.5 Query Utility

```
@QU;<param1>
01    SQM242 DLL Version
02    SQM242 Mode (0/1)
03    SQM242 Period
04    SQM242 Filter
05    SQM242 Number of Cards Installed
06    Front Panel Enabled (0/1)
07    Application Visible (0/1)
11    SQS-242 Software Version
12    SQS-242 Operating System
13    SQS-242 Computer Name
```

5.8.6 Update Utility

```
@QU;<param1>;<Index>
02    SQM242 Mode (0/1)
03    SQM242 Period
04    SQM242 Filter
06    Front Panel Enabled (0/1)
07    Application Visible (0/1)
08    Full Scale Output (Index=1 to 6)
14    Application On Top(0/1)
```

5.8.7 Query Measurement

```
@QM;<param1>
1n    Output n Power (n=1 to 6)
2n    Output n Rate
3n    Output n Thickness
4n    Output n Deviation
5n    Sensor n Rate (n=1 to 8)
6n    Sensor n Thickness
7n    Sensor n Frequency
8n    Sensor n % Life
9n    Analog Input n Voltage
```

5.8.8 Query Register

```
@QR;<param1> (returns register value in HEX)
0     Layer/Phase Register
1     Sensor/Output Register
2     Analog/Output Register
20    Source Index Register
21    Source Index Done Register
22    Relay Register
24    Input Register
25    Layer Index Register
26    Layer Index Done Register
```

5.8.9 Update Register

```
@UR;<param1>;<value> (value in HEX)
0     Layer/Phase Register
1     Sensor/Output Register
2     Analog/Output Register
20    Source Index Register
21    Source Index Done Register
22    Relay Register
24    Input Register
25    Layer Index Register
26    Layer Index Done Register
XXX   Any Register
```

Chapter 6
Loop Tuning

This section will help you adjust your control loop PID parameters to achieve a stable deposition process. Keep in mind that there is no "best" way to determine PID parameters, and no one set of settings that are "best."

1. **Setup System Parameters:** Be sure that the output Full Scale voltage and crystal Min/Max Frequency parameters are accurate for your system. All Tooling parameters are best set to 100% for now. A Period of .25 seconds is also a good starting point. Simulate should be OFF.
2. **Create a One-Layer Test Process:** Create a new process that has a single film as its only layer, and select it as the current process. Set the film's Initial Rate to your desired rate and Final Thickness to a large value, say 10X your desired Final Thickness. Select the proper Sensor(s), Output, and Material. Set Max Power to 100% and Slew rate to 100%. Disable all errors except Crystal Fail. Set On Error to Stop Layer.
3. **Test the Setup:** Press Auto/Manual to start the layer in Manual mode. Slowly turn the control knob to a power of 10%, and verify that your power supply output is about 10% of full scale. Continue to turn the control knob until a Rate(Å/s) above 0 is shown. Again, verify that the power supply output agrees with the SQS-242 Power(%) reading. If the readings don't agree, check your wiring and process setup. In particular, verify that the System, Outputs, Full Scale voltage agrees with your power supply input specifications.
4. **Determine Open Loop Gain:** Slowly adjust the control knob until the Rate(Å/s) reading approximately matches your Initial Rate setting. Record the Power(%) reading as PWRDR (power @ desired rate). Slowly lower the power until the Rate(Å/s) reading is just at (or near) zero. Record the zero rate Power(%) reading as PWR0R.
5. **Determine Open Loop Response Time:** Calculate 1/3 of your desired rate (RATE1/3), and 2/3 of the desired rate (RATE2/3) for this layer. Slowly increase the power until Rate(A/s) matches RATE1/3. Get ready to record the loop's response to an input change. Quickly adjust Power(%) to PWRDR. Measure the time for the Rate (A/s) reading to reach RATE2/3. You may want to do this several times to get an average response time reading. Displaying the Rate graph will also help. Twice the measured time is the step response time, TIMESR. TIMESR is typically 0.7 to 1.5 seconds for E-Beam evaporation, 5 to 20 seconds for thermal evaporation.

Press Abort Process, then Manual/Auto to return to Auto mode. Follow these steps to set the loop PID parameters:

6 **Set PID Values:** In the Edit Process, Deposition tab set P=25, I= TIMESR, D=0. Assure that all Conditioning values are set to zero. Save the values and close the Edit Process dialog. Press Start Process and observe the Power graph. The power should rise from 0%, and stabilize near PWRDR with little ringing or overshoot. If there is more than about 10% overshoot, lower the P Term. If the time to reach PWRDR is very slow, increase the P Term. A lower I Term will increase response time, a higher value will eliminate ringing and setpoint deviations. It is unlikely you will need any D Term.

Continue to Start the process and adjust PID until steady-state response is smooth and the step response is reasonably controlled. You don't need to totally eliminate ringing during the step if the steady-state response is smooth. Preconditioning will minimize step changes.

7 **Set Preconditioning:** The power level you recorded as PWR0R is the power where deposition just begins. That's a good value for Ramp 1 power. PWRDR, or slightly less, is a good value for Ramp 2 Power. This will eliminate a large step change when entering the deposition phase.

Once PID terms are established for a material, they will typically be similar for other materials. Only the P Term and preconditioning power levels may need adjustment.