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EIES-IV Guardian
Deposition Controller

EIES-IV Software
Version 2.15

User's Guide



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Safety Information

Read this manual before installing, operating, or servicing equipment. Do not install substitute parts, or perform any unauthorized modification of the product. Return the product to INFICON for service and repair to ensure that safety features are maintained.

Safety Symbols

WARNING: Calls attention to a procedure, practice, or condition that could possibly cause bodily injury or death.

CAUTION: Calls attention to a procedure, practice, or condition that could possibly cause damage to equipment or permanent loss of data.



Refer to all manual Warning or Caution information before using this product to avoid personal injury or equipment damage.



Hazardous voltages may be present.



Mains Power ON: In position of bi-stable push control.



Mains Power OFF: Out position of bi-stable push control.



Earth ground symbol.



Chassis ground symbol.



Equipotential ground symbol.

Warranty Information

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Appendices

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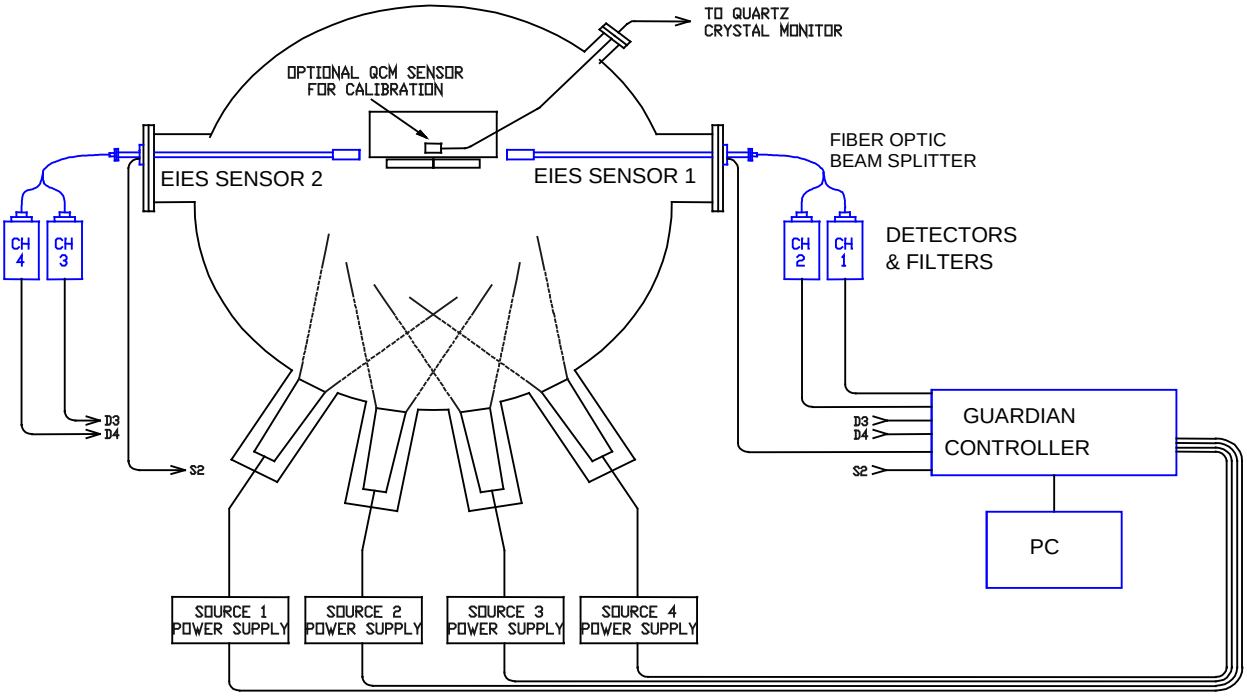
Chapter 1 - Introduction

1.0 Introduction

The EIES-IV Guardian uses Electron Impact Emission Spectroscopy (EIES) to control vacuum deposition of thin films.

In EIES, the material being deposited is energized by a thermionic emitter, which creates optical emission spectra. An optical filter passes a characteristic wavelength of the spectra to a detector, which measures the intensity of the emission. The measured intensity is fed to a PID control loop, which generates a control signal for the material's evaporation power supply. By proper filter selection, multiple detectors can control deposition of multiple materials simultaneously.

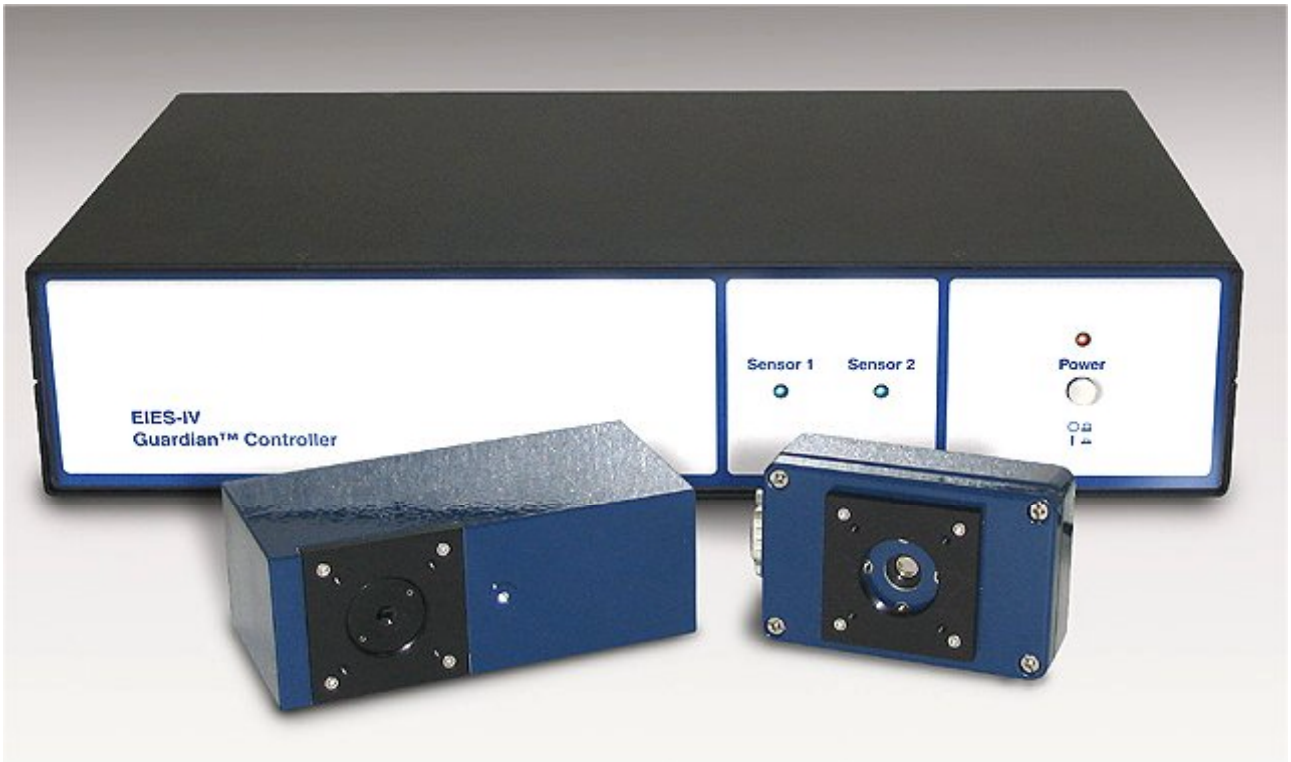
The EIES-IV Guardian consists of five basic elements: controller, sensor(s), detector(s), software, and an optional quartz crystal monitor. A typical four channel, two sensor system schematic is shown below



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1.1 EIES Controller

The EIES-IV Guardian Controller serves as the interface between the EIES sensor(s) and detector(s), the evaporation power supply, and the computer running the EIES software.



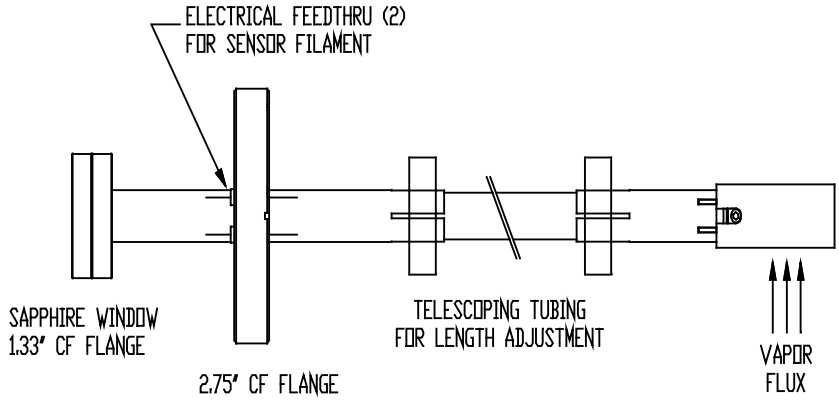
The controller supplies power to both the filament of the sensor assembly and to the detector modules. It communicates with each detector, passing the detector measurements to the computer running the EIES program. Control voltages for evaporation power supplies are also generated in the controller. Finally, relays and digital inputs to operate shutters, filter changers, etc. are included in the controller.

The controller is operated from a computer running the EIES software via RS-232 or Ethernet. Other than a power switch and a few status LEDs, there are no operator controls on the EIES-IV Guardian Controller.

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1.2 EIES Sensor

In the sensor assembly, high-energy electrons from a hot filament excite the valence electrons of the deposited material. These excited electrons emit light at wavelengths that are characteristic of each material. A light tube conducts the light to a feedthrough with a viewport, where it is measured by the PMT of the detector module(s). A single sensor can be used to create emissions from multiple materials.

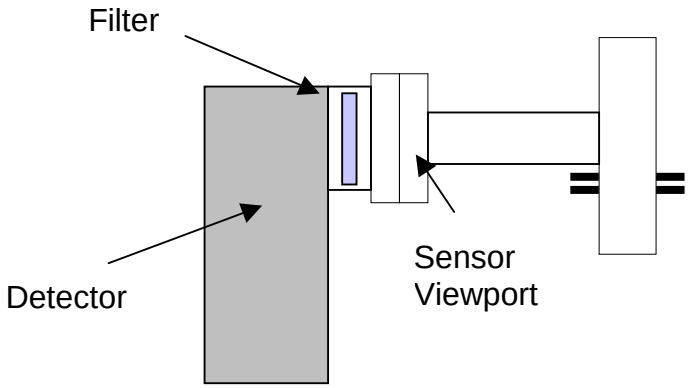


The sensor assembly consists of a 1.33" sapphire viewport attached to a 2.75" Conflat flange. On the vacuum side of the flange, a telescoping light tube and two electrical connections are attached to the thermionic emitter. The telescoping tube can be adjusted to locate the thermionic emitter in the vapor flux.

1.3 EIES Detector

The EIES detector module's photomultiplier tube (PMT) measures the emission intensity of a characteristic wavelength of the deposited material.

For detecting a single material, an optical filter and detector module can be attached directly to the viewport.

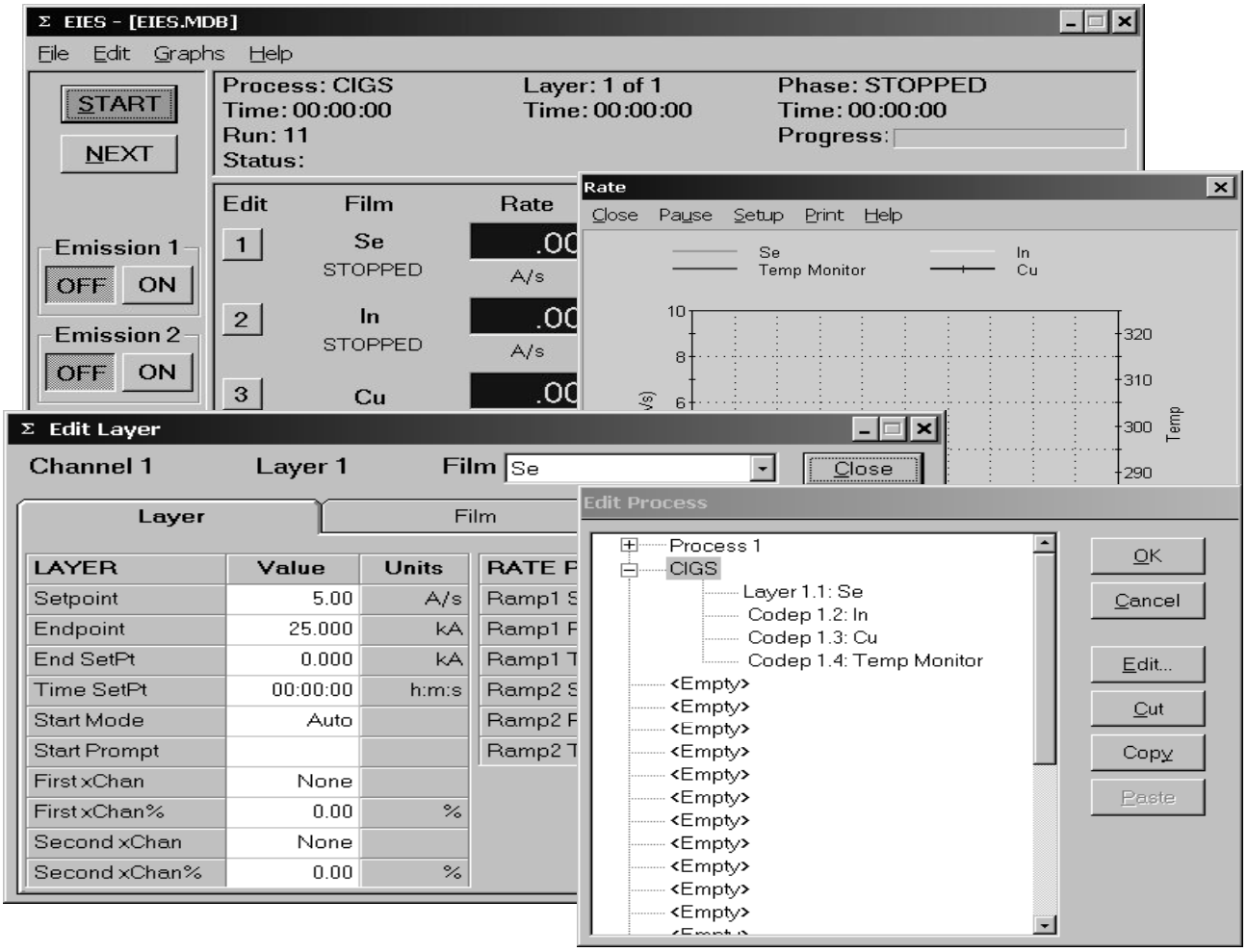


For multiple materials, a fiber optic beam splitter is attached to the viewport. The split signal is then fed to multiple detectors. Each detector is fitted with a filter specific to the material it measures.

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1.4 EIES Software

The EIES software provides the user interface for operating the EIES-IV Guardian system. The program provides all of the functions required for an eight sensor, eight output, multi-layer co-deposition controller. Process settings, numeric data, and graphs can be displayed during all phases of deposition.



The EIES software stores process recipes in a Microsoft Access compatible database. Process data is logged to disk in comma-delimited format for easy import into spreadsheet and graphing programs, such as Microsoft Excel.

Other programs can read data or control the EIES program using Active X and simple text commands. The program can also be controlled from another computer using RS-232 or Ethernet.

Chapter 3 details EIES software functions.

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1.5 Quartz Crystal Monitor

In the EIES system, rate is proportional to light intensity, measured as detector current. To calibrate the detector current to actual rate, an optional quartz crystal monitor (QCM) is available.

The EIES system uses INFICON's SQM-242 PCI card or Q-pod Transducer for QCM calibration of the EIES detector(s). QCM calibration can be initiated by the user, or automatically at regular intervals during deposition.

A separate User's Guide covers installation of the SQM-242 or Q-pod, and hook up of the quartz sensors.

1.6 Analog Measurements

INFICON's SAM-242 analog input card measures four 0 to +/-10V DC signals. The SAM-242 card can be used to measure process parameters, such as temperature and pressure, to control those process variables.

The SAM-242 card is also installed in the computer running the EIES software. Installation is covered in the SQM-242 User's Guide.

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Chapter 2 - Quick Start

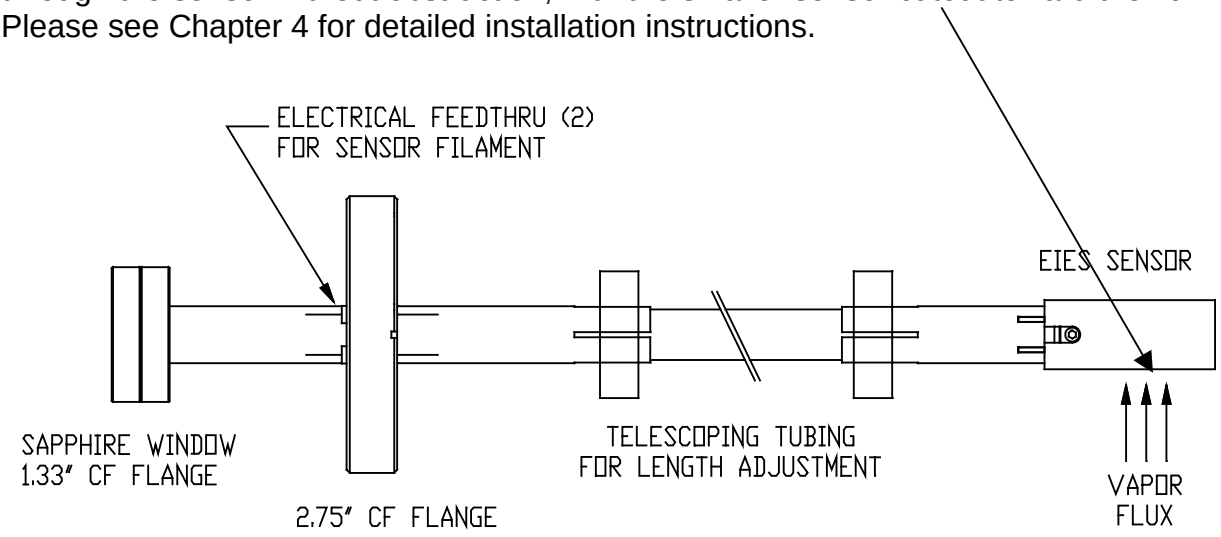
2.0 Introduction

This section covers the minimum system connections and software setup needed to run the EIES-IV Guardian system. Consult later chapters for more detailed installation and operating instructions.

2.1 Installation

2.1.1 Sensor Installation

Placement of the EIES sensor is the most significant factor determining EIES system performance. The sensor must be placed so that the material vapor flux passes through the sensor without obstruction, with the smaller sensor cutout toward the flux. Please see Chapter 4 for detailed installation instructions.



To install the sensor, loosen the collar that secures the telescoping tube, and separate the 2 ¾" flange from the sensor assembly. Install the 2 ¾" CF feedthrough to the vacuum chamber port, with the telescoping tube inside the chamber.

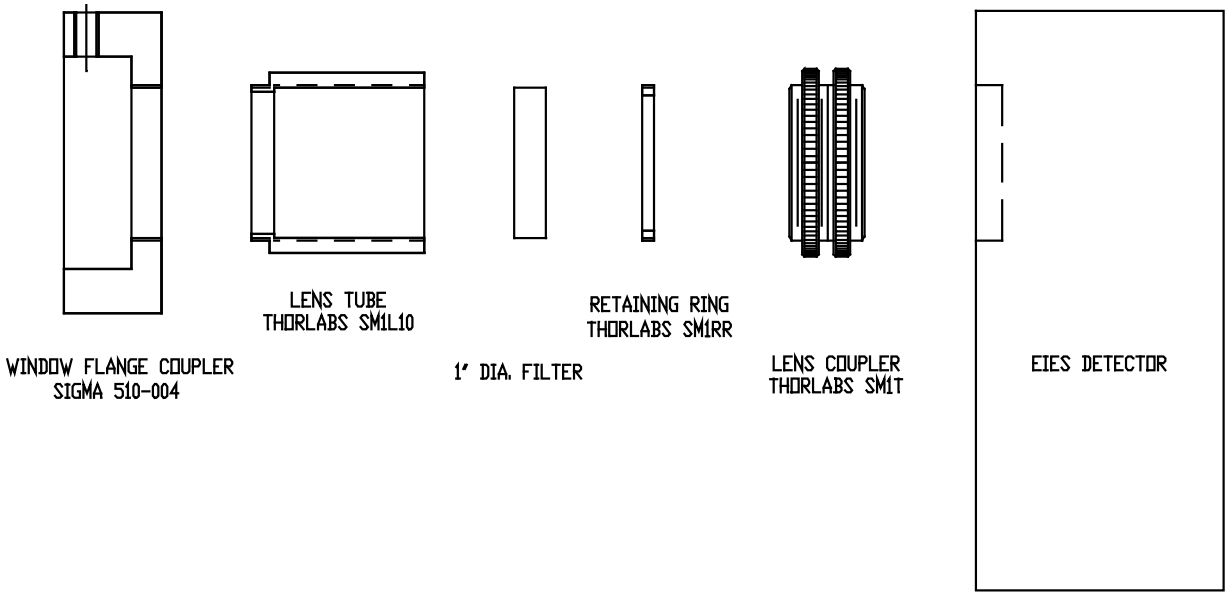
In the vacuum chamber, slide the sensor assembly onto the telescoping light tube and adjust the length so that the vapor flux passes through the sensor. The smaller opening in the sensor cover points toward the evaporant. If necessary, provide mechanical support to stabilize the sensor assembly. However, do not block the flux path. Secure the assembly by tightening the tube collar.

Attach the cables from the feedthrough to the sensor. Polarity is not important, but the electrical signal is biased at 180V to ground. Assure there are no potential shorting paths to the chamber.

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2.1.2 Detector - Direct Installation

For single detector applications, the detector may be mounted directly to the sensor assembly viewport. Please see Chapter 4 for detailed installation instructions.



Thread the lens tube onto the flange coupler. Insert the filter into the lens tube and secure it with the retaining ring. Thread the lens coupler into the lens tube, then thread the assembly into the detector. Slide the flange coupler over the 1.33" viewport and secure with three screws.

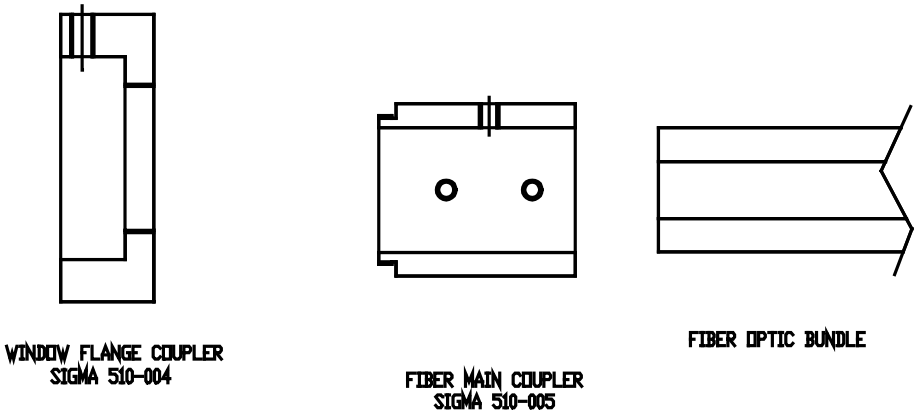
When co-depositing multiple materials, multiple detectors and filters are required. It is possible to attach a beam splitter to the flange coupler, then mount multiple detectors and filters using off-the-shelf optical components. However, the assembly will be bulky and require additional support.

For multi-detector installations, a fiber optic beam splitter is suggested.

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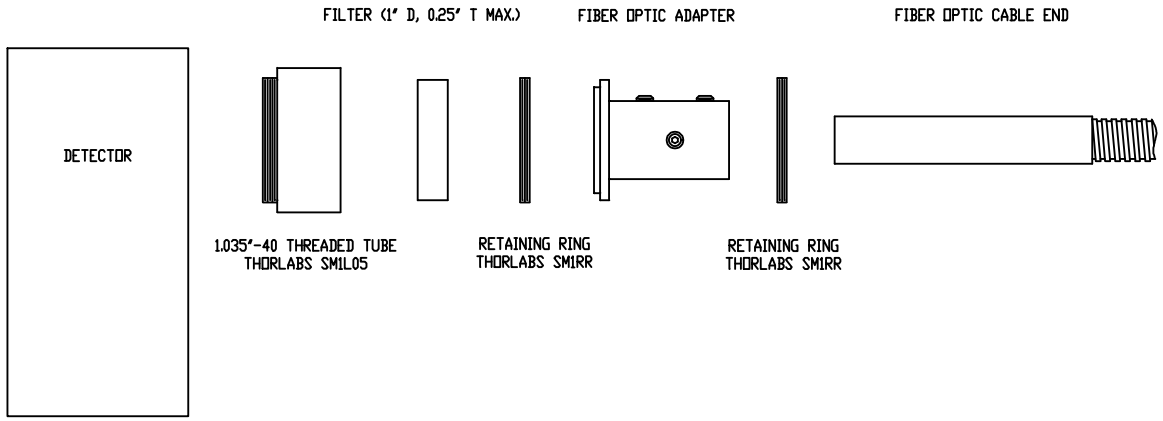
2.1.3 Detector - Fiber Optic Installation

In multi-material applications, a fiber optic beam splitter attached to the viewport can tailor signal transmission and detector mounting to your needs. Contact INFICON for fiber optic beam splitting requirements and capabilities. Please see Chapter 4 for detailed installation instructions.



To attach the main fiber optic bundle to the viewport, thread the fiber coupler onto the window flange coupler. Insert the main fiber optic bundle into the coupler and secure the fiber optic bundle with set screws.

Now attach each leg of the fiber optic splitter to an EIES detector.

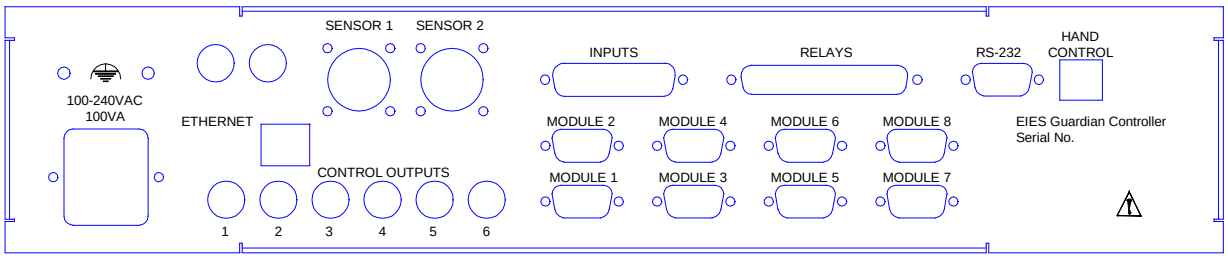


Thread the filter tube onto the EIES detector. Insert the filter and capture it with the retaining ring. Thread the cable adapter into the threaded tube. Insert the fiber optic cable into the adapter and capture with screws.

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2.1.4 Controller Installation

Mount the controller in a location that allows easy wiring access to the EIES sensor and detector assemblies. The controller may be placed up to 25 feet from the EIES computer.



Sensor(s): Connect the sensor power cable (PN 505-067 or 505-073) from the controller to the electrical connections on the sensor feedthrough. Contact INFICON if a cable longer than 10 feet (3 m) is required.

WARNING: The sensor outputs are energized at ±90VDC and constitute a potential shock hazard. If a sensor cable is damaged, contact INFICON for a replacement..

Detector(s): Connect the 9-pin cables (PN 505-065) from the controller to the EIES detector module(s).

Control Outputs: Connect a BNC cable (not supplied) from the EIES controller output to the control input of your evaporation power supply. The control signal is a DC voltage from 0 volts, to +/- 10V. Consult your power supply vendor's manual for proper connection.

Note: *Connect a heavy braided cable from the EIES controller to vacuum chamber ground. If you are using multiple power supplies, be sure that the outer conductor of each BNC cable is at system ground potential.*

Computer: Connect the EIES controller to the computer RS-232 port with a straight-through 9-pin cable (PN 902-003). If needed, you can use a USB to RS-232 adapter that supports 115K baud rates. Alternatively, connect an Ethernet cable from the controller to the computer or an Ethernet hub.

Digital Inputs and Relays: Unless digital I/O is required for initial setup, do not connect it at this time. Consult Chapter 4 for information on digital I/O wiring.

WARNING: Relay contacts are rated for 30VDC maximum duty. Any customer supplied relay contact circuit must be fused at not more than 5A if the circuit is capable of supplying more than 5A, including the available short circuit current.

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Power: With the power switch OFF, connect the AC mains to the controller power input. The controller automatically accepts 100-240 VAC, 50-60 Hz.

WARNING: Verify that the power cable provided is connected to a properly grounded mains receptacle.

WARNING: Maintain adequate insulation and physical separation of sensor, detector, and I/O wiring from hazardous voltages.

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2.1.5 QCM Option Installation

Consult the SQM-242 or Q-pod User's Guide for detailed instructions on installing the QCM and sensors.

For accurate rate calibration, locate the QCM sensor(s) in the vacuum chamber so that it receives a representative sample of the materials being deposited.

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2.2 EIES Software

Leave the Guardian Controller power OFF while you become familiar with the EIES program. This section will introduce the concepts necessary to operate the EIES-IV Guardian system.

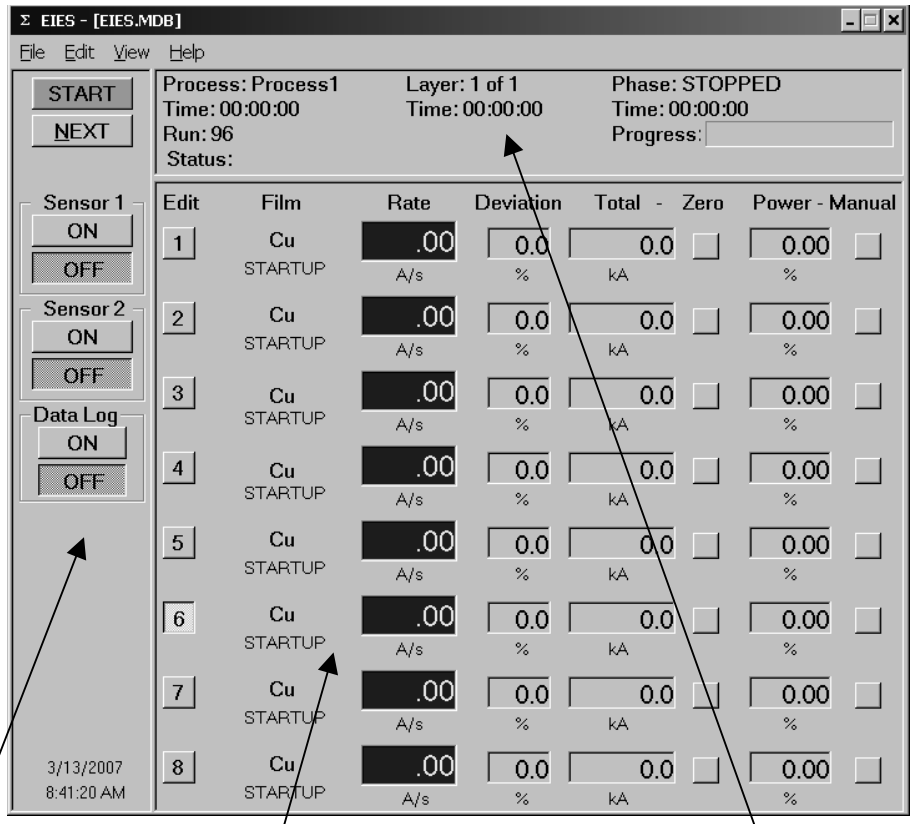
2.2.1 Installation

Insert the INFICON Program Disk into your CD-ROM drive. The Products Menu should appear after a few seconds. If not, open Windows Explorer and run the UtilityDisk.exe program on the CDROM.

On the Products Menu, click EIES-IV Guardian, then click Install Multi-layer software. When EIES software installation finishes, you may be prompted to restart your computer.

2.2.2 EIES Main Screen

Click the EIES-IV icon on your desktop (or click Start, Programs, Sigma Instruments, EIES-IV). Initially, your display may look slightly different than the one below.



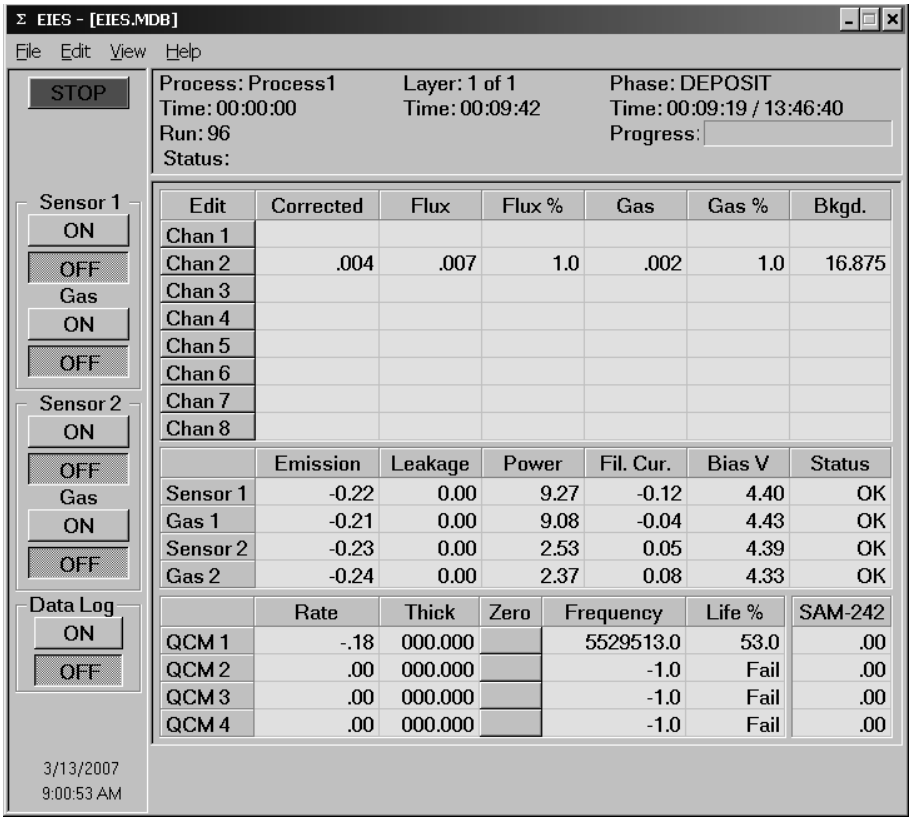
The EIES main screen shows operating controls for running your process in the left Control Panel. Process status information is in the top Status Panel. Below the Status Panel is the large Readings Panel where individual channel readings are displayed.

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The readings panel has three display modes – Process, Ratio, and Readings. Click View, Process to see the display above. The Process display mode shows process related information such as films, setpoints, and manual operating controls.

The View, Ratio display is similar to the Process display except that the deviation readings are replaced with the ratio of the channel's reading to another channel. The other channel number is shown below the ration reading. Ratios are set up in the Edit, Layer dialog box. See Chapter 3 for more information on channel ratios.

Click View, Readings to see the Readings display mode. This display shows unfiltered readings from all sensors and detectors. The Readings display is useful for equipment setup and trouble shooting.

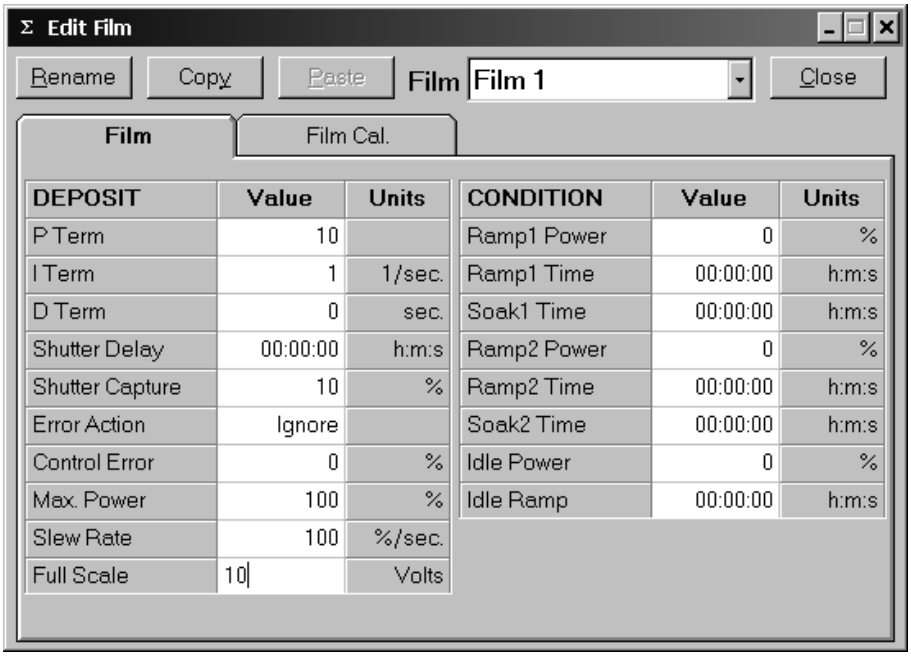


Notice that, unlike the previous display, there are several references to a Gas sensor in both the Readings Panel and the Control Panel. The EIES Guardian controller can be configured for standard EIES sensors or Gas Compensating (GC) sensors. When a Gas Compensating controller is detected, the extra controls and readings are displayed automatically. Operation with GC sensors is covered later in the manual.

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2.2.3 Edit Film

Each material deposited will require unique setup parameters for proper deposition. Click the Edit menu, then Films to display the Edit Film dialog box.



Click the film drop-down to see a list of all films. Select the first film in the list, then click the Rename button. Change the film name to Cu, for Copper. This film will define the basic deposition parameters for Copper. We could adjust the film parameters, but for now we'll just rename a few more films.

Use the film drop-down to Rename the next three films In, Ga, and Se. Close the Edit Film dialog box and return to the main screen.

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2.2.4 Edit Processes

Select Edit, Processes to view a listing of the 25 processes. A process is a sequence of layers, each consisting of one or more deposited films. We will use the Edit Process dialog box to create a multi-layer co-deposition process.

Click the first process, then click Edit. Name the first process CIGS.

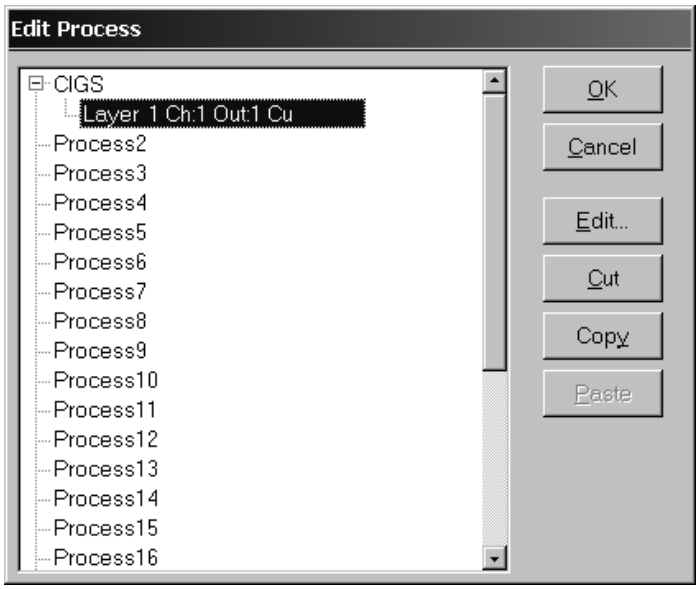
Processes are shown in an outline view, similar to Windows Explorer. Click the + beside a process to expand the process and show the individual layers. Click – to collapse the view of the process.

Layers are numbered sequentially starting at layer 1. After the layer number is the EIES software channel that will display readings. Next is the EIES Guardian output that will control the deposition power supply. And finally, the film that will be deposited.

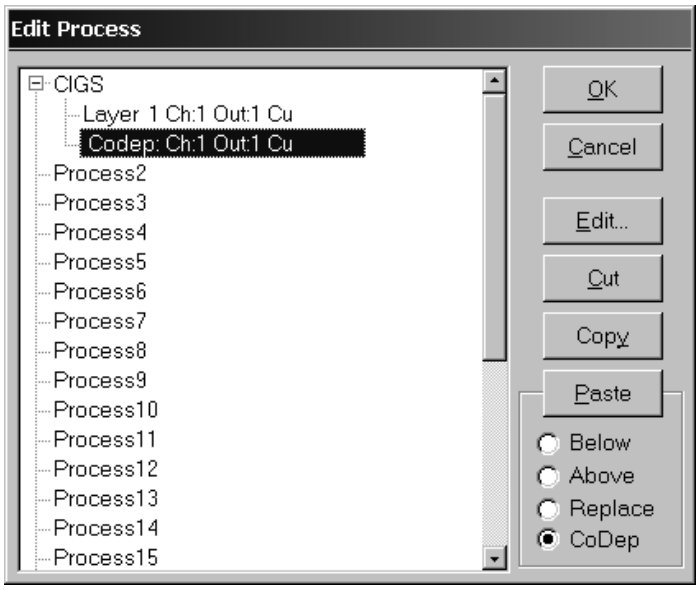
It is important to know which channels and outputs are being used in co-deposition, to avoid assigning more than one film to the same measurement channel or control output.

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Now, click the first layer of process CIGS (don't worry if the material is different than shown below). Be sure the first layer is highlighted, then click the Copy button.



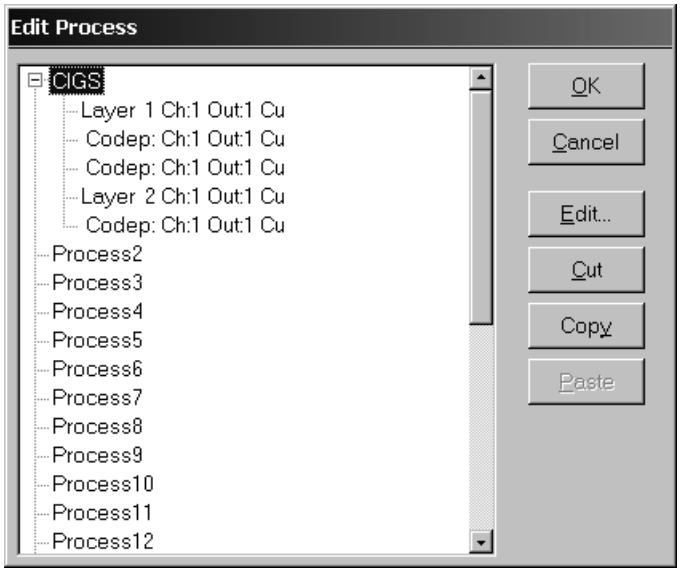
This places a copy of the selected layer on the edit clipboard and enables the Paste button. With the first layer still highlighted, click the CoDep option below the Paste button, and then click the Paste button.



A co-deposition film has been added to the first layer. Click Paste again to create a three film co-deposition layer.

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Now select the Below option and click Paste to add a second layer below layer 1. Finally, select the CoDep option and click Paste to add a CoDep film to layer 2.

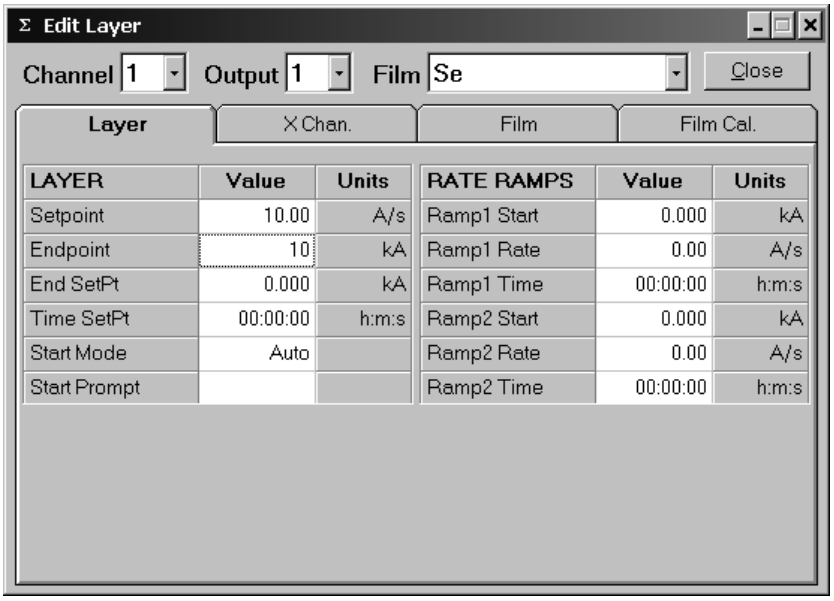


The CIGS process now consists of Layer 1 and Layer 2. Layer 1 will co-deposit three films, and Layer 2 will co-deposit two films. However, the channel, output, and films are all duplicates. We will correct that error in the next section.

2.2.5 Edit Layer

Highlight Layer 1: Ch:1 Out:1 Film1 and click Edit to display the Edit Layer dialog box.

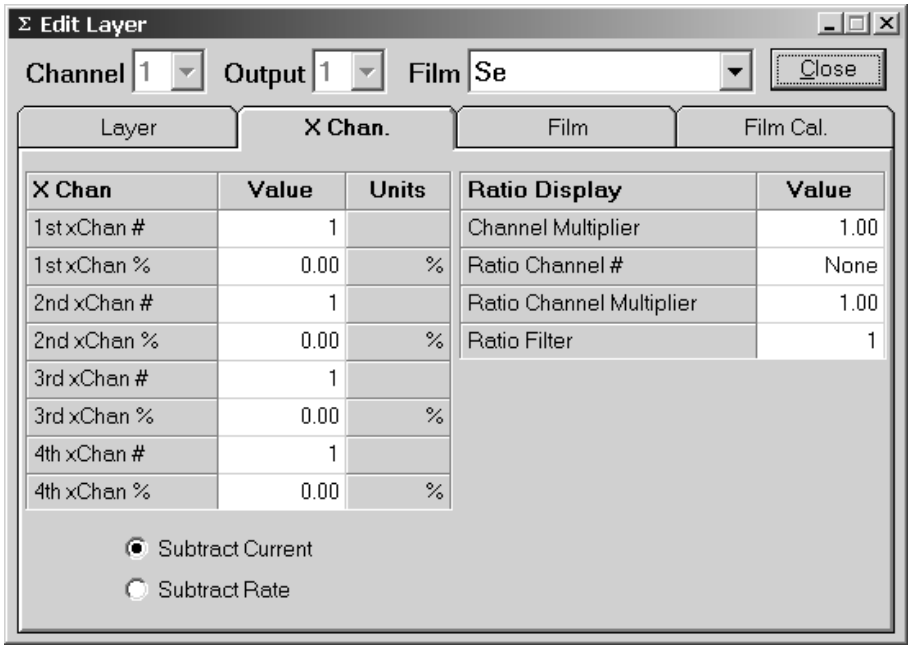
The Edit Layer dialog box shows all of the parameters needed to deposit the selected layer. At the top of the dialog box you select the measurement channel and output to be used, and the film to be deposited in this layer. Select Channel 1, Output 1, and Film Se.



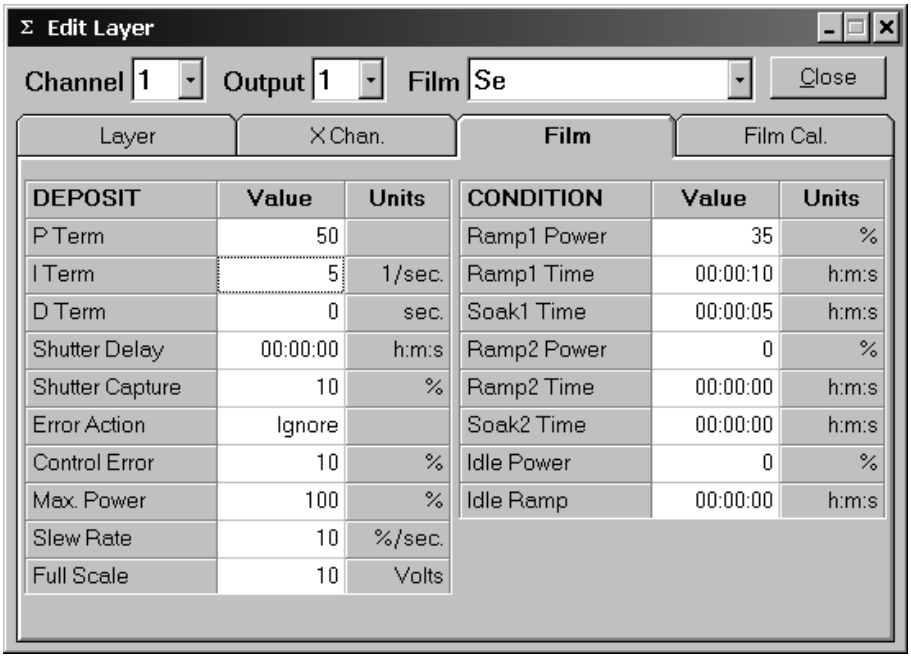
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Select the Layer tab and set the rate Setpoint to 10 A/s, and the thickness Endpoint to 10 kA.

Click the X Chan tab to view the settings used to eliminate cross channel interference and display the ration of two channel's readings. For now we will not use these features.

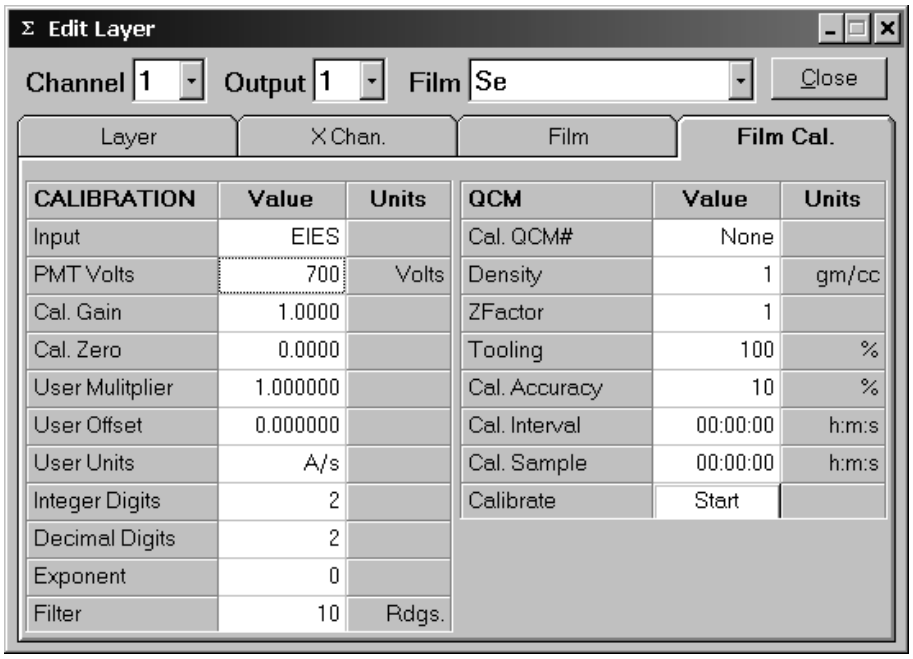


The Film and Film Calibration tabs are for the selected film, Se. On the Film tab set preconditioning Ramp1 Power, Ramp1 Time, and Soak1 Time as shown below:



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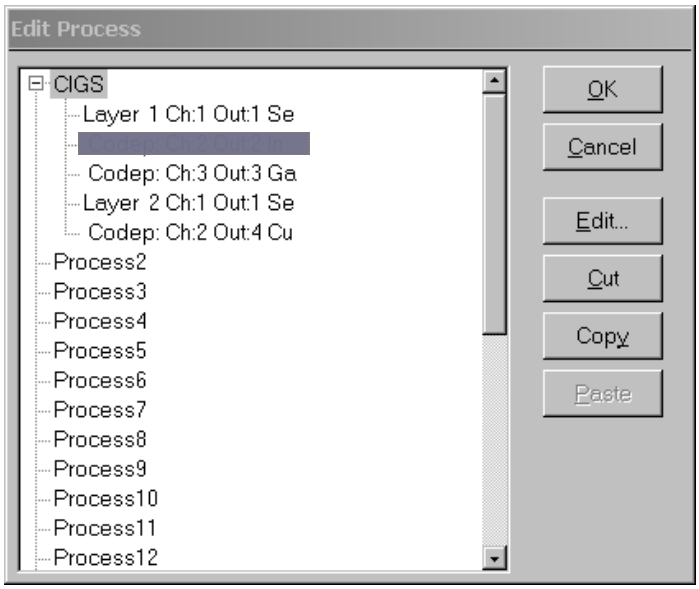
Now select the Film Calibration (Film Cal.) tab and verify Channel Input and Cal. QCM# are as shown below:



Keep in mind that parameters on the Layer and X Chan tabs are unique to this layer. Those on the Film and Film Calibrate tabs pertain to any layer using the Se film.

Take a few minutes to review the parameters on each tab. As you hold your mouse pointer over each parameter, a brief explanation appears. You can also press <F1> to view the help file for the selected tab.

When you are ready, return to the Edit Process dialog box and click the indented CoDep film, immediately below Layer 1 Ch:1 Out:1 Se.



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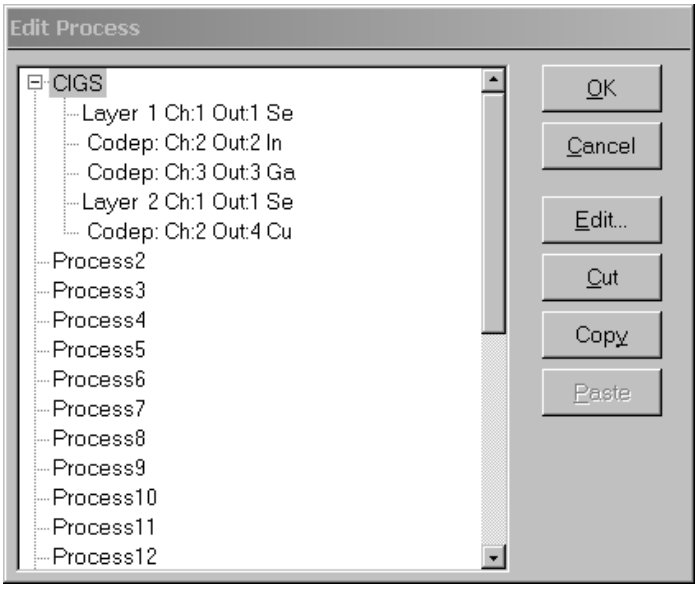
The Edit Layer dialog box will update to show the parameters for the selected layer.

In the Edit Layer dialog box, set this CoDep film to Channel 2, Output 2, and select film In. On the Layer tab, enter a Setpoint of 5 A/s and an Endpoint of 5 kA. On the Film tab, set Ramp1 Power to 25%. Edit the remaining Film and Film Cal. parameters to match those for Se, as shown on the previous page.

Return to the Edit Process dialog box and click the CoDep film immediately below Codep Ch:2 Out 2 In. In the Edit Layer dialog box, set this CoDep film to Channel 3, Output 3, and film Ga. On the Layer tab, enter a Setpoint of 2 A/s and an Endpoint of 2 kA. On the Film tab, set Ramp1 Power to 15 %. Edit the remaining Film and Calibrate parameters to match those for Se and In, as shown on the previous page. That completes the definition of the first co-deposition layer, consisting of Se, In, and Ga.

Edit Layer 2 so that the first entry is Layer 2 Ch:1 Out:1 Se with a rate Setpoint of 10 A/s and thickness Endpoint of 10 kA. Change the codep layer for Layer 2 to CoDep Ch:2 Out: 4 Cu with a Setpoint of 3 A/s and Endpoint of 3 kA.

When you are finished, you should have a 2-layer CIGS process as shown below:



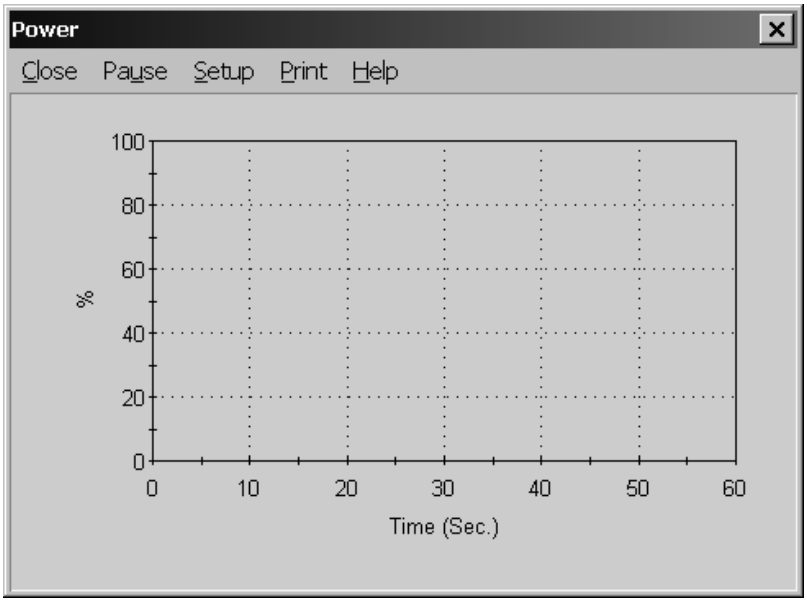
Notice that in Layer 1, channel 2 is measuring In, and controlling its deposition through output 2. In Layer 2, we are using channel 2 to measure Cu (same filter). But Cu deposition is controlled by output 4 - connected to a different source power supply.

Click OK to return to the main screen with CIGS as the active process.

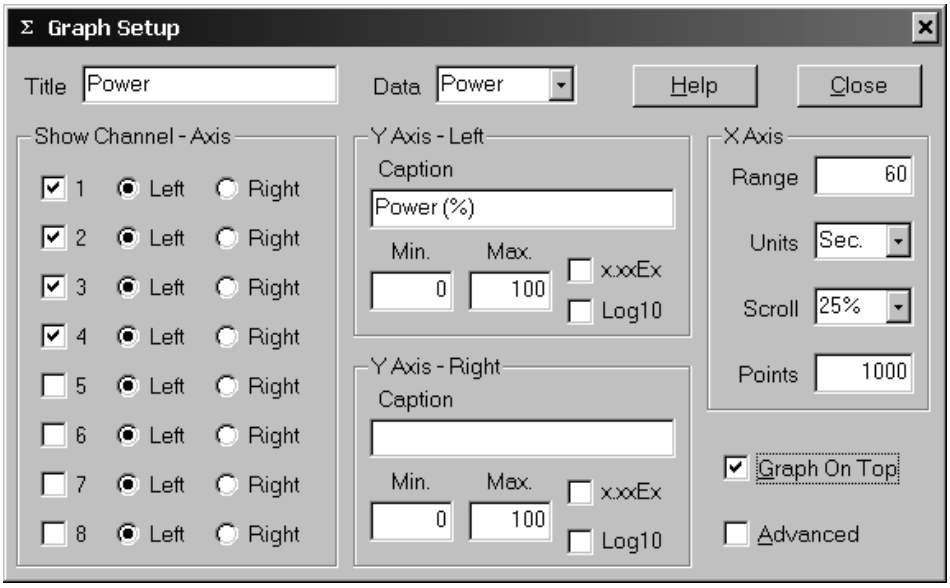
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2.2.6 Graphs

On the main screen click the Graphs menu and select Graph 3. You may want to rearrange some program windows at this point. You can also resize the graph by dragging its window border.



Graph 3 is normally a graph of the output power of the active channels during deposition. Click Setup on the graph menu to show the Graph Setup dialog box.



Assign channels 1 to 4 by checking the Show Channel check boxes. Also, check Graph On Top to keep the graph above other windows. When your Graph Setup dialog box matches the one above, close the Graph Setup dialog box.

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2.2.7 Summary

Spend some time with this process to become familiar with its setup. Especially, the creation of a multi-layer and codeposition layer process. Also, review the parameters contained in the Layer Edit screen. The Layer Edit screen will be crucial to fine tuning your process.

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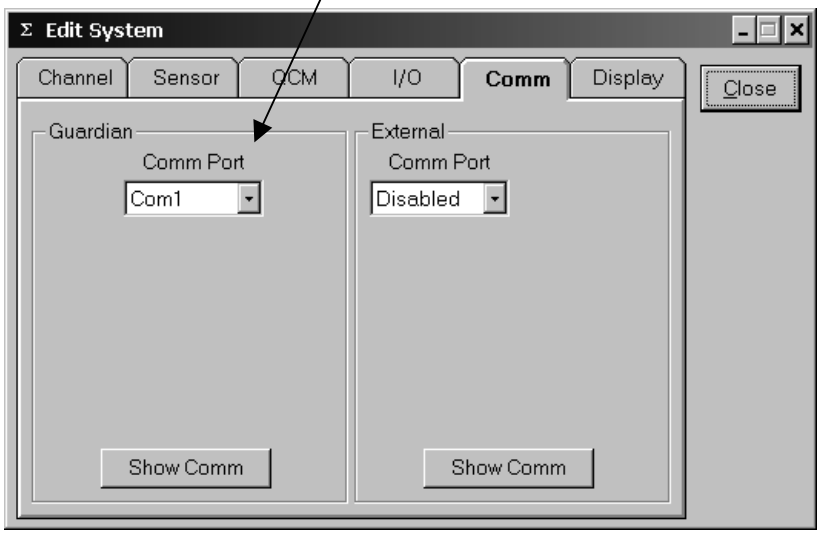
2.3 Initial Setup

Connect the Guardian controller rear panel RS-232 connector to your computer serial port using a straight through DB-9 Male-Female cable. Connect your detector module(s) to the rear panel of the Guardian controller with straight through DB-9 Male-Female cable(s).

Depress the power switch on the Guardian controller.

2.3.1 Communications

If a Comm Error message appears on the main screen status line, click Edit, System, and the Comm tab. Select the Comm Port used for communications with the Guardian controller.



If you are connecting to the Guardian controller by Ethernet, select Ethernet in the Comm Port dropdown box. Enter the Port (typically 2101) and address (typically 192.168.1.200).

When the proper communications parameters are entered, the main screen Comm Error message will disappear.

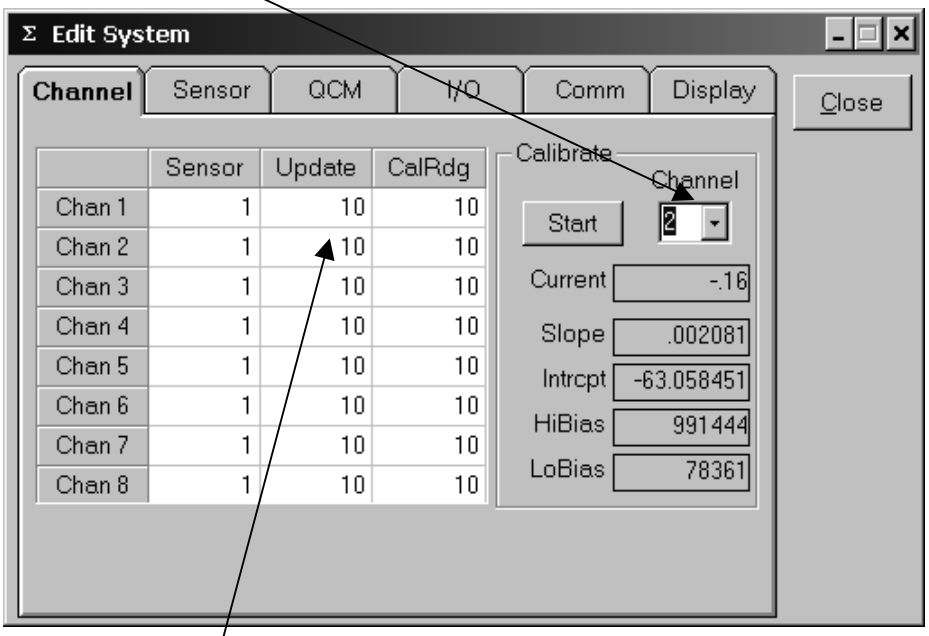
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2.3.2 Detector Calibration

The internal electronics of each EIES detector module must be calibrated before it can be used.

Note: *If you replace or exchange a detector, you must recalibrate!*

To calibrate a detector, select the Channel tab of the System Edit dialog box. Select the Channel you wish to calibrate.



Verify that a “No Response!” error message is not shown below the Start button in the calibration frame. If it is, check the detector to controller cable. You can also try powering the controller off, then on.

Set the detector Update rate to a value from 1 to 10 Hz and Cal Readings to 10.

When there are no errors, click the Start calibrate button. After a few seconds the updated calibration values are shown. Verify that the current readings for the selected channel are near zero.

Select and calibrate any additional detector channels.

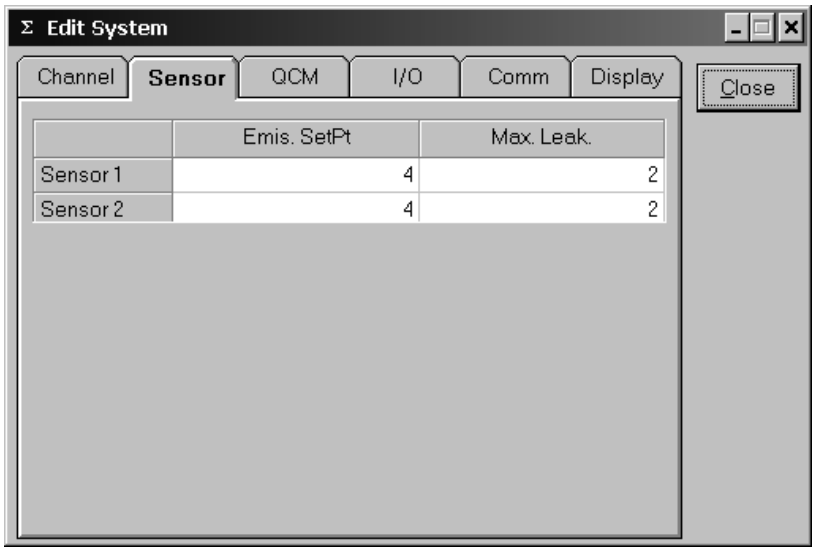
Note: *The bias, slope and intercept values shown in the calibrate frame are for diagnostic purposes only. They are not needed for normal operation of the EIES system.*

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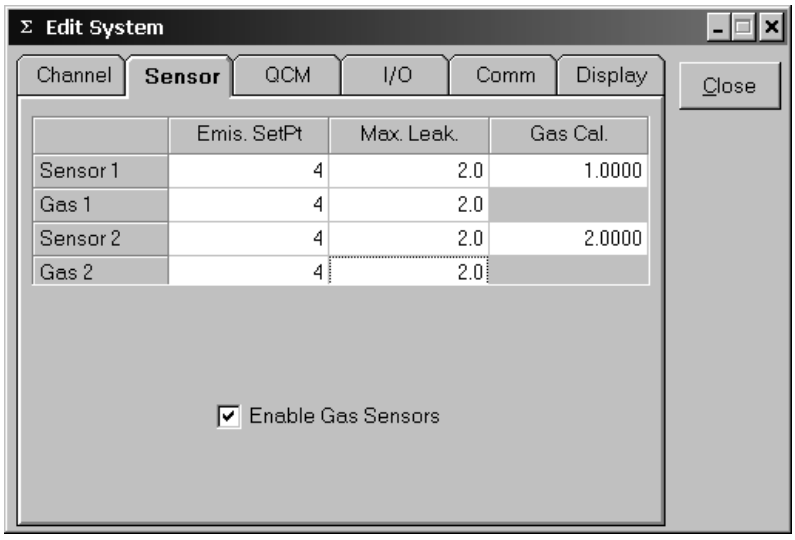
2.3.3 Sensor Setup

The Guardian controller can operate up to two sensors. During operation, the controller must maintain a constant sensor emission current. As a sensor is used and material is deposited on the sensor, an unwanted leakage current can develop. When the leakage current becomes too large, the Guardian controller can no longer control emission current.

The Emission (4 mA) and Leakage (2 mA) settings shown below are adequate for most applications. See chapter 3 for more information on sensor setup.



Guardian controllers with Gas Compensating sensors have additional Emission and Leakage parameters for the gas sensor. A Gas Calibration factor is used to null the gas effect from the main sensor readings.

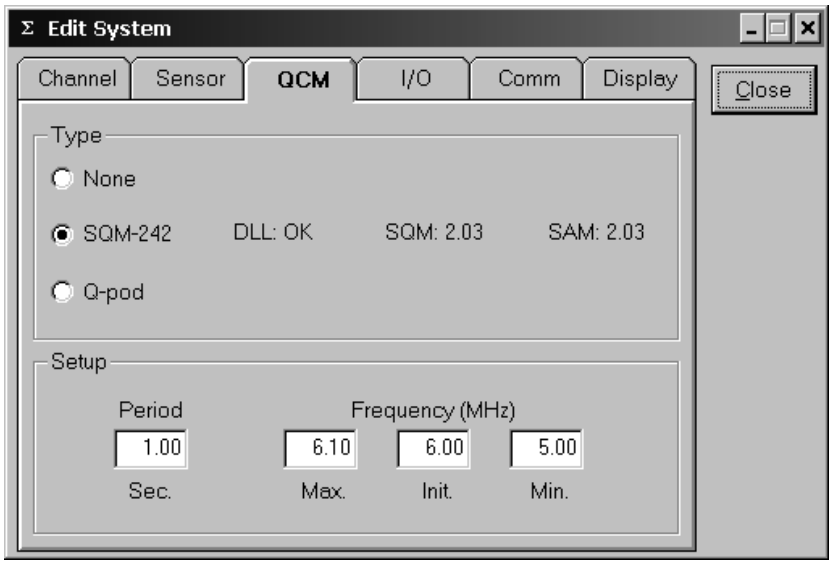


Section 3.7.2 covers gas sensor calibration in detail. For now, uncheck Enable Gas Sensors if it is checked.

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2.3.4 QCM Option

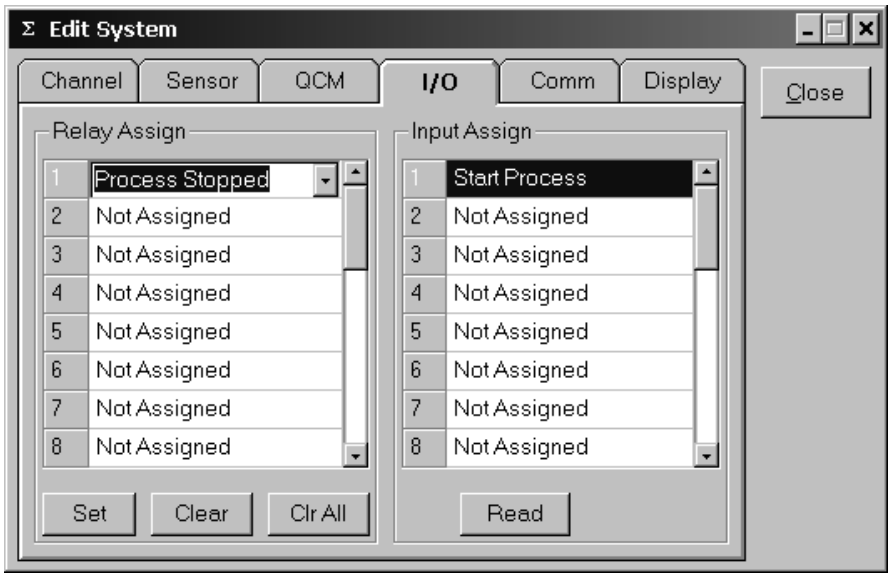
If you installed the optional SQM-242 card or Q-pod, click the QCM tab of the Edit System dialog box.



If the SQM-242 card is installed properly, Card: 2.XX, DLL: OK appears below the readings grid. If you are using a Q-pod its serial number appears. Verify that each sensor attached to the QCM displays a frequency reading on the main screen.

2.3.5 Digital I/O

The I/O tab of the System Edit dialog box assigns the Guardian controller's relays and digital inputs to program functions. Most digital I/O is not necessary for initial operation. Consult Chapter 3 for I/O programming, Chapter 4 for I/O wiring.



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2.4 Operation

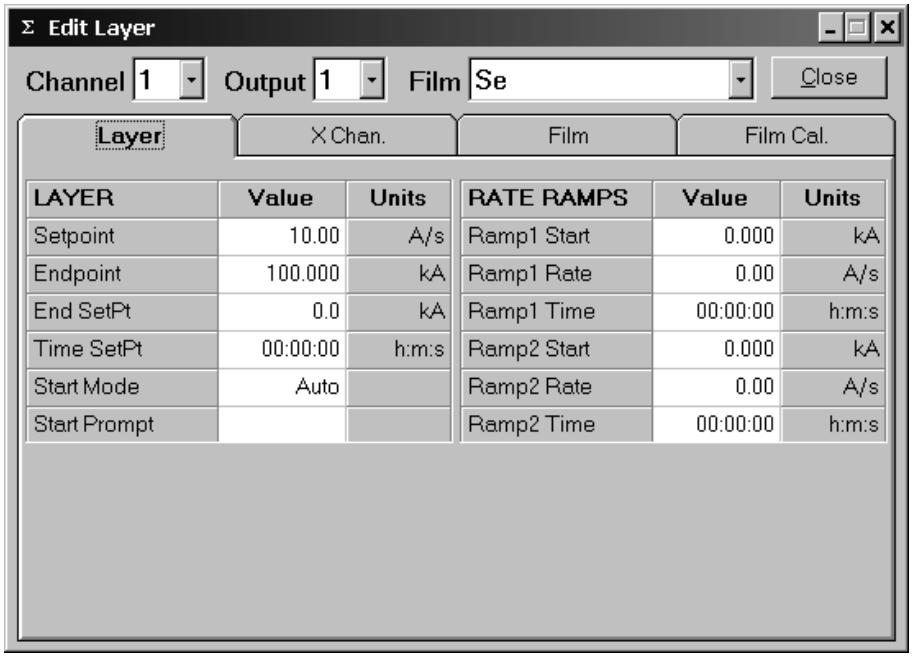
This section assumes that you have worked through the example process of Section 2.2 and the initial detector calibration of Section 2.3.

2.4.1 Build a Single Layer Process

Build a simple single-layer, single-film process in the EIES program and make it the active process (see section 2.2). Verify that the EIES channel you are using has no errors, and a reading near zero (see Section 2.3).

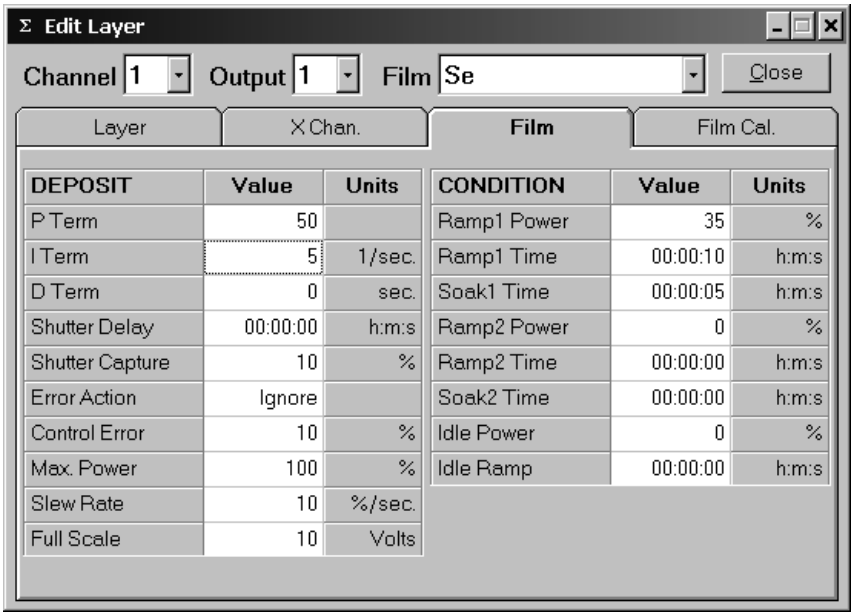
2.4.2 Setup Layer Parameters

Display the Edit Layer dialog box for the channel you are using by clicking the Edit button to the left of that channel on the main screen. Select the Layer tab of the Edit Layer dialog box, and verify that the Endpoint is at value high enough to avoid prematurely halting the process during calibration.



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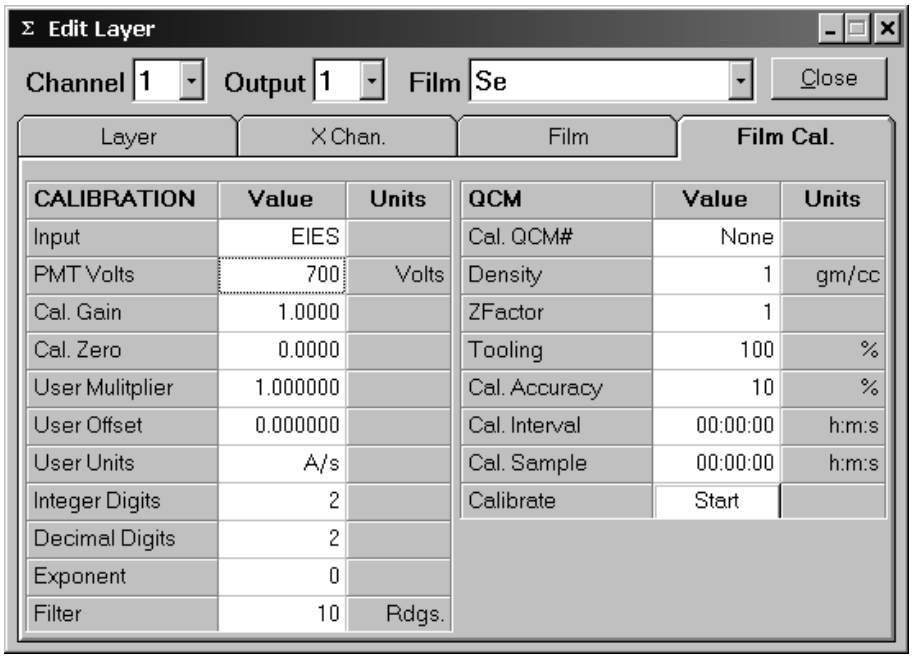
On the Film tab verify that the Full Scale voltage matches the input of your power supply. Also verify that Max. Power is consistent with the material you are evaporating.



DEPOSIT	Value	Units
P Term	50	
I Term	5	1/sec.
D Term	0	sec.
Shutter Delay	00:00:00	h:m:s
Shutter Capture	10	%
Error Action	Ignore	
Control Error	10	%
Max. Power	100	%
Slew Rate	10	%/sec.
Full Scale	10	Volts

CONDITION	Value	Units
Ramp1 Power	35	%
Ramp1 Time	00:00:10	h:m:s
Soak1 Time	00:00:05	h:m:s
Ramp2 Power	0	%
Ramp2 Time	00:00:00	h:m:s
Soak2 Time	00:00:00	h:m:s
Idle Power	0	%
Idle Ramp	00:00:00	h:m:s

Select the Film Calibration tab, and verify that the PMT voltage setting is about 700V.



CALIBRATION	Value	Units
Input	EIES	
PMT Volts	700	Volts
Cal. Gain	1.0000	
Cal. Zero	0.0000	
User Mulitplier	1.000000	
User Offset	0.000000	
User Units	A/s	
Integer Digits	2	
Decimal Digits	2	
Exponent	0	
Filter	10	Rdgs.

QCM	Value	Units
Cal. QCM#	None	
Density	1	gm/cc
ZFactor	1	
Tooling	100	%
Cal. Accuracy	10	%
Cal. Interval	00:00:00	h:m:s
Cal. Sample	00:00:00	h:m:s
Calibrate	Start	

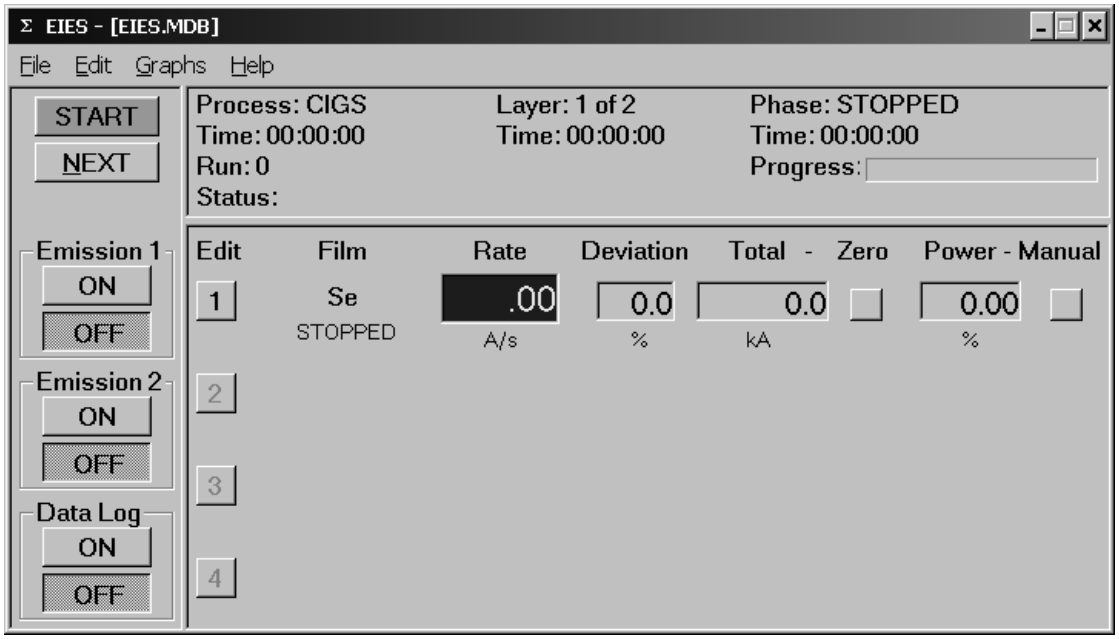
If you are using QCM calibration of the EIES measurements, select the proper QCM Sensor# and enter the material Density and ZFactor (see Appendix B). For now, it is probably best to disable QCM calibration by setting Cal QCM# to None.

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2.4.3 Start Deposition

Note: *Pump down the vacuum chamber to below 1E-5 Torr before operating the EIES-IV system!*

On the EIES main screen verify that there is no error message below the Film on the channel(s) being used, and verify that Rate reading is near zero.



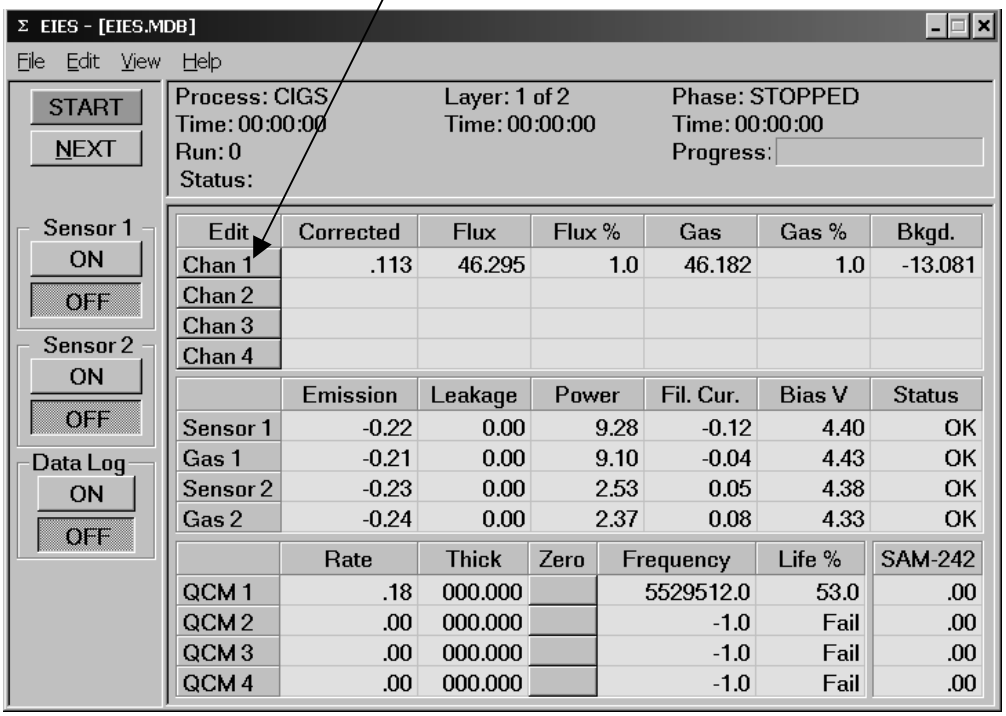
On the main screen, turn Emission ON for the sensor(s) you are using. The rate reading on each channel should still be near zero, but changing slightly.

Turn on your evaporation power supply. Click the Channel 1 Manual Power button (on the right side of the screen). Enter a small power value and press <Enter> to send the value to the power supply. Slowly increase power until the material vaporizes and the rate reading starts to increase above zero.

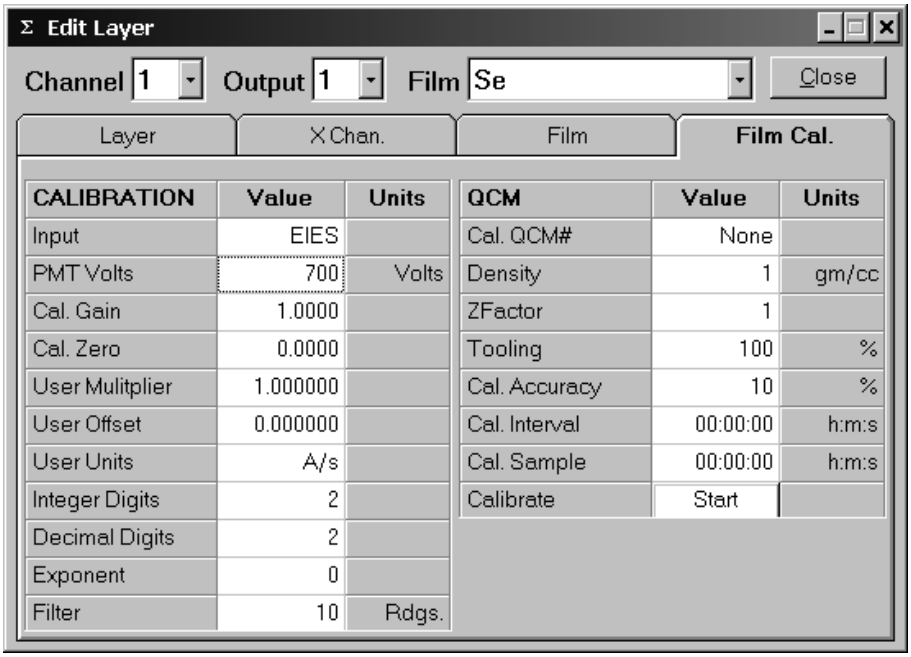
If everything looks OK, increase the power to near the desired deposition rate. The deposition rate can be determined before EIES calibration from previous experience with the power supply output level, another measurement reference, or from the optional QCM readings.

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To optimize the detector PMT voltage, select View, Readings to show the detector readings. Click the channel Edit button.



On the Film Cal. tab of the Edit Layer dialog box, adjust the PMT voltage until the detector Current is between 200nA and 1800nA. Low current values cause noisy readings. High values may saturate the PMT.



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2.4.4 Manual Calibration

Calibrate the main screen rate reading to match the actual rate by entering a Cal. Gain on the Edit Layer, Film Cal. tab. The Cal. Gain parameter is calculated by:

Cal. Gain = EIES Measured Rate / Actual Rate

2.4.5 QCM Calibration

If you are not using the QCM calibration option, skip to the next section.

If you are using the QCM calibration option, select View, Readings to display the QCM readings grid. Verify that the QCM measured rate is as expected. The QCM measured rate will be used to calibrate the EIES detector channel.

On the Edit Layer dialog box, Film Cal. tab, click calibrate Start. After a few seconds the calculated Cal. Gain will appear. Verify that the main screen's rate reading matches the QCM rate.

2.4.6 Stop Deposition

This completes the initial operational checkout. Set Manual Power to zero on the main screen to stop deposition. If you previously pressed Start, click Stop to halt the process.

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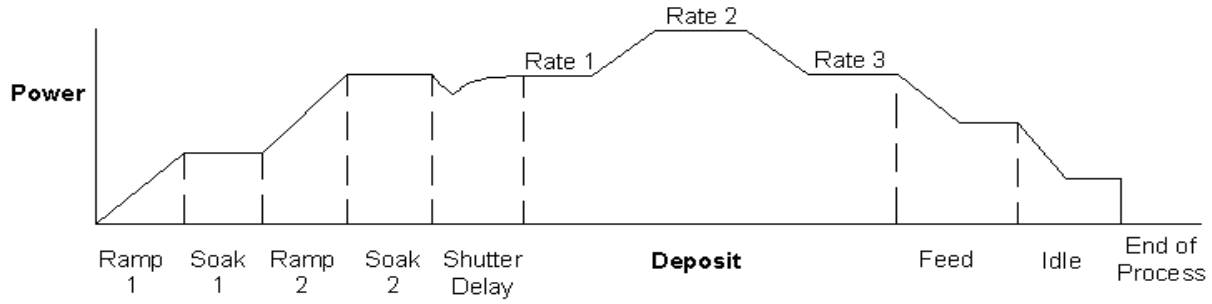
Chapter 3 - EIES Software

3.0 Introduction

The EIES-IV Guardian software is a powerful PC-based thin film deposition controller that can:

- Measure up to eight materials simultaneously.
- Operate two standard or GC sensors.
- Control up to eight deposition sources simultaneously.
- Calibrate EIES sensors against quartz crystal sensors (SQM-242 or Q-pod option).
- Control analog variables such as temperature and pressure (SAM-242 option).
- Store unlimited processes of up to 25 processes and 250 layers on disk.
- Graph, and log deposition data to disk, for process documentation and analysis.

A typical deposition cycle for a thin film can be broken into three distinct phases: pre-conditioning (ramp/soak), deposition, and post-conditioning (feed/idle).



During pre-conditioning the source material is prepared for deposition. The first ramp/soak pre-conditioning 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. During deposition, multiple rates (rate ramps) can be programmed.

When the desired thickness is reached, the evaporation source can be set to feed or idle power. At this point the process may be complete, or deposition of another layer may begin. Up to eight separate films can be co-deposited within a single layer.

In addition to using EIES PMT detector modules for rate control, QCM inputs (from INFICON's SQM-242 card or Q-pod) can also be used to control deposition, or to calibrate the EIES PMT detector module. DC voltage inputs (measured by INFICON's SAM-242 card) can also be used to control other process variables.

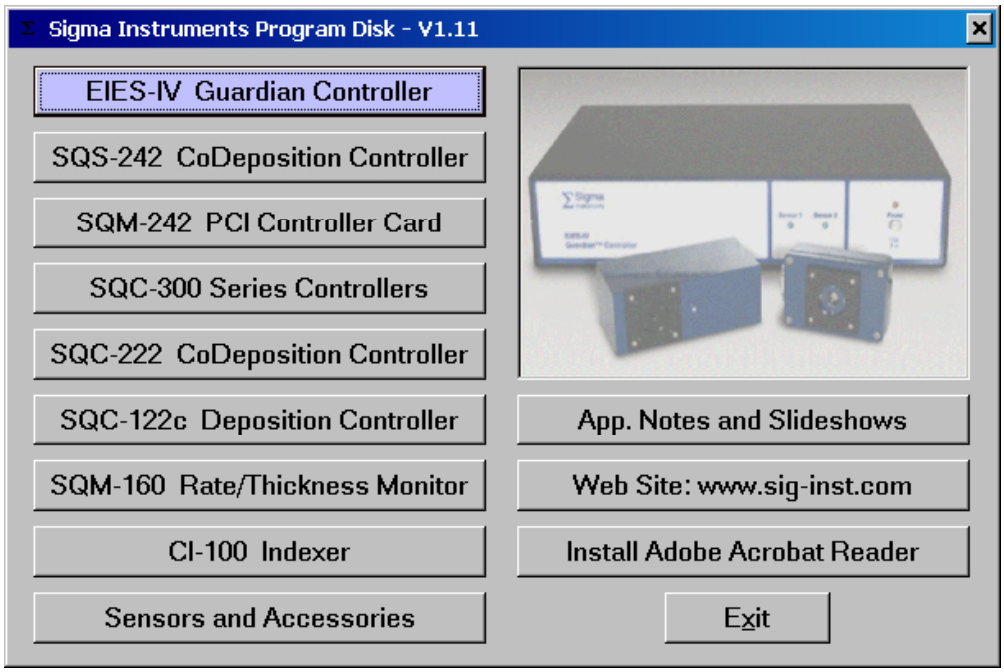
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3.1 Installation

Note: *The EIES program may be installed and used in Simulate mode without an EIES-IV Guardian controller. This is useful for learning the software, and for off-line process development.*

To install the EIES software, insert the INFICON Program CD-ROM. If the setup program does not start automatically, click Start, then Run, then type <d>:UtilityDisk (where <d> is the drive you are using). The Program Disk main menu should appear.

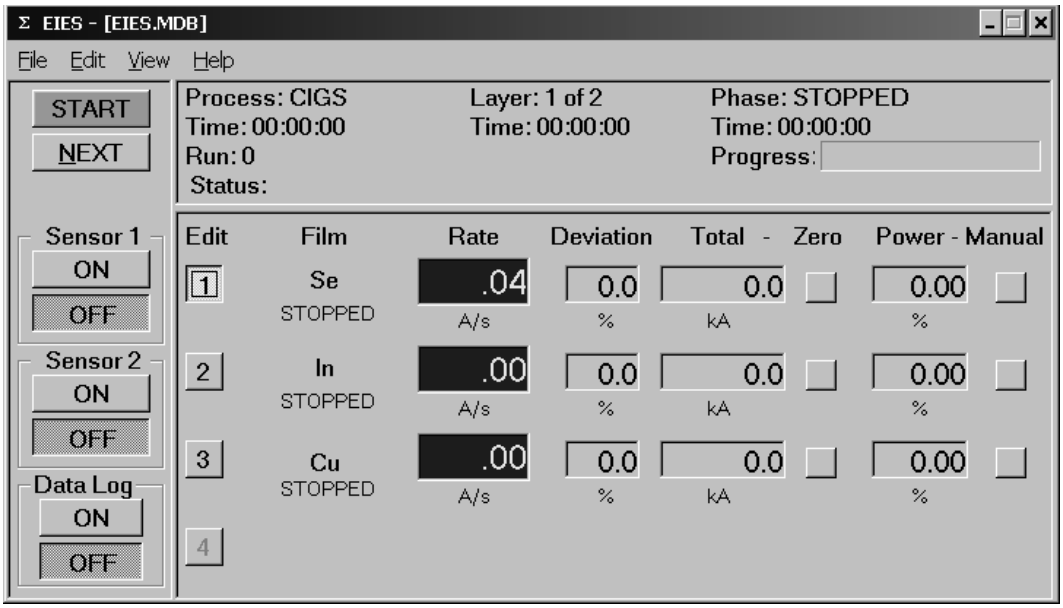
On the program disk menu, click EIES-IV Guardian Controller, then click Install Multi-Layer on the drop down menu. When installation is complete, you may be prompted to restart the computer.



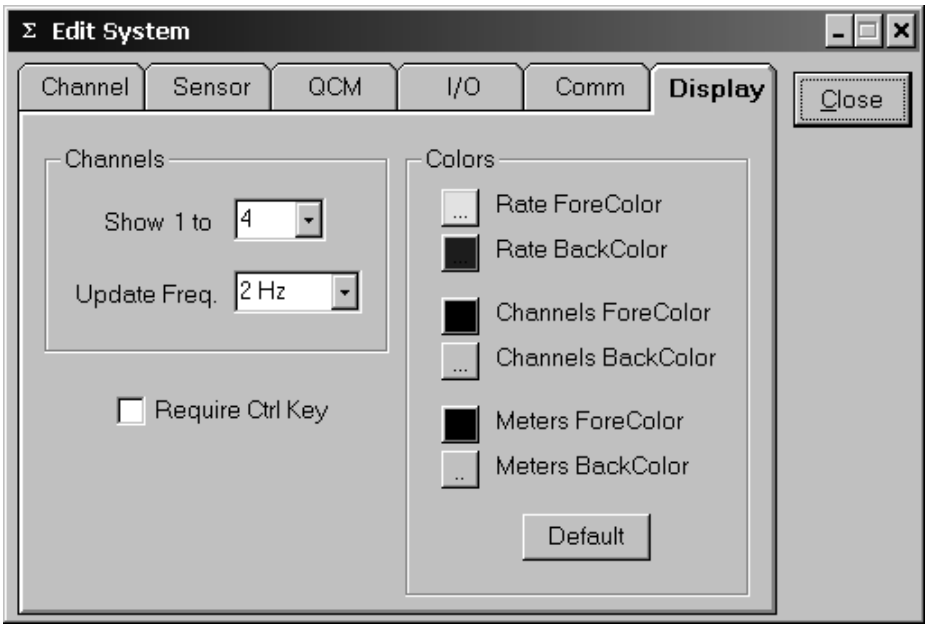
You may also want to install the Single Layer version of the EIES program. The single layer version of the EIES program is useful for research, initial evaluation of material settings, and single layer depositions.

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To start the EIES program, click the EIES desktop icon, or click Start, Programs, Sigma Instruments, then EIES.



The EIES main screen displays the last used Process, and the film(s) defined for the first layer of the process. In the screen above, three films (Se, In, and Cu) will be deposited simultaneously in the first layer.



The main screen can show from four to eight channels of data. For most users four channels will be adequate. To select the number of channels displayed, click the Edit menu, then System. On the System Edit dialog box, select the Display tab. Select the number of channels you want to Show.

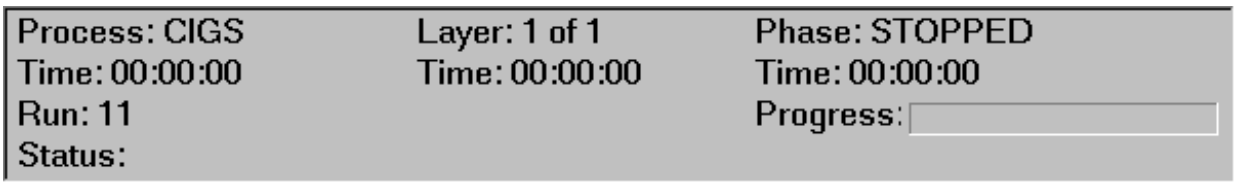
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3.2 Main Screen

The EIES main screen consists of three panels and a menu bar. The Status Panel (top) displays information on the active process. The Control Panel (left) controls operation of the EIES-IV Guardian system. The Readings Panel displays readings from each of the channels used by the active process layer. Finally, the menu bar provides access to process recipe and instrument setup functions.



3.2.1 Status Panel



Process: Name of the current process. Select the active process from the menu File, Open Process.

Process Time: The accumulated time for this run of the selected process. Resets to zero, then starts counting when the Start button is clicked.

Process Run: The number of times this process has been run. The run count can be zeroed on the File, DataLog screen.

Status: Displays error conditions and other status information.

Layer: Displays the current layer and the total number of layers in the active process. Use the Next button on the Control Panel to select layers.

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Layer Time: The accumulated time for this layer. Resets to 0 if the layer is stopped.

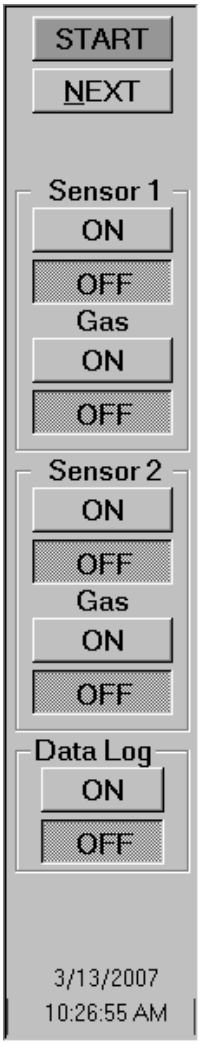
Phase: The current layer phase. Phases consist of pre conditioning (Ramp1, Soak1, Ramp2, Soak2), Shutter Delay, Deposition, and post conditioning (Idle Ramp). Additional phases, such as Stopped, Layer Stopped and Filter change are also displayed.

Phase Time: Phase time is shown as ElapsedTime/TimeRemaining.

Progress: A graphical display of the percent complete for the current phase.

3.2.2 Control Panel

***Note**: To avoid accidental activation of the Start/Stop, Auto/Man, and Emission controls you may need to press and hold the <Ctrl> key while clicking the control. This feature can be disabled on the Display tab of the Edit System screen.*



Start/Stop: Click **Start** to run the process. The Start control is disabled if there are no communications with the EIES controller. When the process is running, the top control displays **Stop**. Click **Stop** to stop the process and set all outputs to 0. Press **Start** again to restart the layer.

Next: When the process is stopped, click **Next** to move to the next process layer. The selected layer is displayed in the Status panel. When Start is clicked, the process will start at the selected layer.

Reset: When a process is stopped, click **Reset** to abort the process, and reset the selected layer to 1.

Emission Controls: When first started, both the EIES instrument and this program turn both sensors Off. Be sure Emission On is selected when running the process or no EIES readings will occur. Turn sensor Emission Off when not in use, or not under vacuum.

When Gas Compensating sensors are used, both the main sensor and the Gas sensor should be on. The main and gas sensor can be turned on/off simultaneously by holding the <Shift> key and clicking the main sensor on/off.

When emission is On, the sensor's emission current is displayed with a green background. If the leakage current reaches 70% of the maximum allowed value the background turns yellow. Maximum Leakage is set in the Edit System dialog box, Sensor tab.

DataLog Control: Turns disk data logging on/off. Data is logged only while the process is running. Edit data logging options in the File, DataLog menu.

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3.2.3 Readings Panel – Process Mode

The readings panel has two display modes - Process and Readings. Click View, Process to see the process display. The Process display mode shows process related information such as films, setpoints, and manual operating controls. Only channels that are defined for the selected layer are displayed. Use Edit, System, Display to select a 4 to 8 channel display.



Edit Button: Click the Edit button to display the Edit Layer dialog box for the channel. Consult the Edit Layer section of this manual for detailed layer edit information.

Channel Film Display: Displays the film assigned to the channel and the current phase of the channel. During deposition, also displays the current rate setpoint for the channel.

Channel Rate: Displays the deposition rate reading for the channel. The EIES detector module measures rate as a current. The current reading is converted to A/s (or the desired user units) using film parameters described in the Edit Film section of this manual.

Deviation: The deviation of the measured rate from the desired rate setpoint.

Total: The accumulated Total thickness for the channel. Typically, rate is displayed in Angstrom per second (A/s) and Total is displayed in kA. For EIES detector measurements, Total is calculated by summing each reading times the reading period (then dividing by 1000 to convert to kUnits). For QCM inputs, Total is the thickness returned by the quartz crystal. If a channel uses a SAM analog input, Total is meaningless, and is not displayed.

Zero (Total): Zeroes the accumulated total for the channel. To zero all channel totals, hold the <Shift> key and click any channel Zero button.

Power: Displays the output power in percent of full-scale voltage.

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Manual (Power): Switches the output power between PID loop control and manual user setting. When depressed, the background of Manual power button and the Power display turns green. The initial manual power value is the same as it was when the Manual power button was depressed. In Manual power mode, you may type a new power setting and press <Enter> to change the output power setting. Or use the hand controller to adjust output power.

Click the Manual button again to return to auto (PID control) mode. If the process is stopped, the power will be set to zero. If the process is running, the channel goes immediately to the deposit phase, with power set by the PID control loop.

Note: *Because the Edit Process dialog box allows editing of a layer's input and output assignments, Manual Power can only be changed when the Edit Process dialog box is closed.*

3.2.4 Readings Panel – Ratio Mode

Click View, Ratios to see the ratio display. The ratio display is nearly identical to the process display mode, except that the deviation readings are replaced with ratio readings. This display is useful when you are more concerned with the deposition ratio between two channels than the absolute deposition rate of a channel.

The ratio is the current channel's reading divided by the reading of the channel shown below the ratio display. The channel used for the ratio and a ratio correction factor are set in the Layer dialog box, xChan tab.

3.2.5 Readings Panel – Readings Mode

Click View, Readings to see the readings display. The readings display mode shows unfiltered channel (detector), sensor, and QCM readings.

Edit	Corrected	Flux	Flux %	Gas	Gas %	Bkgd.
Chan 1	.115	46.300	1.0	46.185	1.0	-13.162
Chan 2						
Chan 3						
Chan 4						

	Emission	Leakage	Power	Fil. Cur.	Bias V	Status
Sensor 1	-0.23	0.00	9.36	-0.12	4.40	OK
Gas 1	-0.22	0.00	9.19	-0.04	4.43	OK
Sensor 2	-0.23	0.00	2.54	0.04	4.34	OK
Gas 2	-0.24	0.00	2.38	0.07	4.32	OK

	Rate	Thick	Zero	Frequency	Life %	SAM-242
QCM 1	.00	000.001		5529511.0	53.0	.00
QCM 2	.00	000.000		-1.0	Fail	.00
QCM 3	.00	000.000		-1.0	Fail	.00
QCM 4	.00	000.000		-1.0	Fail	.00

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Channel Readings

Each channel uses either two or three measurements to calculate the channel current signal. The measurements used are:

PMTCurOn: The first measurement cycle measures the detector current with sensor bias voltage on. This is a measure of the deposition flux, plus any background signal from ambient light or the sensor filament. This measurement also includes any broadband emission from other process gases.

PMTCurOff: The second measurement cycle measures the PMT current with sensor bias voltage off. With bias voltage off, no electron emission occurs. Hence, this is a measure of only background light.

PMTCurGas: The third measurement cycle is used only with INFICON's gas compensating sensor. The GC sensor includes an element that is not exposed to materials being deposited. It measures only the emission caused by gases, especially water vapor and nitrogen (plus any background light as explained above).

When the three measurements are completed, the channel readings are displayed as:

Flux = PMTCurOn - PMTCurOff

Gas = PMTCurGas - PMTCurOff

Corrected = Flux - (GasCal x Gas)

The Gas Calibration factor compensates for differences in GC sensor geometry and placement. It is used to completely remove the gas constituent from the measured signal.

Corrected: The corrected current (in nA) measured by the channel detector.

Flux: The flux plus gas signal, minus the background light.

Flux %: The % of full scale for the PMT and A/D converter circuits. Large values risk overloading the measurement circuit. Small values cause poor signal to noise ratios. Adjust the sensor emission current or detector PMT voltage to achieve 30 to 80%.

Gas: The GC sensor gas signal, minus the background light.

Gas %: The % of full scale for the PMT and A/D converter circuits of the GC sensor.

Background: The ambient light signal.

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Sensor Readings

Emission Current: The sensor filament emits electrons to excite the electrons of the measured material. Emission current is a measure of that electron current. 2 to 4 mA. is a typical value.

Leakage Current: As a sensor is used, material deposited on the sensor can create leakage paths for the emission current. Leakage current is measured when the bias on the filament is at +180V, and no emission occurs. Values above 2 mA indicate the sensor may need to be cleaned or replaced.

Filament Power: The power, in watts, supplied to the sensor filament. Seven watts is normal. As the chamber pressure rises or the filament wears, filament power will increase. If the power rises above 10 watts, inspect the electrical connections going to the sensor and the sensor filament. If the power is still high, replace the filament.

Filament Current: The current flowing through the filament. Around two amps is normal.

Bias Voltage: The voltage used to accelerate the emitted electrons. 180V is normal.

Status: Fail indicates an open filament.

QCM Readings

The QCM grid is shown only when an SQM-242 or Q-pod QCM is installed.

Rate: The deposition rate (in A/s) measured by each QCM sensor.

Thickness: The deposited thickness measured by each QCM sensor.

Zero: Click to zero the measured thickness, or <Shift> click to zero all thickness. Normally handled automatically by the EIES software when a new layer begins.

Frequency: The measured frequency of each QCM sensor. A negative value indicates a sensor failure. A QCM requires a density, Z-Factor, and tooling factor to properly display rate and thickness. However, frequency is always displayed. During deposition, the frequency will decrease. With no deposition the frequency reading should be stable.

Life %: The estimated percent life remaining on the crystal. If crystals consistently fail prematurely, raise Freq. Min. on the Edit System dialog box, QCM tab to match the expected failure frequency.

SAM-242: The measured volts DC on an SAM-242 analog measurement card.

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3.2.6 Menu

The menu along the top of the main screen provides access to functions for building deposition processes, configuring the hardware for your vacuum system, and data display.

The following sections of this chapter detail the functions of each menu selection. For an overview of program operation, click each menu selection, then read the corresponding section in this chapter to understand the concepts involved.

Once you have worked through all menu items, go back to the Quick Start chapter and build the sample process for a better operational understanding.

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3.3 File Menu

***Note**: The current process must be stopped for the File menu to be available.*

3.3.1 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.

3.3.2 File: Open and Save Database

Open Database: Selects a database of processes to be used for deposition. A single process database holds 25 processes. However, the number of process database files is unlimited.

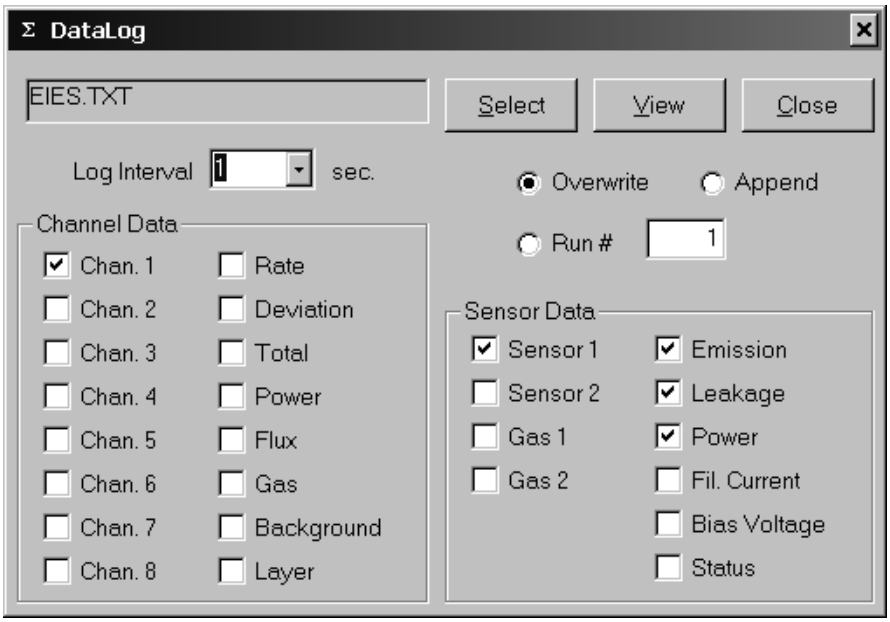
Save Database As: Saves the current process database to disk under a different name. This is useful for saving the process database to floppy disk (for backup!), or for making trial changes without affecting your working database. Process databases are saved in Microsoft Access format.

3.3.3 File: Data Log On/Off

Turns disk data logging on/off. Data is logged only while the process is running. This menu item duplicates the functionality of the main screen DataLog On/Off control.

3.3.4 File: Data Log Setup

Configures the disk data logging functions. Data is saved on disk in “comma delimited” format for easy import into a spreadsheet for graphing and analysis.



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Filename: Displays the name of the current DataLog file as explained below.

Select: To modify the DataLog file's path or name, click Select. A Save LogFile As dialog box will be displayed. Enter a new filename and click Save.

***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.*

View: Opens the selected DataLog using Window's Notepad program.

Log Interval: The elapsed time between data log entries. The data log is updated only when the process is running.

Overwrite: The log file will be overwritten each time data logging is started by pressing DataLog On on the main screen. Only the last run of the process is saved, and it appears as FileName.LOG.

Append: Data is added to the end of the existing FileName.LOG file.

Run#: A data file, FileName_Run#.LOG, is written for each process run. Run# is incremented each time the process is started. Enter a new Run# to reset the counter.

Channel Data: Selects the channel(s) to log, and the data that is logged for each channel.

Sensor Data: Selects the sensor(s) to log, and the data that is logged for each sensor.

Format of the DataLog file

```
Start Log      Process Name      Run:364      Date   Time

Layer: 1 Setup:
Chan:1  Film:Se           Rate:000.000  Units:A/s    Total:005.500  TimeSP:00:05:00
Chan:2  Film:Press Mon.   Rate:000.000  Units:Torr   Total:000.000  TimeSP:00:00:00
Chan:3  Film:Temp         Rate:000.000  Units:DegC   Total:000.000  TimeSP:00:00:00
Chan:4  Film:Se           Rate:000.000  Units:A/s    Total:005.500  TimeSP:00:05:00

Time,       Phase,      Chan#,      Rate,       Dev     Total    Power
00:00:05,   RAMP 1,     CH1:,        0.00,       0.0,   000.0,   00.0,
00:00:10,   RAMP 1,     CH1:,        0.00,       0.0,   000.0,   00.0,
```


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How to Graph data in Microsoft Excel:

Start the Excel program and select File Open. In the File Open dialog box, select Files of Type: All Files. Navigate to the proper folder and click on the data log you wish to open, then click Open.

In the Excel Text Import Wizard select Delimited, then Next. Select Comma as the delimiter. Check Treat Consecutive Delimiters as One. Select Text Qualifier {None}. Click Finish to open the DataLog in Excel.

To graph the data, select the column with time, then each of the channel data columns you wish to graph. For example, to graph channel rates select column A (time), column D (Chan1 Rate), and column I (Chan2 Rate). Click Insert, Chart.

In the Chart Wizard select Line chart, then Next. The chart should appear with the rates graphed against time. There will be some extra entries along the time axis; you are welcome to clean this up, but the graph will be quite useable with just these few steps.

3.3.5 File: Print Screen

Sends a copy of the main screen to the printer selected in the Page Setup menu.

3.3.6 File: Page Setup

Provides printer selection and page orientation for the Print Screen function.

3.3.7 File: Exit

Stops the current process, turns off Emissions, and exits the EIES program.

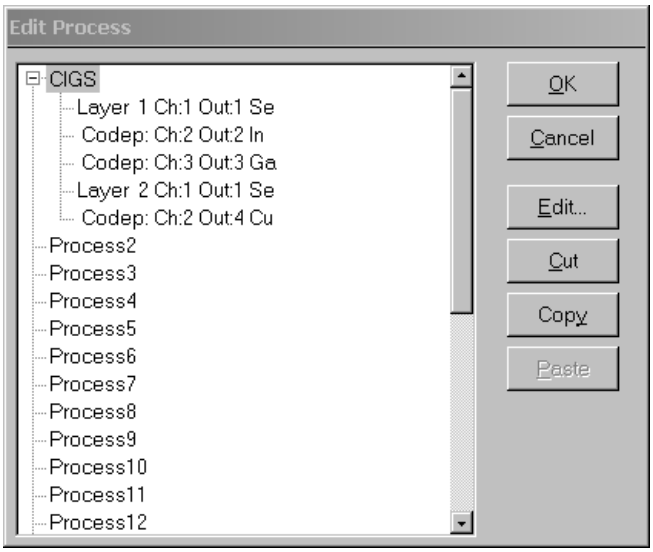
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3.4 Edit Processes

The Edit Menu, Processes dialog box provides the functions needed to create and edit thin film deposition processes. A few definitions will be helpful as you use this manual.

- A ***Process*** is a sequence of *Layers* of different *Films*.
- Each ***Layer*** establishes the desired rate and thickness of the deposited *Film.*
- A ***Film*** defines the physical material being deposited, plus all of the instrument setup parameters associated with that material.
- Multiple films deposited simultaneously are known as a ***CoDeposition (or CoDep) Layer***.

The Edit Process screen displays the 25 processes of the current database in a "treeview" display (similar to the file folders of Windows Explorer). Unused processes are marked <Empty>. Click the [+] beside a process to show the layers in that process.

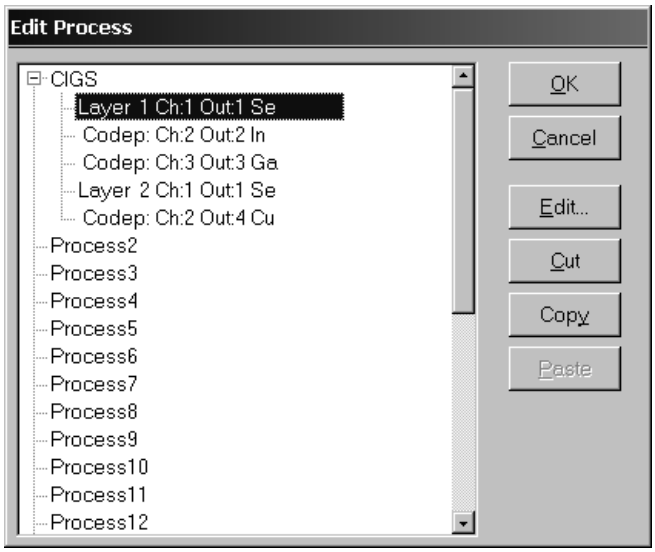


Layers are shown as **Layer# Channel# Ouput# FilmName**. Channel number is the EIES channel used for monitoring deposition. Codeposited layers are marked as CoDep and listed similarly.

Note: *The Edit Process dialog box can only be accessed when the process is stopped.*

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To add additional layers to a process, click any existing layer (in any process) then click Copy. This places a copy of the highlighted layer on the clipboard, and enables the Paste button.



There are four Paste options:

Below: Insert the clipboard layer below the highlighted layer.
Above: Insert the clipboard layer above the highlighted layer.
Replace: Replace the existing layer with the clipboard layer.
CoDep: Insert the clipboard layer as a codeposition layer of the highlighted layer.

Now click a layer in the process where you wish to paste the clipboard layer, and click Paste.

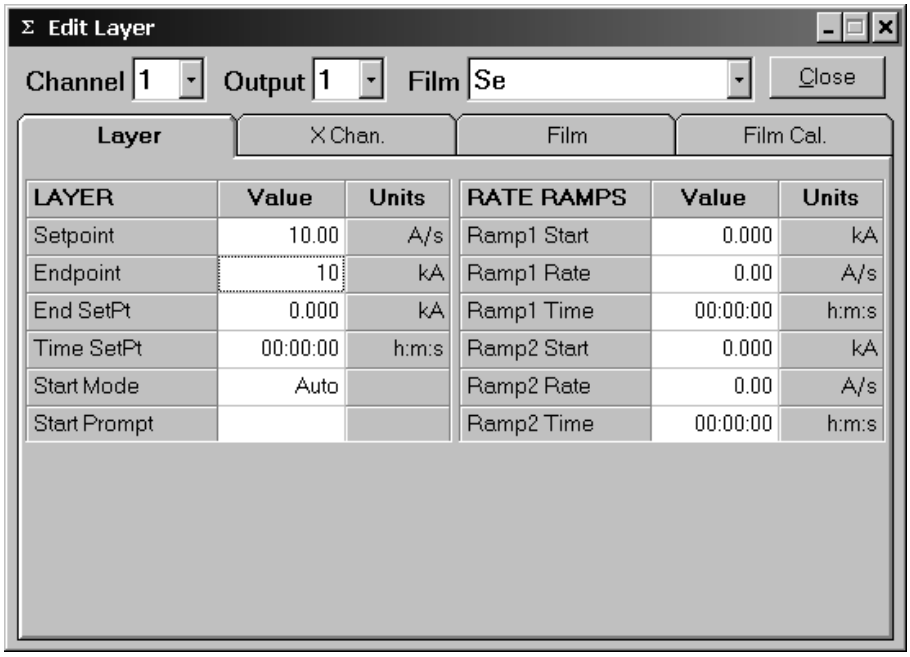
To copy an entire process to the clipboard, click on the process, then click Copy. Click another process and click Paste to replace it with the clipboard process. Be careful when pasting processes, there is no undo function!

To edit a layer's parameters, click the layer, then the Edit button. The Edit Layer dialog box for the selected layer is displayed. See the next section for detailed information on using the Edit Layer dialog box.

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3.5 Edit Layer

A *Layer* establishes the desired rate and thickness (plus a few other parameters) for a deposited film. The Edit Layer dialog box can be accessed by clicking a channel Edit button on the Main Screen, or by highlighting a layer and clicking Edit on the Edit Process dialog box.



Note: *The Channel and Output settings can only be changed by accessing Edit Layer from the Process Edit dialog box when the process is stopped.*

Channel: The channel that displays this layer's readings on the main screen. Typically this is the same as the detector input channel on the Guardian controller. If a QCM or analog input is used as the input for this layer, it is selected on Channel Input of the Film Cal. tab (section 3.6.3).

Output: The Guardian controller output that is used when depositing this layer.

Film: This the most important layer parameter. It establishes the material to be deposited, and many of the instrument setup parameters associated with that material. Select the desired film from the Film dropdown box. This selection determines the values that are displayed on the Film and Film Cal. tabs of the Edit Layer dialog box.

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3.5.1 Layer Grid

Pause the mouse over any parameter to see a brief description. Edit a parameter by clicking in the parameter's value cell, then typing a value, or by selecting a value from a dropdown box. Time values may be entered in hh:mm:ss format, or as whole seconds (which are automatically converted to hh:mm:ss format).

When you click in another cell, or press <Enter>, the parameter value is checked for validity and stored in the process database. If the process is running, the parameters are also sent to the EIES.

Setpoint: The desired deposition rate for the layer. The PID loop will control the channel output voltage during deposition to achieve the setpoint. Rate is typically displayed in Angstroms per second (A/s). This value can be modified by user-supplied Units conversion factors consisting of a Multiplier and Offset, found on the Channel tab. The displayed deposition rate is calculated as:

Rate (A/s) = (ChannelRate - QCMCalZero - xChan1 - xChan2) x QCMCalFactor

– or –

Rate (User Units) = (Rate(A/s) x UserMultiplier) + UserOffset

See the next few sections of this chapter for detailed information on xChan, QCMCal and UserUnits.

Endpoint: The desired material thickness for the layer. When Endpoint is reached, deposition ends for the layer. The value is typically in kA, but may be scaled by the user units as described in Setpoint above. The displayed thickness is calculated as:

Endpoint (kA) = Sum of (Rate(A/s) x Measurement Period / 1000)

- or -

Endpoint (UserUnits) = Sum of (Rate(UserUnits) x Measurement Period / 1000)

EndSetPt: When EndSetPt is reached, the EndSetPt relay is activated. However, deposition continues until EndPoint thickness is reached.

Time SetPt: Ends deposition for a layer after a certain time. If Time SetPt occurs before EndPoint thickness is reached, the layer stops.

Start Mode: A layer may start in three ways. In Auto, the layer starts immediately upon completion of the previous layer. In Manual, the layer waits for the user to click the Start button. If there are CoDep channels, they will also wait for a user Start if any channel Start Mode is set to Manual.

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Constant start is a special case used for controlling constant process variables such as temperature and pressure. Constant start holds the channel at the rate setpoint throughout the process. Only pressing Reset or completing the process will set the channel output to zero.

Start Prompt: Allows a user prompt to appear at the beginning of a Manual Start layer. If any text is entered in this parameter, it shows as an on-screen prompt with two user choices: OK to start the layer, or cancel to stop the layer. This is useful for prompting for operator actions such as opening valves or checking settings.

3.5.2 Rate Ramps Grid

Rate ramps change the initial rate Setpoint. Each rate ramp has a starting thickness, an elapsed time to ramp to the new Setpoint, and a new setpoint. Each layer can have two rate ramps.

Note: *These rate ramps alter the rate during deposition. Do not confuse these ramps with the preconditioning ramp/soak power ramps on the Film tab.*

Ramp Start: The thickness that triggers a timed ramp to a new rate. Setting Ramp Start to zero disables the rate ramp. Ramp Start should be greater for each subsequent ramp, and less than the layer Endpoint, otherwise the rate ramp is ignored.

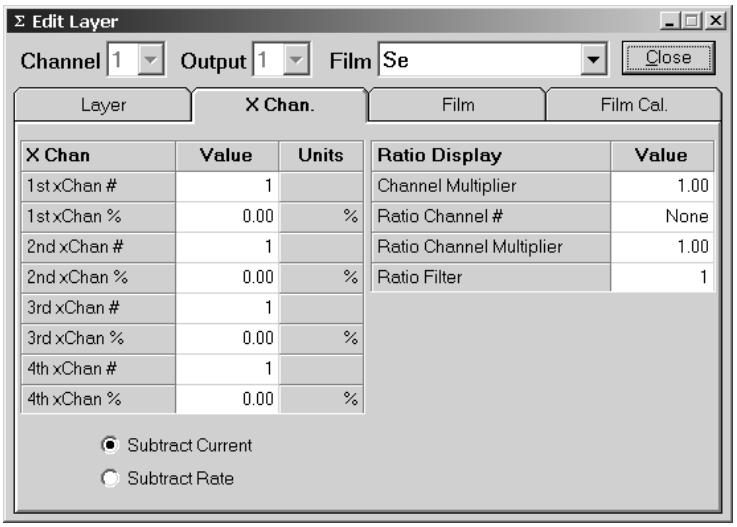
Ramp Setpoint: The new deposition Setpoint for the layer.

Ramp Time: The time to ramp to the new Setpoint. If the rate ramp is too fast, a PID control error may be generated.

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3.5.3 Cross Channel Grid

Each EIES detector channel measures an emission line that is unique to the material. However, other materials may have emission lines that overlap the bandwidth of the desired material's filter. In that case, a portion of the unwanted channel's signal must be subtracted from the reading. Cross channel (xChan) calibration establishes the amount of the unwanted signal(s) to subtract.



The channel listed at the top, left of the form is the channel being measured. A percent of the channels in the grid will be subtracted from that measurement channel. Up to four cross channel readings may be subtracted.

xChan #: The readings of the channel selected at the top of the form will be modified by subtracting a portion of each xChan# readings.

xChan%: The percent of the xChan signal to be subtracted from the measurement channel reading.

Subtract Current: A percent of each xChan Detector current is subtracted, before any material calibration, tooling factors, etc. have been calculated. The advantage of this method is that a change in the xChan calibration factors does not impact the amount of xChan compensation.

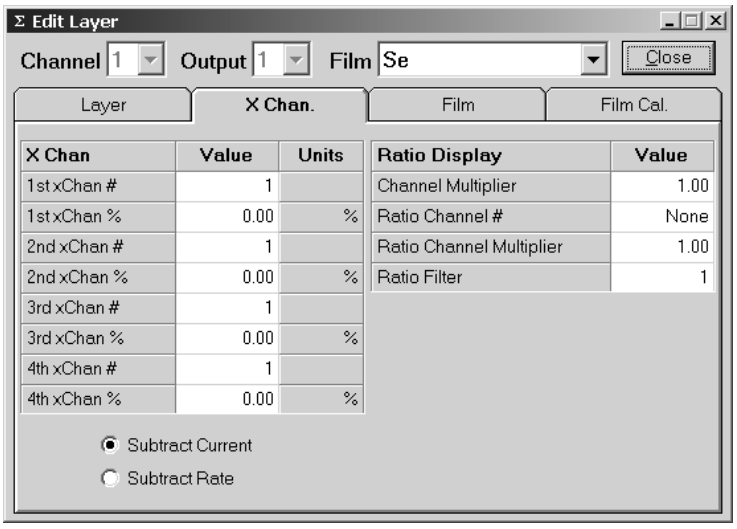
Subtract Rate: A percent of each xChan Detector rate is subtracted, after material calibration, tooling factors, etc. have been calculated. This method allows recalibration of an xChan to alter the amount of xChan compensation.

Note: *The remaining parameters (on the Film and Film Cal. tabs) are actually Film parameters. They are determined by the Film selected for a layer. If you change the parameters on either of these tabs, they will be changed for any layer (in any process) that uses the selected film.*

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3.5.4 Ratio Display Grid

In addition to cross channel calibration, the xChan tab of the Layer Edit dialog allows setup of the Main Screen Ratio Display.



Channel Multiplier: The channel reading is multiplied by this value before the ratio is calculated. Useful for scaling or calibrating to a desired value.

Ratio Channel #: Channel used for (denominator of) ratio calculation.

Ratio Channel Multiplier: Multiplies ratio channel reading by this amount.

Ratio Filter: The number of readings averaged for the ratio display. Because we are dividing two channels, and possibly multiplying their readings, a larger filter may be desirable.

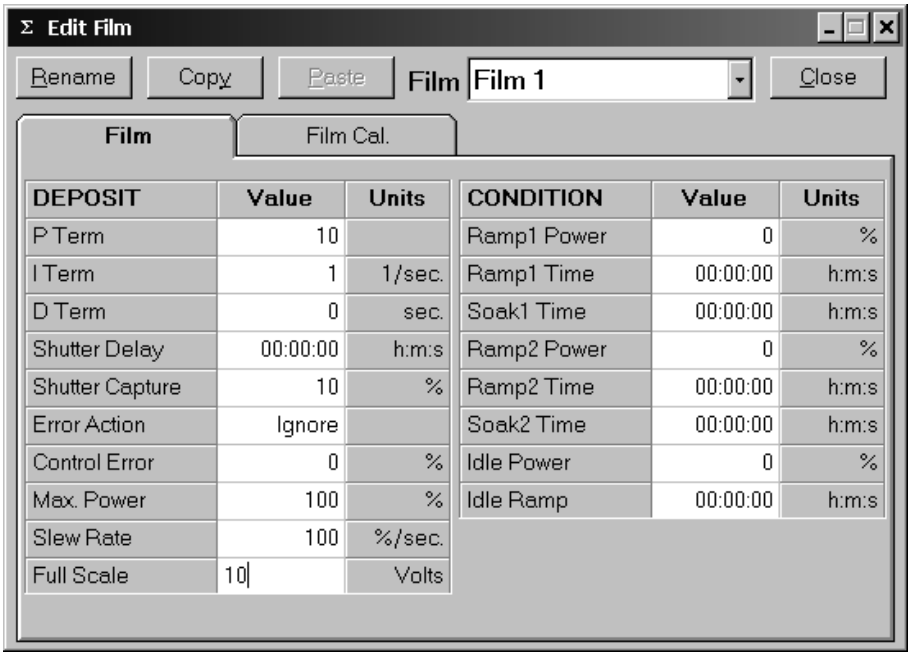
The value displayed is:

Ratio Display = (Chan. Reading x Chan. Multiplier) /
(Ratio Chan Reading x Ratio Chan Multiplier)

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3.6 Edit: Film

A *Film* sets the parameters for the material to be deposited in a layer, the control loop tuning, pre/post conditioning, and many of the instrument hardware parameters associated with that material.



The Film tab displays the deposition and pre/post conditioning parameters for the selected film. The Film Calibration (Film Cal.) tab contains instrument, display, and QCM parameters.

Pause the mouse over any parameter to see a brief description. Edit a parameter by clicking in the parameter's value cell, then typing a value, or by selecting a value from a dropdown box. Time values may be entered in hh:mm:ss format, or as whole seconds (which are automatically converted to hh:mm:ss format).

When you click in another cell, or press <Enter>, the parameter value is checked for validity and stored in the process database. If the process is running, the parameters are also sent to the EIES.

Rename: Gives a meaningful name (often the material) to the film.

Copy: Copy the film parameters to the clipboard.

Paste: Select another film and click Paste to replace it with the clipboard film parameters. Be careful when pasting films, there is no undo function!

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3.6.1 Deposit Grid

P Term: Sets the gain of the control loop. High gains yield more responsive (but potentially unstable) loops. Try a low value then gradually increase/decrease to respond as desired to step changes in setpoint.

I Term: The integral term controls the time constant of the loop response. A small I term, say .5 to 1 seconds, will smooth the response of most loops. An I value of 0 effectively disables PID control.

D Term: The differential term causes the loop to respond quickly to changes. Use 0 or a very small value to avoid oscillations.

Shutter Delay: Shutter delay sets the time allowed for a channel to achieve deposition control. Shutter delay assures that the channel reaches a certain accuracy before deposition begins. If the accuracy is not reached, the process halts. If accuracy is reached, and maintained for 5 seconds before Shutter Delay time, the substrate shutter opens and deposition begins. Set Shutter Delay to zero to disable this function.

Shutter Capture: Sets the shutter delay rate accuracy that must be reached for deposition to begin.

Control Error: If the control loop cannot maintain the desired Setpoint (due to loss of source material, excessively high rate ramps, or equipment malfunction) a control error occurs. 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; Or Hold deposition at the last good Power setting to "estimate" rate and thickness. For best results, use shutter delay to assure adequate process control before entering the deposition phase.

Control Percent: The accuracy that must be maintained during deposition to prevent a control error. Set Control Percent to zero to disable this function.

Max Power: The maximum output power allowed for the film. Max Power controls the maximum % of the full scale voltage that can be used by this film in any process phase.

Slew Rate: The maximum power change allowed on an output, per second. If rate ramps or PID power requirements exceed this value, an error occurs.

Full Scale: The maximum output voltage for your deposition supply’s input range. Values from 0 to +/-10V are possible.

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3.6.2 Condition Grid

Ramp1 Power: The power level desired at the end of the Ramp 1 phase, in % of full scale.

Ramp1 Time: The time to ramp with a linear rate from the initial power to the Ramp 1 Power. If multiple channels have preconditioning programmed, the start of Ramp1 may be delayed so that the Soak2 phase for all channels ends concurrently.

Soak1 Time: The time the output remains at Ramp 1 Power. At the end of Soak 1 Time, the Ramp 2 phase starts.

Ramp2 Power: The power level desired at the end of the Ramp 2 phase, in % of full scale.

Ramp2: The time to ramp with a linear rate from Ramp1 Power to Ramp2 Power.

Soak2: The time the output remains at the Ramp 2 power level. At the end of Soak 2, all channels will enter the Shutter Delay phase.

Feed Power: The power level desired for wire feed of new material.

Feed Ramp: The time to ramp with a linear rate from deposition power to Feed Power.

Feed Time: The time the output remains at the Feed power level.

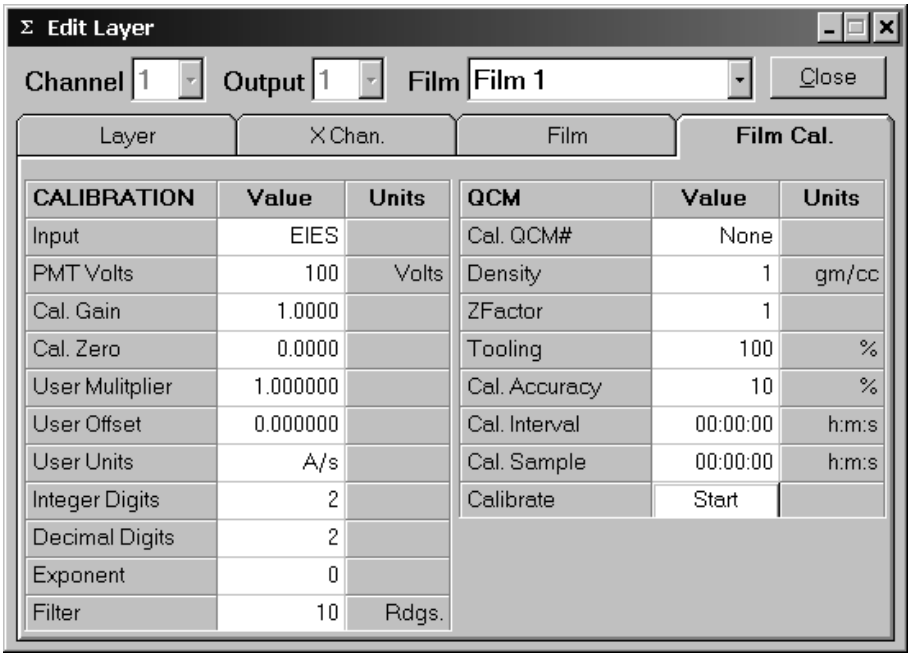
Idle Power: Idle power usually holds the material at a state that is ready for deposition, typically the same as Ramp 2 power.

Idle Ramp: The time to ramp with a linear rate from deposition power to Idle Power.

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3.6.3 Calibration Grid

The Film Cal. (Film Calibration) tab displays parameters that control the calibration and display of channel readings. Depending on the Input type selected, all of the parameters listed may not be available.



Input: Selects which sensor is used for measurement of the channel. Select EIES to use the selected EIES detector channel input. Select a QCM input to use an SQM-242 card or Q-pod sensor for deposition measurement. SAM uses the SAM-242 analog card inputs for measurement.

PMT Volts: Sets the bias voltage (gain) of the channel's photomultiplier tube. The emission from different materials may require different PMT voltages to optimize performance.

Cal Gain: The multiplier used to convert EIES current measurements to calibrated rate/thickness. You may enter a value manually, or the value is updated each time QCM Calibrate is clicked.

Cal Zero: Due to gas background emission, there may be an EIES rate reading when there is no deposition. Enter the background rate to correct EIES rate to zero.

User Multiplier: This value is multiplied by the calibrated rate (in A/s) to convert to User Units on the main screen rate display. Set the multiplier to 1 to display readings in A/s. Also used with the SAM-242 analog card to convert volts to different units.

User Offset: Value subtracted from the calculated rate (in A/s) to convert to User Units shown in the channel's reading display. Set the offset to 0 to display readings in A/s.

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User Units: The units displayed below the channel reading on the main screen. Typically Angstroms per second (A/s).

Integer Digits: The number of integer digits (left of the decimal point) displayed in the channel's rate display. The channel rate display can show four total digits, plus the decimal point and sign. If IntDigits plus DecDigits is greater than four, the left-most digits will not be seen.

Decimal Digits: The number of decimal digits (right of the decimal point) displayed in the channel's rate display. The channel rate display can show four total digits, plus the decimal point and sign. If IntDigits plus DecDigits is greater than four, the left-most digits will not be seen.

Exponent: Scales the channel rate display by powers of 10. For example, select 3 to display kilo-units or –3 to display milli-units.

Filter: The number of readings that are averaged for display on the main screen..

Indexer: Selects the optical filter number or indexer pocket used for this film.

3.6.4 QCM Grid

Cal QCM#: Establishes which QCM sensor is used to calibrate this channel's EIES detector.

Density: Sets the QCM density for this material. Material density has a significant impact on deposition calculations when a QCM is used for calibration or control. See Appendix B for common material densities.

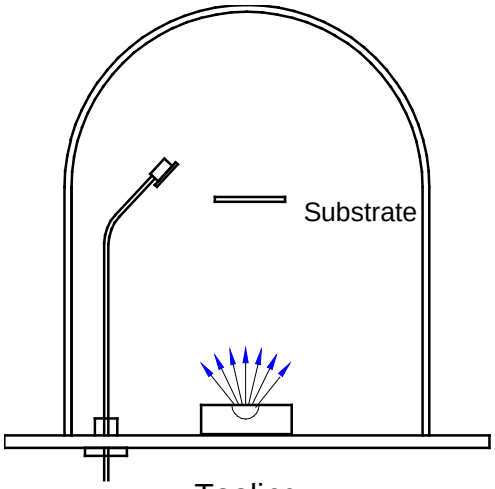
Z Factor: Sets the QCM Z-Factor, the measure of a material's effect with increased thickness on QCM accuracy. See Appendix B for common material Z Factors.

Tooling: Adjusts for deposition rates measured by the QCM that differ from the substrate deposition rate. A higher tooling value yields higher rates. For example, if the sensor sees only 50% of the substrate rate, set Tooling to 200%. Setting Tooling to 0% causes a sensor to be ignored for this film.

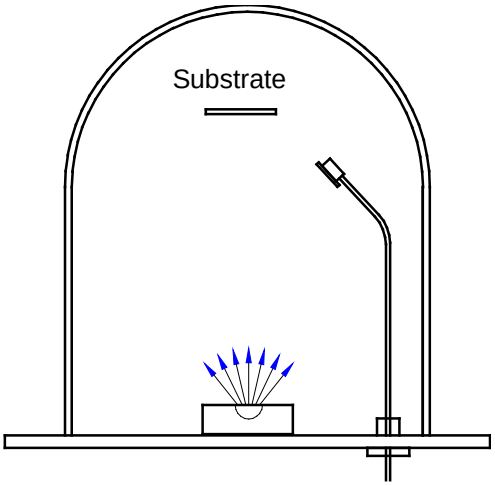
The defining equation is:

$$\frac{\text{Substrate Thick}}{\text{Sensor Thick}} = \frac{\text{Correct Tooling}}{\text{Current Tooling}}$$

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Tooling
Over 100%



Tooling
Under 100%

Cal Accuracy: The EIES channel calibration accuracy to be achieved during QCM calibration.

Cal Interval: The time interval between automatic QCM calibration of the EIES channel.

Cal Sample: The time the QCM shutter remains open for QCM calibration of the EIES channel.

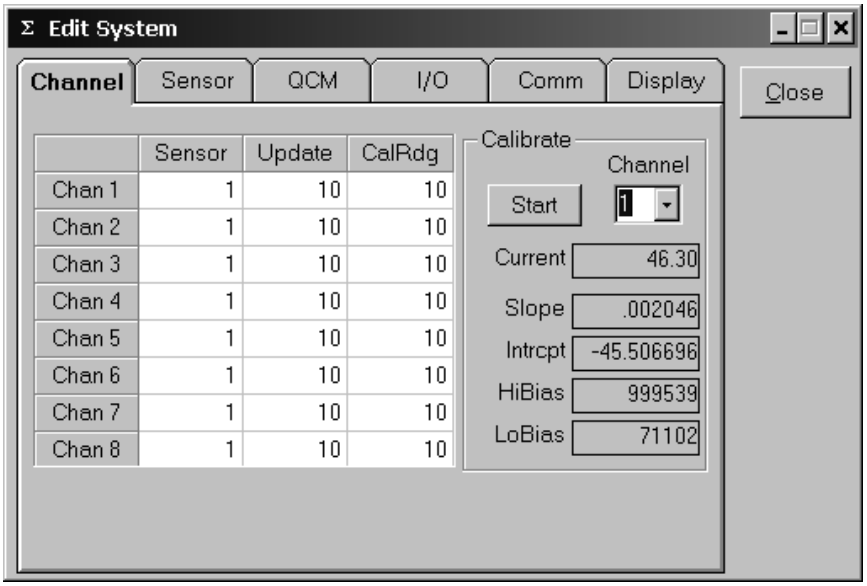
Calibrate: Starts a QCM calibration cycle as defined by Cal Accuracy and Cal Sample. Shown only when the Layer version of this dialog box is selected.

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3.7 Edit: System

The Edit System dialog box contains parameters that apply to all of the processes in a process database. The settings are arranged on a tabbed dialog box.

3.7.1 Channel Tab



Sensor: Selects the sensor that is measured by the channel detector. When using INFICON's gas compensating sensors, a gas calibration factor is used to adjust for sensor geometry. This assignment determines which gas compensating factor is used.

Update: The rate at which readings are returned from the EIES detector. The detector module takes 1000 readings per second, and averages readings between updates.

Cal Readings: The number of detector readings averaged to calculate the calibration constants. The total calibration time for a channel is 4 x Cal. Readings / Update.

Start: Starts calibration of the selected EIES detector. Depending on the number of readings and the channel update interval, calibration may take several seconds.

Note: *This calibrates the detector electronics assuming no current from deposition. It is different from QCM calibration, which calibrates detector readings relative to a QCM.*

Calibrate Channel: The detector channel selected for calibration.

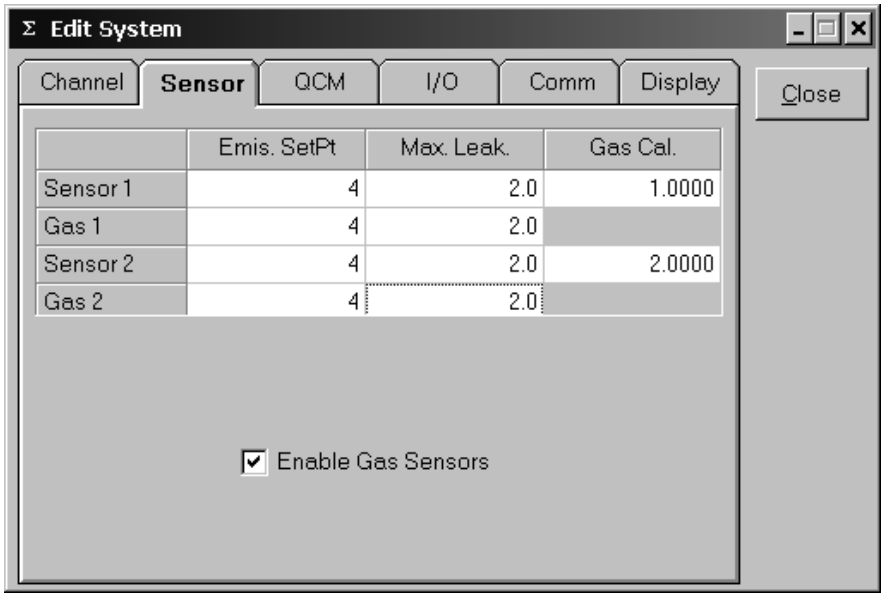
Current: Displays the current reading from the detector. With no deposition, this value should be near zero.

Slope/Intercept/HiBias/LoBias: These values are for diagnostic purposes only. They are not needed for normal operation of the EIES system.

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3.7.2 Sensor Tab

The format of the Sensor tab is determined by the type of sensor used. The screen below is shown when a gas compensating controller is used. For non-GC controllers, only Emission SetPt and Maximum Leakage fields are visible.



Emission Setpoint: The emission current can be set from 2 to 10 mA. Higher emission creates more measurement signal for the detectors, but decreases sensor filament life.

When co-depositing materials, you may need to find a balance between signal strength and noise for multiple channels. Changing the detector PMT voltage (Edit Layer, Film Cal. tab) can help match the materials to the selected sensor emission current.

Max. Leakage: As material is deposited on a sensor, the leakage current increases until the controller cannot adequately control emission current. This field establishes the leakage current that will stop deposition.

When leakage current reaches 70% of Max. Leakage, the background of the emission current reading on the main screen turns yellow.

Gas Cal: INFICON's gas compensating sensors provide a measurement of the emission caused by background gases. The gas calibration factor is used to null this portion of the signal from the main flux sensor measurements.

Enable Gas Sensors: Click to select the gas compensating feature. Requires gas compensating (GC) sensors.

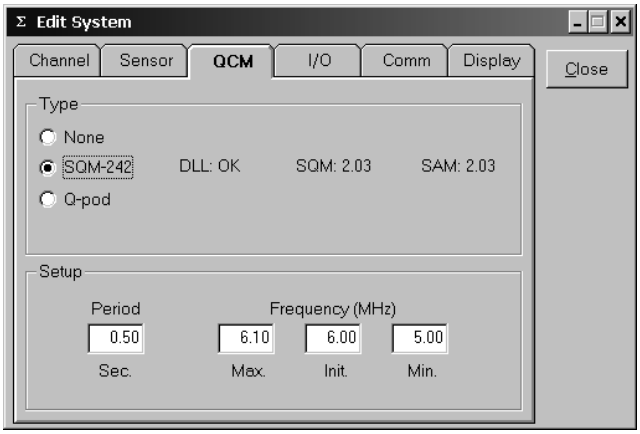
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3.7.3 QCM Tab

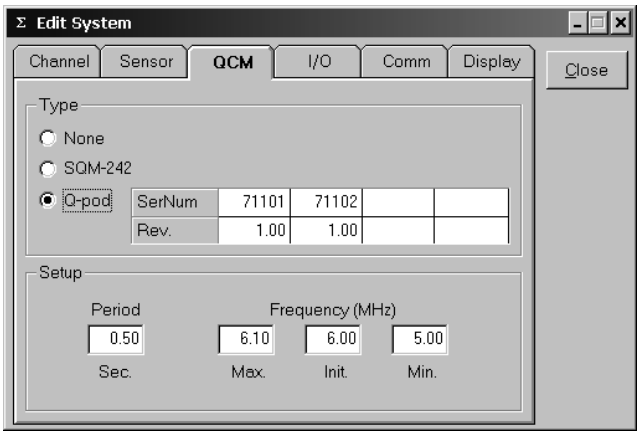
See the SQM-242 Card or Q-pod Manual for detailed QCM installation and troubleshooting instructions.

None: No QCM inputs are used.

SQM_242: INFICON SQM-242 card is used for QCM measurements. DLL shows the status of the SQM-242 card's Windows drivers. DLL return values of 9XX indicate a card installation error. The firmware revision of the installed SQM-242 and SAM-242 cards are also listed. A value of 0 indicates the card is not installed.



Q-pod: INFICON's Q-pod transducers are used for QCM measurements. The serial number and revision of each installed Q-pod is shown.

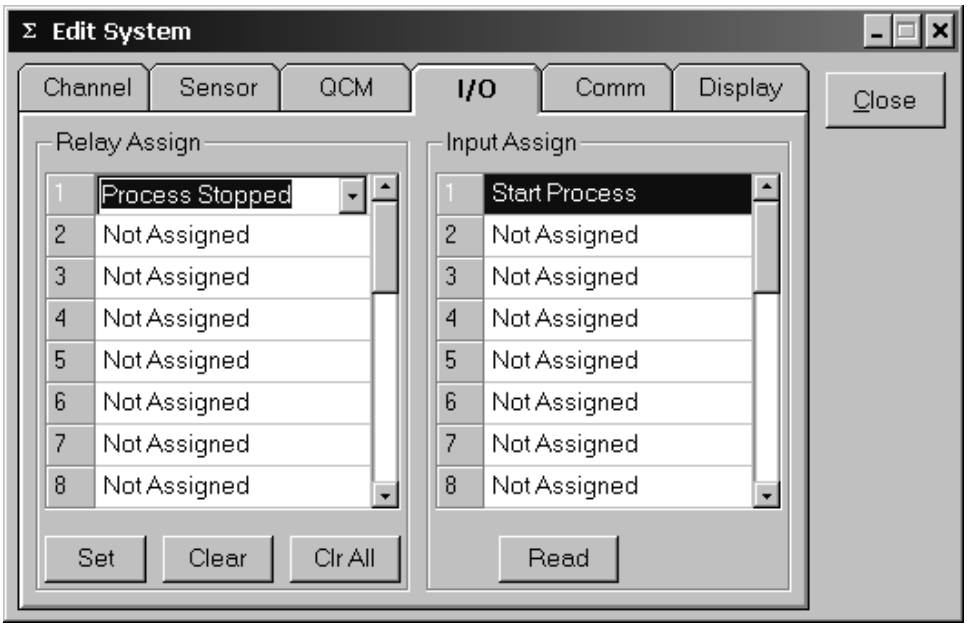


Period: Sets the QCM measurement period between .2 seconds (5 readings per second) and 2 seconds. A longer period gives higher reading accuracy, especially at low rates.

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.

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3.7.4 Digital I/O Tab



Relay Assign

To assign a deposition event to a relay, click the Relay #, then select the desired event from the dropdown box. The Set, Clear, and Clear All buttons manually operate the selected relay. A description of each relay event follows:

Process Stopped and Running Relays
These relays indicate the overall status of the process. The Process Running relay closes as soon as Start is selected (by front panel or digital input), and opens when Stop is selected. The Process Stopped relay contacts behave in the inverse manner.

Deposit Phase Relay
This relay indicates that you are in the deposit phase of a film. 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. Manual Power.

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.

Time Setpoint Relay
This relay will close when Run Time equals the Time Setpoint.

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Channel Relays 1 to 8
These relays control EIES sensor shutters. They close during shutter delay and deposition.
Source Relays 1 to 8
These relays control the Shutter that covers your deposition source. They close during deposition.
QCM Relays 1 to 4
These relays control QCM sensor shutters. These relays close during shutter delay and deposition.
BCD Relays 0 to 2
These three relays select an indexer or filter position by setting a BCD value from 0 to 7.
Index Relays 1 to 8
These eight relays select an indexer or filter position by setting a single relay.

Input Assign

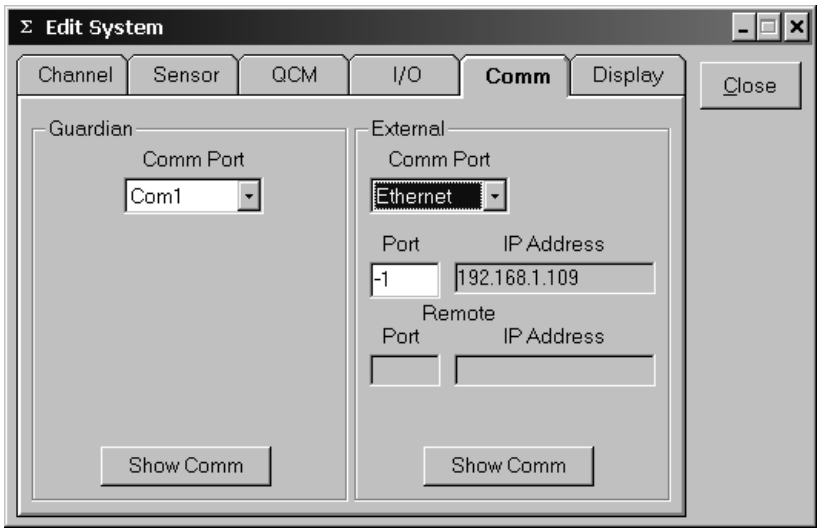
To assign a deposition event to an input, click the Input #, then select the desired event from the dropdown box. Click the Read button to read the current state of the highlighted input. A brief description of each input event follows:

Start Process Input
Triggering this input is the same as pushing the Start Process button.
Stop Process Input
Triggering this input will abort the process.
Zero RunTime Input
Zeroes the run time reading.
Emission 1/2 Interlock
Set this input to inhibit turning on emission from the front panel or digital I/O.
Emission 1/2 On
Turns on emission if interlock signal for that sensor is not active.
Emission 1/2 Off
Turns off emission for that sensor.
End Channel 1 to 8
Stops deposition phase and goes to idle phase.
Calibrate Channel 1 to 8
Starts calibration of the selected channel.
Index Home Single
A single input to signal the indexer is no longer moving.
Index Home BCD0 to BCD2
BCD encoded inputs to indicate the indexer is on a specific pocket.
Index Home 1 to 8
Individual inputs for each indexer pocket home signal.

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3.7.5 Comm Tab

The Comm Tab sets up communications between the EIES program and the Guardian controller.



Guardian

Comm Port: Selects a computer RS-232 serial port for communicating with the Guardian controller. If a comm port is not installed, or is being used by another program, an error message will be displayed.

Show Comm: Displays a diagnostic screen that shows communications between the EIES program and the Guardian controller. For troubleshooting purposes, you can manually send ASCII commands to the EIES instrument and see the response. For example, send an @ to see the EIES instrument version.



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See the chapter on EIES communications for more information on the command protocol.

External

See the chapter on EIES communications for more information on external communications.

Comm Port: Selects an RS-232 port or Ethernet for external control of the EIES program.

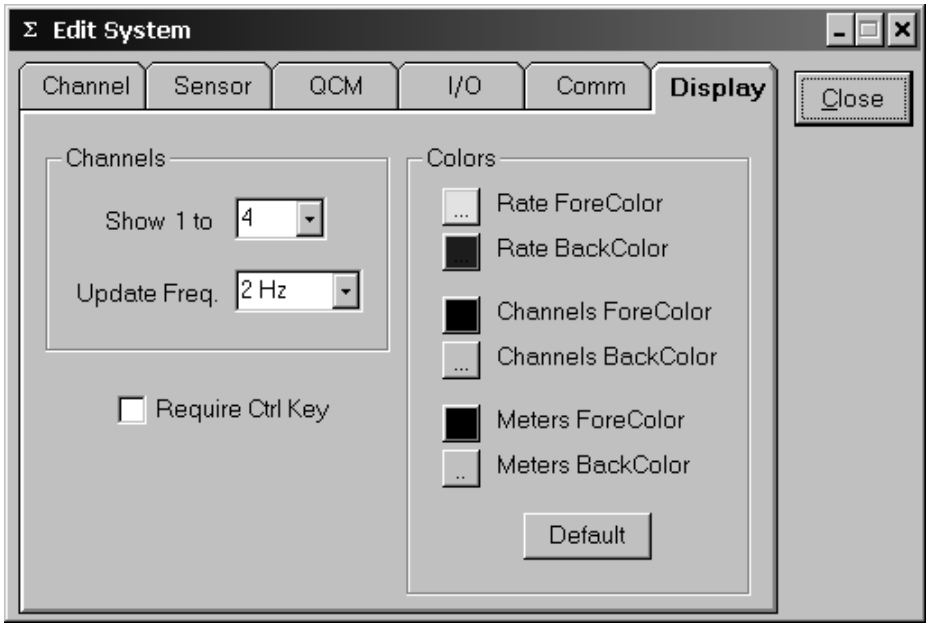
Ethernet Port: Selects the computer running the EIES software's Ethernet port for communicating with an external computer. The Ethernet Port is usually 1001.

IP Address: Displays the Ethernet address of the computer running the EIES software.

Host: When a connection is made with an external computer, the remote computer's Port and IP address are shown.

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3.7.6 Display Tab



Show 1 to : Sets the main screen to display 4 or more channels of EIES data. The minimum number of channels is four to allow adequate space on the left control panel.

Update Frequency: The frequency at which the main screen readings are updated.

Require Ctrl Key: When checked, you must press and hold the <Ctrl> key to activate main screen controls. This helps prevent accidental operation.

Colors: Sets the colors of several of the main screen display elements. Click Default to return the colors to their default settings.

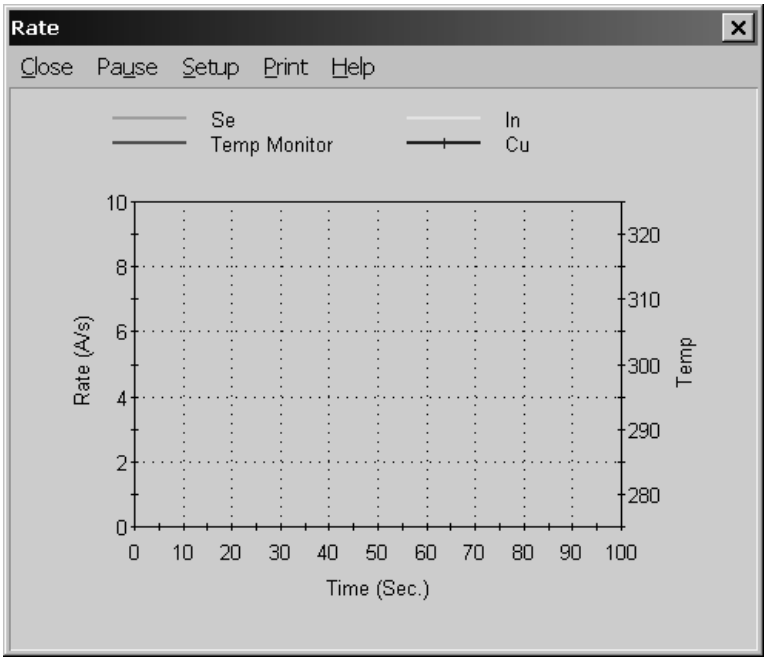
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3.8 Graphs Menu

3.8.1 Graph Selection

The EIES program supports four independent graphs. Initially they are shown on the Graphs menu as 1. Rate, 2. Deviation, 3. Power, and 4. Thickness. However, the titles may be changed by the user.

To size a graph, click and drag the form's border. The size and location are automatically stored on exit from the program.



Close: Closes the selected graph display.

Pause/Run: Click pause to temporarily stop the graph from displaying data. Click Run to resume graphing.

Setup: The graph's name and data, as well as many other setup parameters, can be changed on the Graph Setup screen. Graph setup is detailed in the next section.

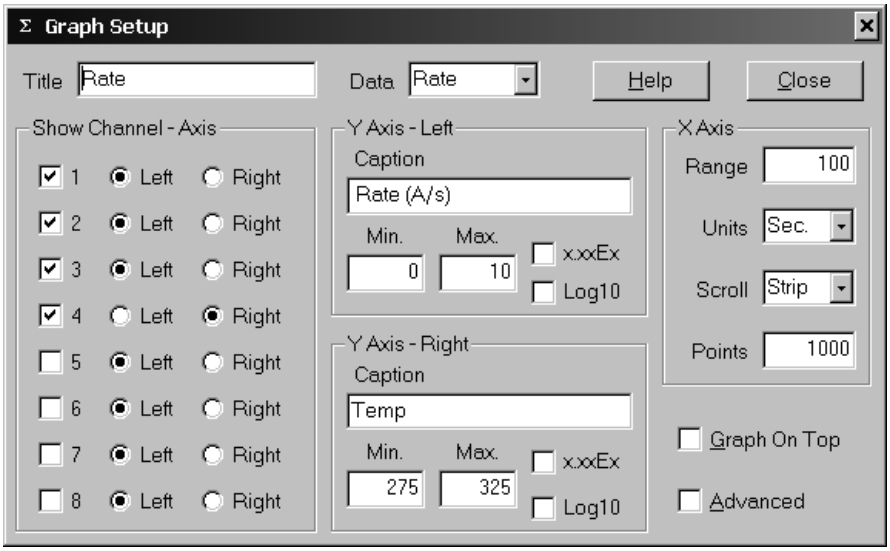
Print: Prints the graph to the system printer.

Help: Displays the graph help screen.

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3.8.2 Graph Setup

The graph setup screen provides access to the most commonly used graph setup parameters. It also provides total control of graph setup, using the Advanced Property Editor.



Title: The caption that appears at the top of the graph screen and on the main screen's Graph menu. However, the graph's setup properties are always stored on disk as Graph 1 to Graph 4.

Data: Selects which of the five possible data sources are used for this graph - Rate, Deviation, Power, Total, or Sensor data. Sensor data displays the main flux and gas compensating signals for each detector.

Help: Shows the graph setup help screen if the Advanced checkbox is not checked. If the Advanced checkbox is checked, shows advanced Property Editor help.

Close: Closes the Graph Edit screen.

3.8.3 Show Channel – Axis

Channel 1 to 8: Selects the EIES channels to be graphed. If the channel is used in a layer, and the channel is checked here, its data is displayed. If the channel is not assigned to a layer, the show channel selection for that channel is ignored.

Left: The data for this channel is referenced to the left axis of the graph. When Sensor Data is selected (see above) the left axis shows the main flux sensor.

Right: The data for this channel is referenced to the right axis of the graph. When Sensor Data is selected (see above) the right axis shows the gas compensating sensor.

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Y Axis Left/Right

Caption: The caption shown along the graph's left or right axis.

Min: The minimum value for the Y axis.

Max: The maximum value for the Y axis.

x.xxEx: Shows the selected Y axis values in scientific format (i.e. 2.00E-4).

Log10: Shows the selected Y axis in Log base 10 values.

X Axis

Range: Sets the width of the X axis in seconds, minutes, or hours. The X axis scrolls as needed to display the current readings, maintaining this range. If the range is set to zero, the program will select the X axis range.

Units: Show the X axis in seconds, minutes, or hours.

Scroll: Selects the % of the graph to scroll when data overruns the X axis maximum value. Select scroll to smoothly scroll the graph.

Graph on Top: When selected, the graph will be shown above other windows. When not selected, other windows may hide the graph. Use Graphs, Show on the main screen to show all opened graphs.

Advanced: The program's graph setup screen is adequate for most users. However, the graphing control used by the EIES program is much more powerful (and potentially confusing). By checking Advanced, you override this setup screen and use the graph control's advanced Property Editor to customize the graph.

Before making changes in the advanced Property Editor, you should make a backup of the original Graph#.OC2 - where # is the number before the graph name in the Graphs menu.

The advanced Property Editor is accessed by right clicking on the graph screen you wish to edit (not this Graph Setup screen), then left click on Properties. To save advanced Property Editor changes, select the Control tab, then click Save to overwrite the Graph#.OC2 file.

The Help button on the advanced property editor does not work. To view Property Editor help, click the help button on (this) Graph Setup screen. Sorry, but we have no control over this bug.

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Chapter 4 - Installation

4.0 Introduction

Chapter 2 provided a "quick start" guide to installation and operation of the Guardian system. This chapter provides more detail on mechanical and optical installation requirements, and our recommendations to help you achieve the best results from your EIES-IV Guardian system.

Optical components (filters, lenses, light tubes, beam-splitters, fiber optics, etc.) are a critical part of the EIES system. INFICON does not manufacture any of these components, but we have an on-going program of evaluating optical components for use with EIES systems. Some components that meet specific performance criteria are sold with our Guardian systems. In many cases, however, you will want to evaluate and purchase components to meet your own specific requirements.

The companies listed below are excellent sources for lenses, filters, and other optical components needed to complete your EIES system installation.

CeramOptec Industries
515A Shaker Road
East Longmeadow, MA 01028
413-525-0600
www.ceramoptec.com

Edmond Scientific
101 E. Gloucester Place
Barrington, NJ 08007
800-363-1992
www.edmundoptics.com

Omega Optical
21 Omega Dr., Delta Campus
Brattleboro, VT 05301
802-254-2690
www.omegafilters.com

Thor Labs
435 Route 206 Box 366
Newton, NJ 07860-0366
973-579-7227
www.thorlabs.com

For additional help, please do not hesitate to contact us.

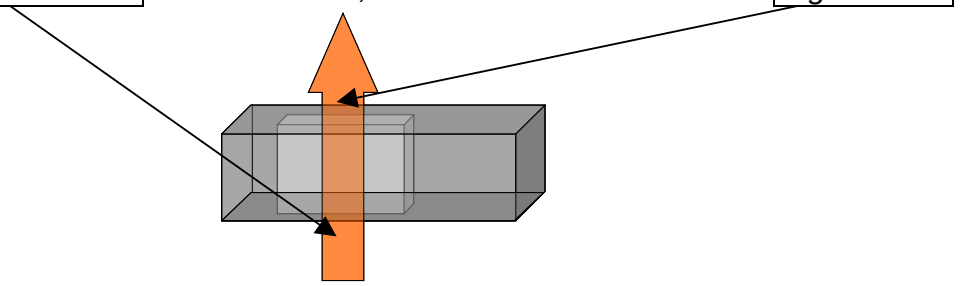
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4.1 Sensor / Feedthrough Assembly

Location of the sensor within the vacuum system is the most significant factor in determining EIES system performance. The optical signal generated by the sensor is often small, especially when the deposition rate for a material is low. The objective in EIES system installation is to maximize the light output from the sensor, and deliver as much of that optical signal as possible to the detector(s).

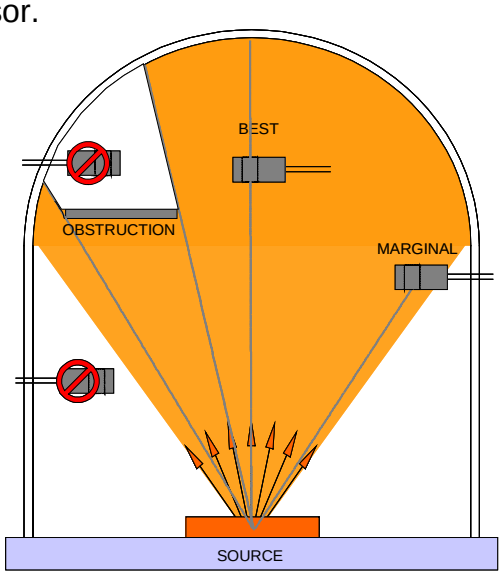
Position the sensor to maximize the material vapor flux passing through it. The best location is directly above the evaporant source, with the sensor opening perpendicular to the vapor flux, so the material passes straight through the opening. When multiple sources are involved, you will have to make a best estimate of the average flux from all sources.

Note: The EIES sensor has two cutouts that allow the flux to pass through the sensor. Place the smaller cutout toward the flux, so that the flux exits via the larger cutout.



You may want to use aluminum foil or other shielding around the light tube to reduce build-up of material on these components, but be careful to not obstruct the vapor path through the sensor.

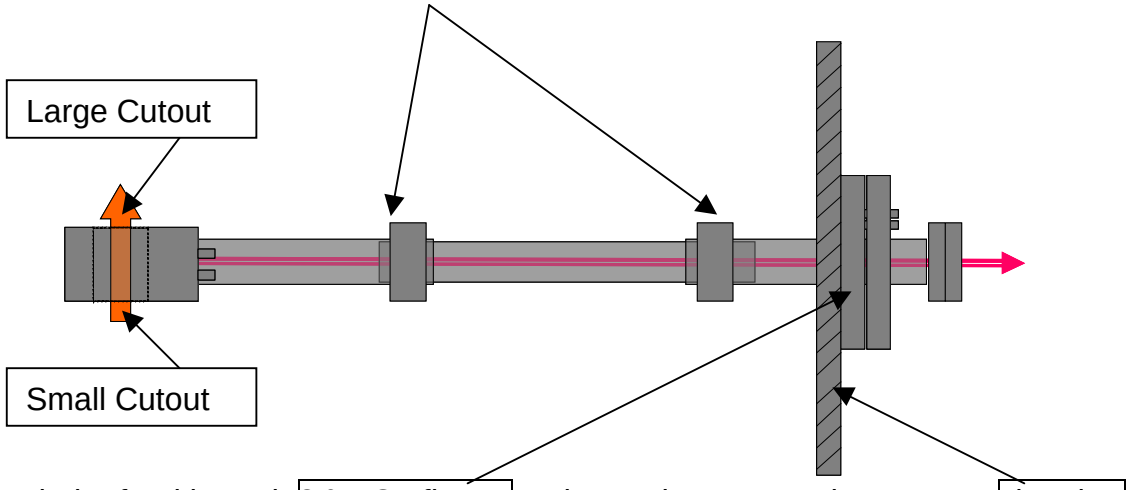
Avoid locations where obstructions such as fixturing would interfere with the flux of material through the sensor.



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4.1.1 Rigid Sensor Installation

1. Loosen the telescoping tube collars and separate the sensor from the feedthrough.



2. Attach the feedthrough 2 ¾" CF flange to the mating port on the vacuum chamber wall with the telescoping tube inside the chamber.

3. Slide the telescoping tube into the feedthrough and adjust it (slide it in or out of the tube attached to the feedthrough) to the approximate position desired. If you are using the optional InVac Quartz Tube (PN 900-062), slide it into the telescoping tube.

4. Tighten the collar around the tube and attach the sensor to the other end of the telescoping tube.

5. Adjust the sensor position and tighten the collar around the tube to hold it in place. Although the light tube assembly is capable of supporting the sensor, additional external support is recommended to prevent vibrations from affecting its position.

6. Attach the two filament cables from the feedthrough to the sensor. Polarity is not important, but make sure there are no potential shorts to the chamber or fixturing. (the signals on these wires are biased ±180V to ground.)

WARNING: The sensor outputs are constitute a potential shock hazard. If a sensor cable is damaged, contact INFICON for a replacement..

7. Wrap aluminum foil or other shielding around the light tube, cables, and sensor assembly. Be sure you do not obstruct the flow of material vapor through the sensor opening.

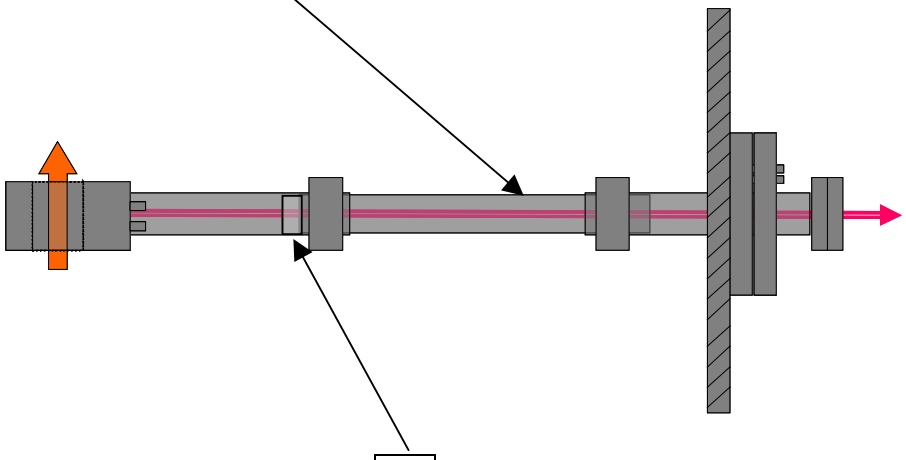
Use the shortest possible length of light tube between the sensor and feedthrough, to minimize light loss. If more than about 25 cm (10") is needed, consider using a fiber optic light tube. Also, avoid stray magnetic fields (>2 gauss), which would affect the path of electrons in the sensor and change the sensitivity to the evaporant material.

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4.1.2 Flexible Sensor Installation

1. Complete steps 1 & 2 in the Rigid Sensor Installation above.

2. Slide the Invac Fiber Optic (PN 900-061) into the feedthrough tighten the collar around the fiber ferrule.



3. Insert the .5” protective sapphire lens (042-008) onto the sensor tube until it seats against the internal C clamp. This lens protects the InVac fiber optic from material deposition.

4. Insert the InVac Fiber optic up to the lens and tighten the collar to hold it in place.

5. You must provide external support to locate and support the sensor.

6. Attach the two filament cables from the feedthrough to the sensor. Polarity is not important, but make sure there are no potential shorts to the chamber or fixturing. (the signals on these wires are biased ±180V to ground.)

WARNING: The sensor outputs are constitute a potential shock hazard. If a sensor cable is damaged, contact INFICON for a replacement..

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4.1.3 Sensor Maintenance

The only maintenance required for the sensor is periodic cleaning, and occasional replacement of the filament. Maintenance is most easily done by removing the sensor assembly from the vacuum system and working with it on a clean bench.

To remove the sensor:

1. Disconnect filament cables, detectors and optical components from the atmosphere side of the feedthrough.

2. Disconnect the sensor from any external supports inside the vacuum chamber.

3. Remove the bolts fastening the feedthrough 2¾ "CF flange to the chamber port.

4. Carefully pull the sensor/feedthrough assembly out of the vacuum chamber.

5. When maintenance is complete, reassemble using the steps above in reverse order.

Filament Replacement:

1. Remove sensor outer cover.

2. Remove foil shield and filament hold-down screw.
.
3. Remove and replace filament assembly.

4. Reinstall filament hold-down screw and foil shield.

5. Replace outer cover.

Cleaning:

Aluminum foil or other shielding will minimize build-up of material on sensor surfaces, but some accumulation is inevitable. You may use the same safe cleaning techniques that you would use to clean any other sensitive devices in your vacuum system. The sensor is constructed of vacuum-compatible materials that may be cleaned using alcohol or other vacuum-friendly solvents.

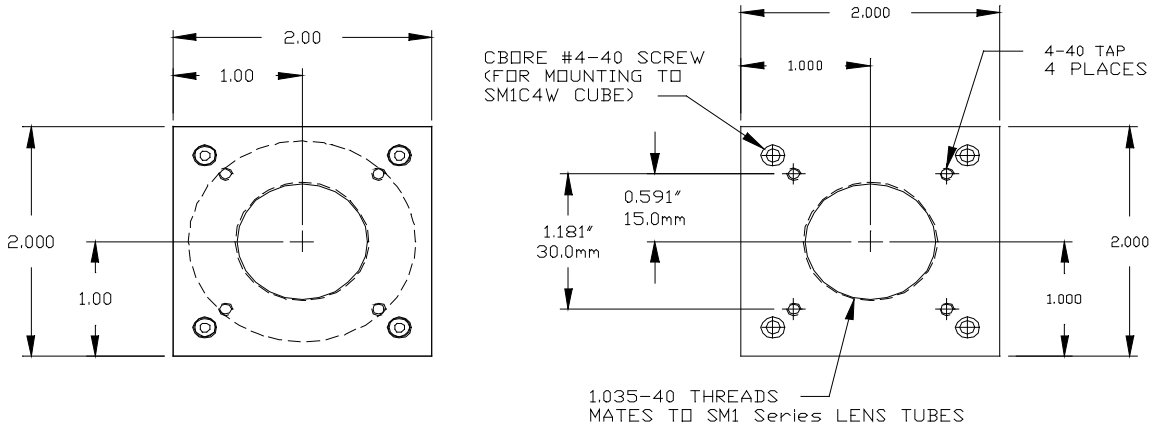
Most Guardian sensor parts can be replaced in the field. In extreme cases, the entire sensor might need to be replaced. Do not return your sensor/feedthrough to INFICON for cleaning. We cannot establish cleaning facilities for all the materials used by all our customers, and protect our employees and the environment from unknown contaminants.

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4.2 Detector

Your specific system configuration and space constraints will determine what you need to connect the light output from the sensor feedthrough to one or more detectors. Couplings, extension tubes, filters, and many other optical components are available from INFICON and a variety of other suppliers, such as those listed at the beginning of this chapter.

The detector uses a Thorlabs BC1 mounting plate to interface to other optical components. Several tapped mounting holes are provided on the mounting plate to attach the unit to external brackets or lens tubes.



The detector may be mounted in any orientation, but should be protected from sources of mechanical shock or vibrations, such as might be generated by valve actuators or mechanical pumps.

The EIES detector has a 1 inch (25mm) internal threaded coupling on the optical inlet. A standard 1" (25mm) round optical filter fits into the coupling and is held in place by a retaining ring.

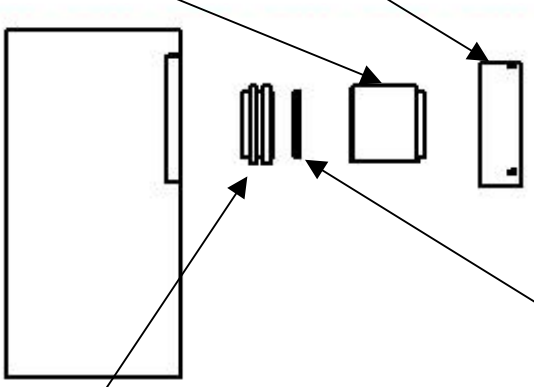
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4.2.1 Single-Detector Systems

For single-material thin film systems, only one detector is needed, and it can be mounted directly to the feedthrough.

1. Slide the Window Flange Coupler (PN 020-033) onto the 1.33" MiniCF-16 flange and is secure with three set-screws.

2. Thread the Lens Tube Spacer (022-008) into the flange coupler.



3. Place the proper filter in the lens tube coupler and secure with the Retaining Ring (PN 022-006)

4. Thread the Lens Coupler (PN 022-022) into the lens tube spacer and the detector module. Secure both with the knurled nuts on the lens coupler.

The feedthrough/viewport assembly can support the weight of one detector mounted directly on the flange. If an extension is required to clear obstructions, additional support of the detector is required.

4.2.2 Multiple-Detector Systems

When multiple materials are being deposited, one detector is typically required for each material. Each detector is fitted with a different optical filter, chosen to pass the specific emission wavelength characteristic of that material.

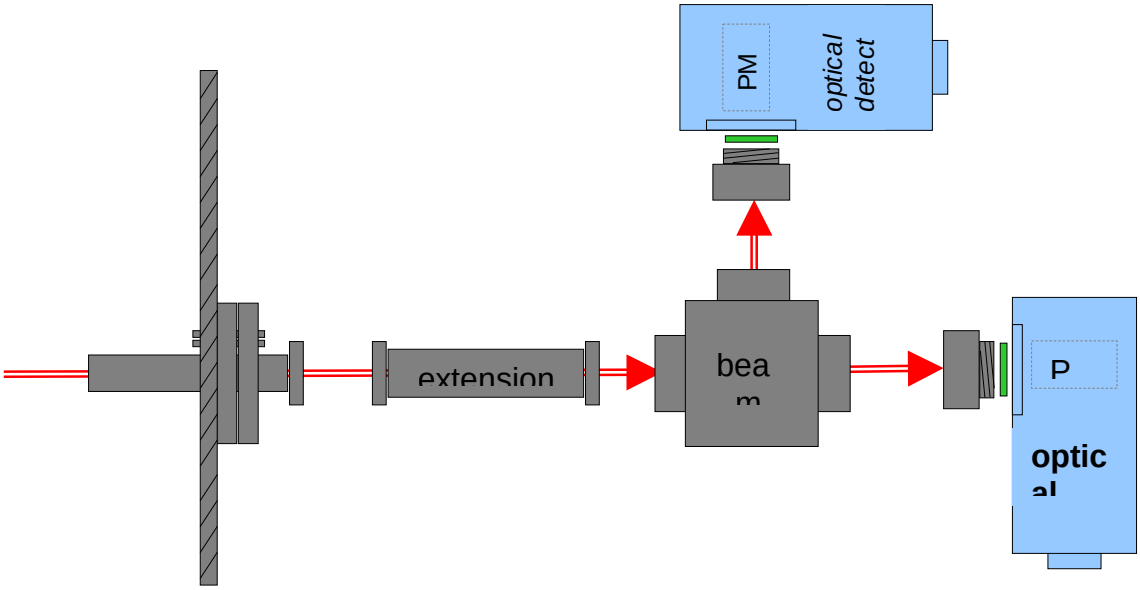
One solution, for two-material systems, is to use a second sensor/feedthrough, and mount the second detector directly on that feedthrough (as in a one-detector system). This configuration achieves the best possible signal/noise ratio. However, the second sensor adds cost and complexity to the in-vacuum mounting and fixturing.

The alternative is to split the optical signal into several beams, which are directed into separate detectors. The beam can be split using traditional optical or fiber-optic beam splitters. In both cases, optical signal losses can be significant, which may result in a signal that has a low signal/noise ratio. As a general rule, we recommend splitting the beam into three detectors at most.

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4.2.2.1 Optical Beam Splitting

For 2-material systems, two detectors are mounted at the two outlets of one beam-splitter. If there were no losses, half the original light signal would go to each detector. In reality, light losses are significant and much less than half actually goes to each detector. The figure below shows a simplified schematic of an optical beam splitting system for two detectors.



Beam splitters from ThorLabs are available with 1" (25mm) threaded fittings to mate with the Guardian detectors and flange couplings.

Multiple detectors and the associated optical components add size and weight to the detection system. Sufficient clearance and support must be provided for all these components. They cannot be supported by the vacuum feedthrough as in the one-detector case. When installing the detector system, be sure to allow clearance for maintenance of the sensor/feedthrough assembly.

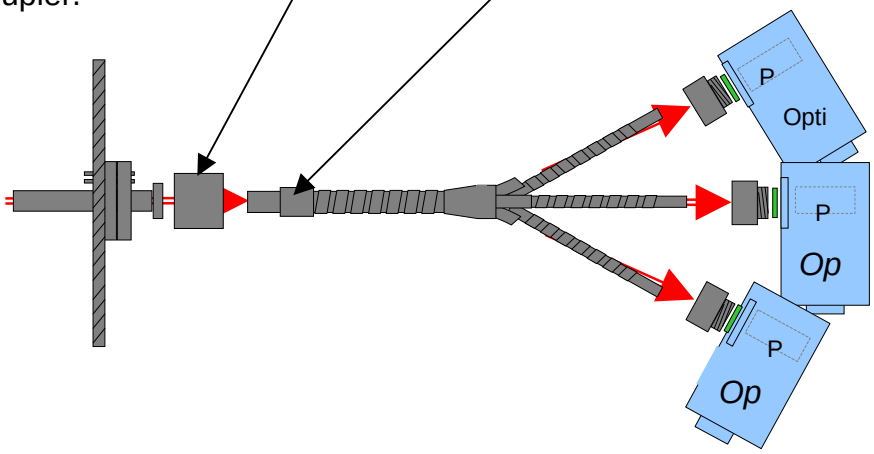
For 3-material systems the signals reaching all three detectors are not the same magnitude. Because of the additional beam split, detectors #2 & #3 each get much less light than detector #1. The Guardian controller and software provide for gain adjustments to compensate for these differences; however, that does not adequately compensate for the lower signals inherent in the setup. If you use this configuration, install the first detector (#1 in this example) on the material with the lowest deposition rate (lowest signal).

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4.2.2.2 Fiber Optic Beam Splitting

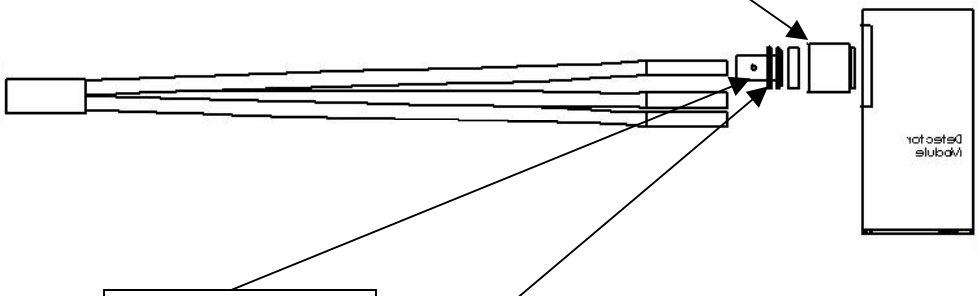
Fiber optic components cost more, but introduce lower light losses than equivalent optical components. They are especially useful when the signal is low or must be split into several components.

1. Slide the Window Flange Coupler (782-020-033) onto the 1.33" MiniCF-16 flange and secure with three set-screws. Thread the Fiber Optic Coupler (782-020-034) into the flange coupler.



2. Slide the large ferrule of the Fiber Optic Beam Splitter into the fiber optic coupler and secure with three set screws.

3. For each detector, thread a Lens Tube Spacer (070-1622) into the detector, and place the proper Filter in the lens tube coupler.



4. Place the PMT Fiber Adapter (782-020-042) into the lens tube spacer. Secure the adapter with the internal Retaining Ring (070-1620)

5. Secure each leg of the fiber optic splitter to the Detector with three set screws.

Be careful when bending fiber optic lines. Individual internal fibers are easily broken, which reduces the light signal at the output. Also, the detectors must be supported by an external means. Do not hang the detector from the fiber optic cable.

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4.3 Filters

A 1" (25mm) round optical filter is mounted in the inlet of each detector. This filter selectively passes a specific wavelength of light that is the characteristic emission from a specific material. The filter is a critical EIES component. The characteristics and quality of the filter have a strong influence on the results. Filter characteristics to consider:

Transmission: The filter should transmit (pass) as much of the light as possible, for the specified wavelength. A filter is a lens with a special coating that blocks all light except for a specified wavelength. Unfortunately, that coating also blocks the desired wavelength. The result is a reduced light beam even for the wavelength of interest.

Bandwidth: A filter passes wavelengths a little above and below the specified wavelength (the transmission curve is a bell-shape). A 100nm filter with a bandwidth of 10nm passes wavelengths from roughly 95nm up to about 105nm. A very narrow-bandwidth filter is more selective in passing only the wavelength of interest, but it may also result in lower signal level as well.

Some materials have primary emission wavelengths very close to other materials, which means the filter and detector cannot distinguish one material from the other. In these cases, a secondary emission wavelength may produce sufficient signal to be usable.

Appendix A lists common materials and their characteristic emission wavelengths.

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4.4 QCM Quartz Crystal Monitor

A Quartz Crystal Monitor is commonly used with EIES systems for 1) calibration of the EIES, and 2) control of materials for which EIES measurement is not suitable. INFICON's SQM-242 PCI Card or Q-pod is the recommended QCM for use with the Guardian system. External QCM controllers can also be used with the EIES, but calibration and process control are done manually.

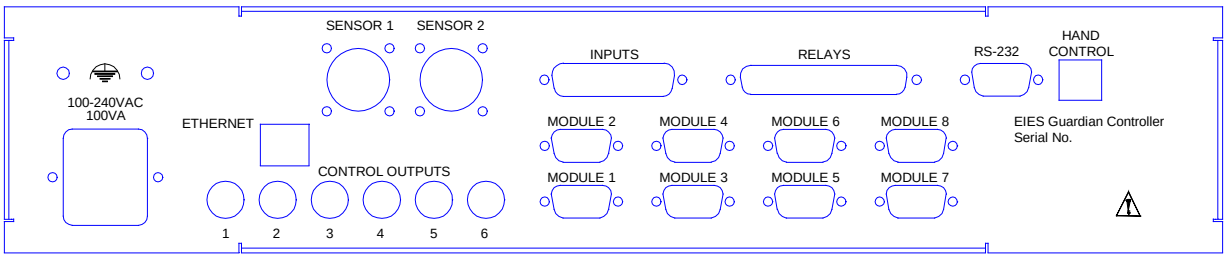
Consult the SQM-242 or Q-pod Installation Guide for detailed instructions on installing the SQM-242 QCM (and optional SAM-242 Analog Input card) or Q-pod in your computer. Chapter 3 of this manual describes setup and operation of the QCM in conjunction with the Guardian system.

For accurate rate calibration, locate the QCM sensor(s) in the vacuum chamber so that it receives a representative sample of the materials being deposited. The InVac cable must be less than 40” (1 m) for proper QCM operation.

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4.5 Digital I/O

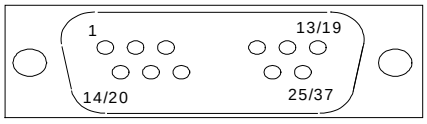
Two connectors on the rear panel provide digital inputs and relay output connections.



WARNING: Digital inputs are not isolated! The voltage level applied must be limited to between 0 and +12 volts with respect to Ground.

WARNING: Relay contacts are rated for 30VDC maximum duty. Any customer supplied relay contact circuit must be fused at not more than 5A if the circuit is capable of supplying more than 5A, including the available short circuit current.

The digital inputs are supplied on a 25-pin male D-sub connector. Relay outputs are on a 37-pin male D-sub connector. The figure below shows the connector pin numbering, as seen from the rear of the Guardian controller.



Relay I/O Connector Rear View

On both connectors, pin one is in the upper left corner. The last pin (25 or 37) is in the lower right corner.

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4.5.1 Input Connector Pinout

Input	Pin	Input	Pin
1	13	7	19
2	14	8	20
3	17	9	21
4	15	10	22
5	16	11	23
6	18	12	24
Common	10		
Ground	3,4,5,6	+12V	1

Tie common (pin 10) to a supply voltage (+12V is available on pin1). Inputs are activated by pulling the input pin to ground.

4.5.2 Relay Connector Pinout

Relay	Pins	Relay	Pins
1	9,27	7	6,24
2	10,28	8	13,31
3	8,26	9	4,22
4	11,29	10	5,23
5	7,25	11	14,32
6	12,30	12	15,33

The relays are Form1A (SPST, normally open) mechanical relays.

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Chapter 5 - Maintenance

5.0 Introduction

WARNING: There are no adjustments or user-serviceable parts inside the EIES Guardian Controller or Detectors. For maintenance or repair, contact

INFICON
Two Technology Place
East Syracuse, New York
13057 USA
Tel 315-434-1100
Fax 315-437-3803

5.1 Cleaning

Use a damp cloth, wetted with water or a mild detergent, to clean the outer surfaces.

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Chapter 6 - Calibration

6.0 Introduction

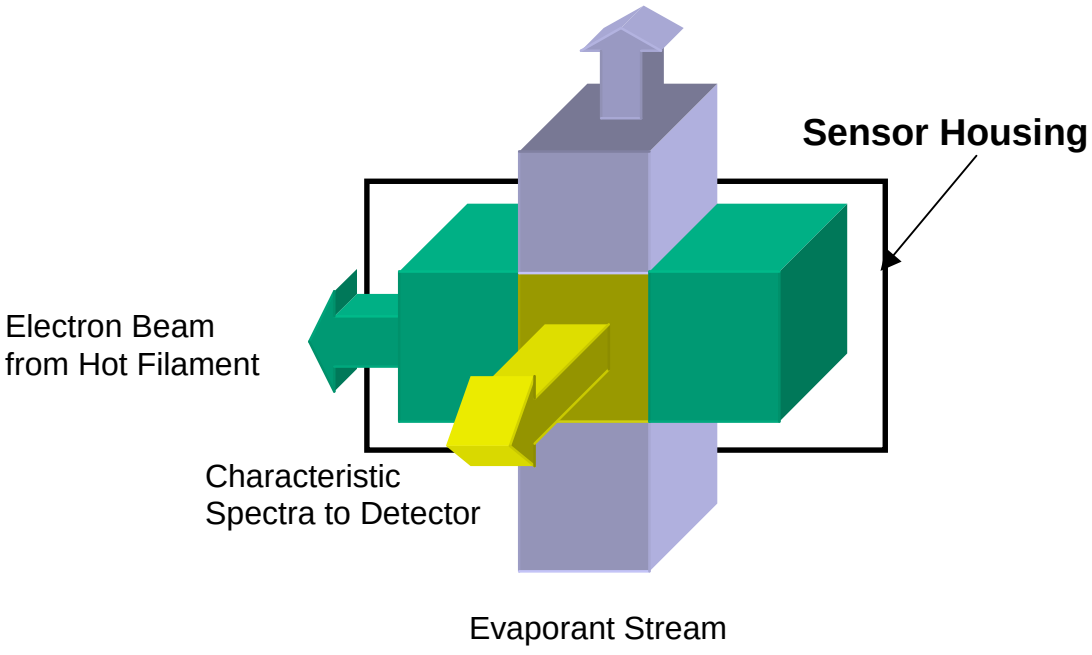
This chapter contains information that is useful for determining calibration values to achieve the best possible performance and accuracy from your EIES-IV Guardian system.

6.1 Theory of EIES Measurements

Electron Impact Emission Spectroscopy (EIES) uses a thermionic emitter to excite outer shell electrons to a higher valence band. When these excited electrons return to their normal state, they emit photons of a characteristic wavelength(s). An optical filter passes the characteristic wavelength to a photomultiplier tube (PMT) detector. The intensity of the characteristic wavelength is proportional to the rate of deposition of the selected material.

6.1.1 Sensor

The EIES emitter assembly (referred to as the "sensor" for historical reasons) consists of a hot cathode filament used to emit high-energy electrons. The sensor is installed so that a portion of the evaporant stream passes through the active sensor region.



Within the sensor housing, electrons from the filament strike the evaporant atoms, raising the energy level of the outer electrons. These excited electrons immediately return to their normal energy level, emitting photons. The wavelength of the photons is characteristic of the material, and the intensity is proportional to the number density of the atoms.

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For any material:

$$J \propto i\,N$$

where

J = Emission Intensity
i = Electron Beam Current
N = Number Density of Atoms

and

$$D = m\,v\,N$$

D = Mass Deposition Rate
m = Mass of Atom
v = Average Velocity of Atoms

Finally, for a constant velocity

$$J = k\,D$$

where k is a calibration constant.

The calibration constant incorporates several assumptions inherent in the above derivation - constant velocity, constant source temperature, and optical losses.

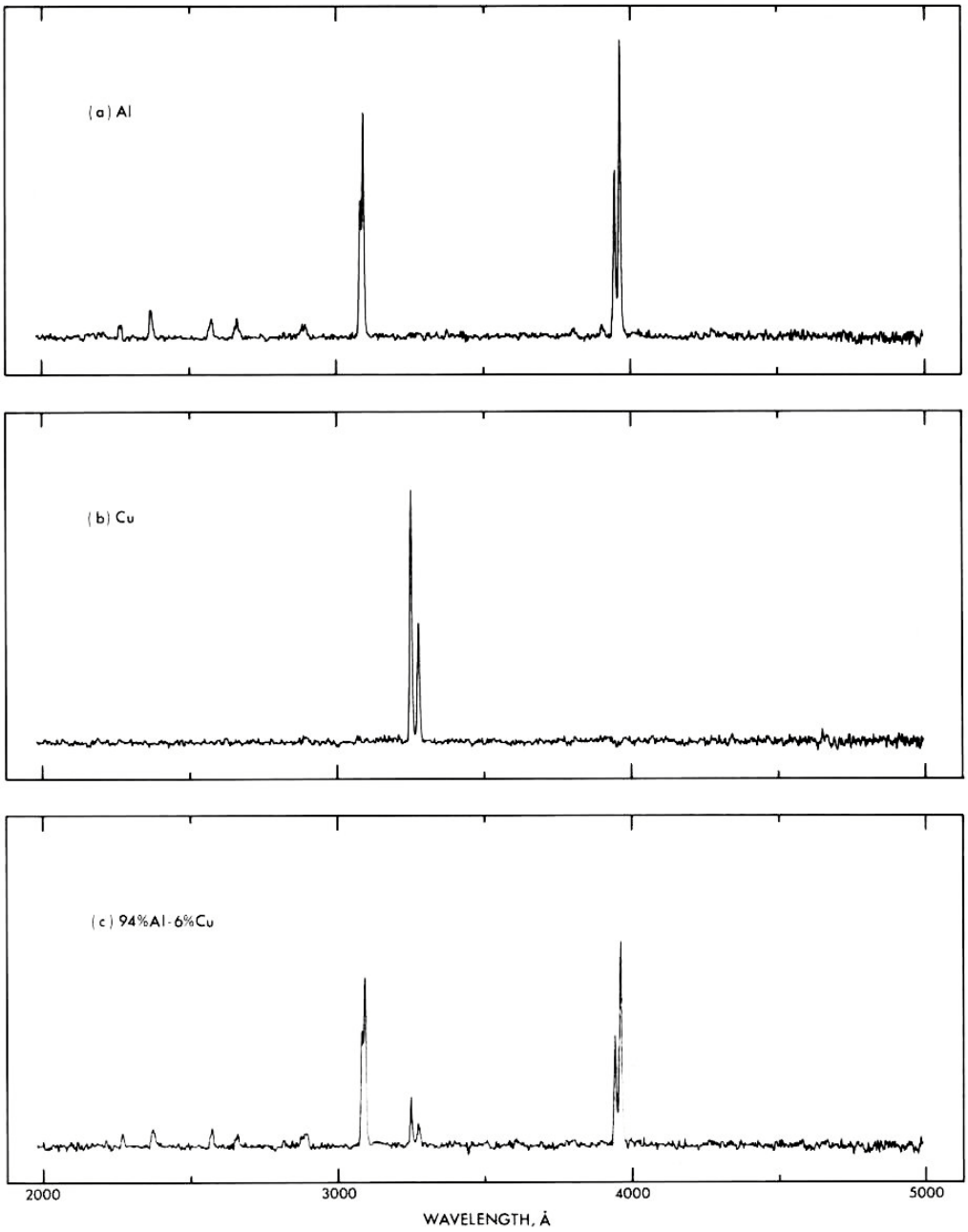
The emitted light must be efficiently transmitted to the detection device(s). For short, straight transmission paths from the sensor to the detector(s), the sensor's hollow tube may be adequate. However, the number of photons reaching the detector is proportional to the inverse of the light path squared ($1/D^2$).

For straight paths, a quartz light pipe placed inside the sensor 's hollow light tube is inexpensive and simple to fabricate. For transmission of the UV wavelengths used in EIES, a high-purity fused quartz guide is required. A quartz light guide can provide nearly a factor of ten improvement in light transmission. For non-linear paths, and efficient signal splitting, a fiber optic splitter allows flexibility in sensor/detector placement, and significantly less optical loss.

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6.1.2 Optical Discrimination

Spectra for Aluminum, Copper, and a codeposition of 94%Al-6%Cu are shown below.



Issues common to material codeposition are clearly illustrated in this example. The Al line near 4000Å is useful. The intensity is not diminished when codeposited with Cu, and no interfering emission lines are nearby.

However, for Cu the line near 3250Å is not only attenuated, but is also near the secondary Al line around 3100Å. To accurately measure the Cu emission, we need a discriminating device with the conflicting goals of a narrow bandwidth and low attenuation of the desired signal.

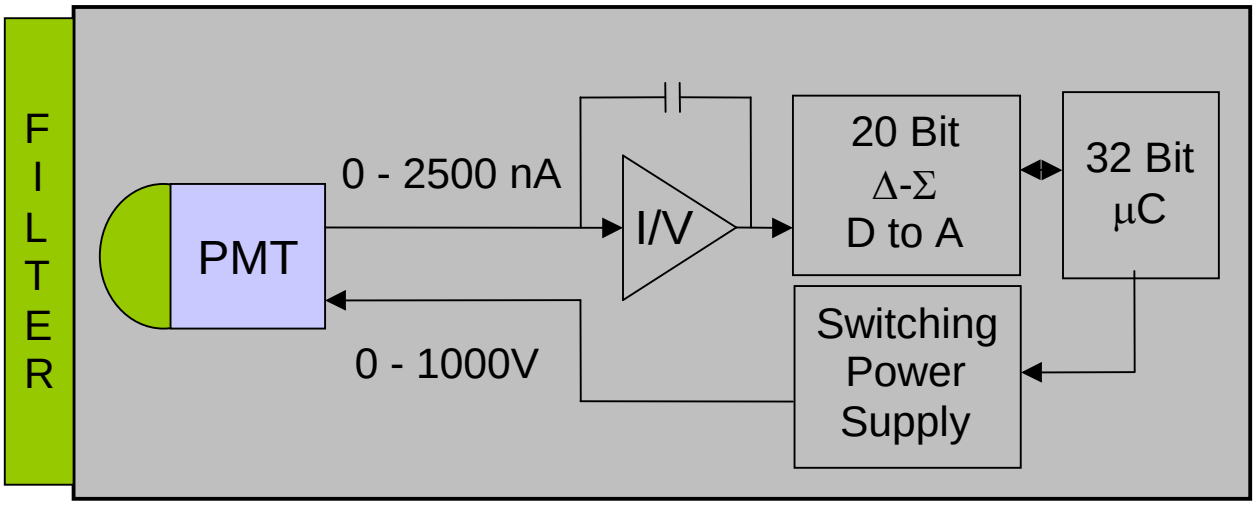
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Thin film optical filters are both efficient and selective. In addition they are readily available, small, and relatively inexpensive. The main disadvantages are that a specific filter is required for each material, and the filters degrade over time. Periodic spectrometer verification of filter central wavelength and pass band is required.

An alternative to optical filters are monochromators. Both wavelength and bandwidth are tunable, but the efficiency does vary with the square of the bandwidth. For applications requiring deposition of many different materials, monochromator size and expense may be an acceptable tradeoff to stocking and changing filters.

6.1.3 Detector

Once the characteristic wavelength is discriminated by a filter or monochromator, it must be accurately measured by a detector. The EIES-IV Guardian uses a photomultiplier tube (PMT) to convert the optical signal to electric current.



In addition to the PMT, a programmable high voltage power supply and microprocessor are housed within the detector module. This allows each detector to be calibrated to a PMT voltage specific to the material and deposition rate being measured. A single DB-9 cable carries the RS-232 communications and low voltage power between the detector and Guardian controller.

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6.2 Theory of QCM Measurements

As material is deposited on a quartz crystal, its frequency decreases. The frequency change correlates to a thickness, using the QCM equation:

$$T_f := \frac{N_q \cdot D_q}{\pi \cdot D_m \cdot F_c \cdot Z} \cdot \operatorname{atan}\left[Z \cdot \tan\left[\frac{\pi \cdot \left(F_q - F_c\right)}{F_q} \right] \right]$$

where the constant terms for the quartz crystal are:

AT crystal constant: $N_q := 1.668 \cdot 10^{13} \cdot \frac{Hz}{m^{-10}}$

Density of quartz: $D_q := 2.648 \cdot \frac{gm}{cm^3}$

6.2.1 Density

Material density tables (in gm/cc) are commonly available in an Appendix to this User Manual, chemical handbooks, and on the Internet. If you cannot find the density of your material, it can be calculated empirically using this method:

1. Place your substrate adjacent to a new quartz sensor.

2. Set QCM Density to an approximate value; Z-Factor =1; Tooling =100.

3. Deposit approximately 1000 to 5000 Å of material.

4. Use a profilometer or interferometer to measure the substrate's film thickness.

5. The actual density value is calculated by:

$$\text{Density}_{ACTUAL} = \text{Density}_{APPROX} \times \frac{\text{Thickness}_{QCM}}{\text{Thickness}_{ACTUAL}}$$

6.2.2 Z-Factor

Z-Factor is used to match the acoustic impedance of the deposited material (Z_m) to that of the base quartz material (Z_q=8.83) of the sensor crystal:

$$\text{Z-Factor} = Z_q / Z_m$$

For example, the acoustic impedance of gold is Z=23.18, so:

$$\text{Gold Z-Factor} = 8.83 / 23.18 = .381$$

Z-Factor can be calculated using the Shear Modulus of quartz (U_q) and the deposited material (U_m):

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$$Z := ((D_q * U_q)/(D_m * U_m))^{1/2} \qquad \text{where } U_q \sim 32\text{Gpa}$$

Unfortunately, Z-Factor and Shear Modulus are not readily available for many materials. Z-Factor can also be calculated empirically using this method:

1. Deposit the material until Crystal Life is near 50%, or near the end of life, whichever is sooner.

2. Place a new substrate adjacent to the used quartz sensor.

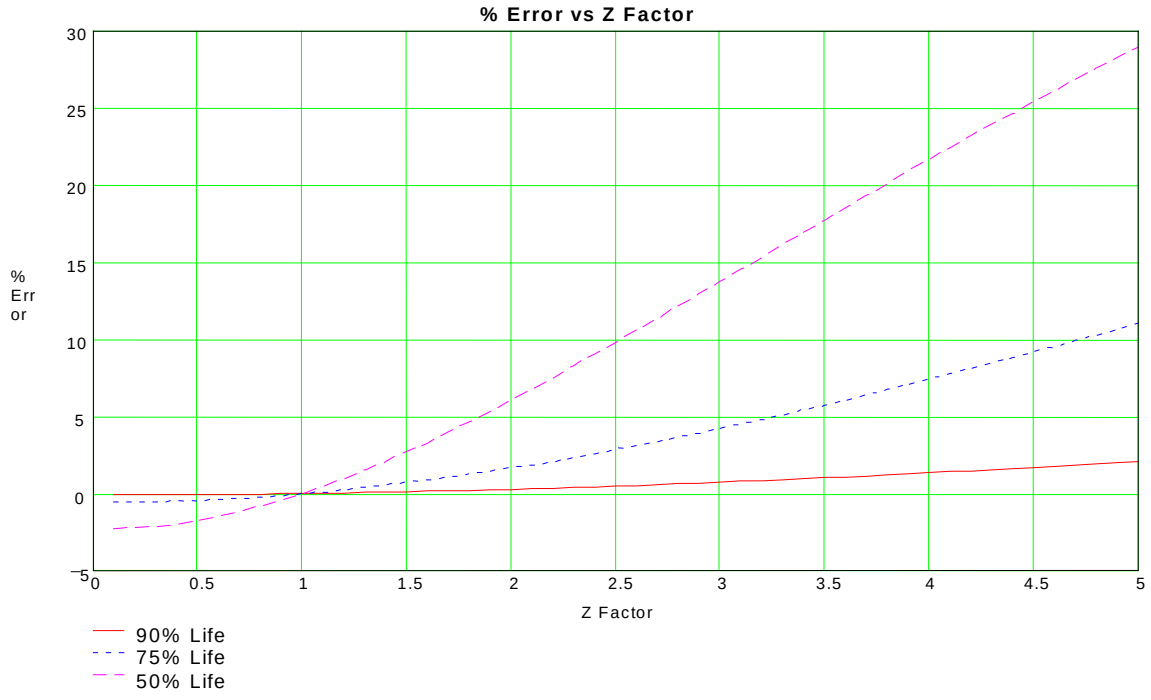
3. Set QCM Density to the calibrated value; Tooling to 100%. Zero thickness.

4. Deposit approximately 1000 to 5000 Å of material on the substrate.

5. Use a profilometer or interferometer to measure the actual substrate film thickness.

6. Adjust the Z-Factor of the instrument until the correct thickness reading is shown.

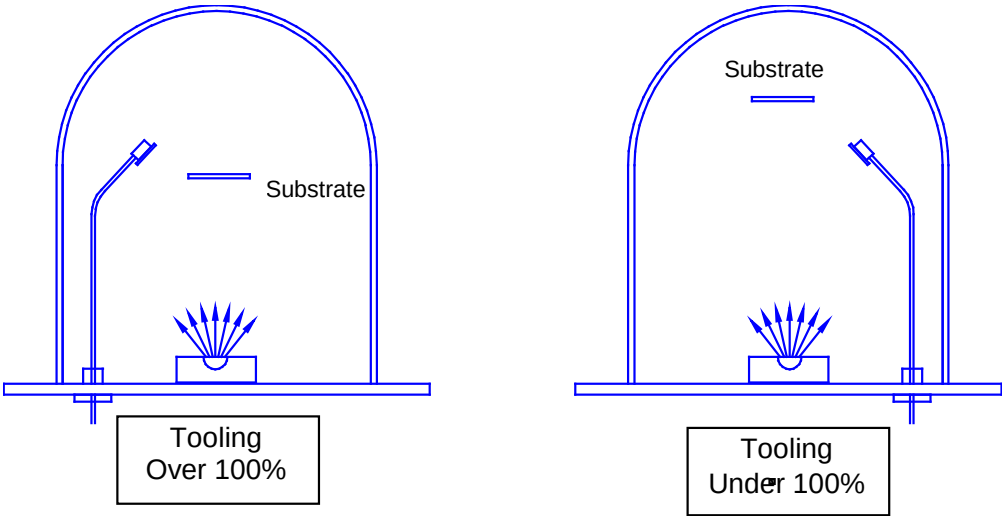
Another alternative is to change crystals frequently. The graph below shows the % Error in Rate/Thickness from using the wrong Z-Factor. For a crystal with 90% life, the error is negligible for even large errors in the programmed versus actual Z-Factor.



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6.2.3 Tooling Factor

Tooling Factor adjusts for the difference in material deposited on the quartz sensor versus the substrate. Tooling may be less than or greater than 100% as shown below:



1. Place your substrate and a new quartz sensor in their normal position.

2. Set Tooling to an approximate value; Density as determined above; Z-Factor =1.

3. Deposit approximately 1000 to 5000 Å of material.

4. Use a profilometer or interferometer to measure the substrate's film thickness.

5. The correct Tooling Factor is calculated by:

$$\text{Tooling}_{\text{ACTUAL}} = \text{Tooling}_{\text{APPROX}} \times \frac{\text{Thickness}_{\text{ACTUAL}}}{\text{Thickness}_{\text{QCM}}}$$

$$Z := ((D_q * U_q)/(D_m * U_m))^{1/2}$$

where U_q ~ 32Gpa

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6.3 EIES Calibration

EIES is an accurate means of measuring deposition rate and deposition thickness over a wide dynamic range. However, as with any instrument, it must be set up properly and calibrated periodically for accurate results.

The following discussion assumes you know how to operate the software (Chapter 3).

6.3.1 Detector Electronics Calibration

Before use, the electronics of each detector must be calibrated and stored by the EIES software. This calibration must occur each time the detector is replaced or moved to another channel on the Guardian controller. Because the PMT voltage is off during this calibration, it can be done at atmosphere or vacuum, with or without deposition.

Connect the detector to the Guardian Controller. Start the EIES software and select Edit, System, Channel tab. Select the channel the detector is connected to. Select calibration readings value that is equal to the Update (Hz) value shown. This will assure 4 seconds for a total calibration time. When calibration is finished the calibration constants for the selected detector will be refreshed.

6.3.2 PMT Voltage Selection

The PMT voltage of the EIES detector can be adjusted to optimize the operating point for the material and deposition rate to be measured. The PMT voltage setting affects the gain (and to a lesser extent, offset) of the detector. A low PMT voltage causes noisy readings, while high voltage risks saturating the PMT output.

In the EIES software, create a layer that uses the desired material (film). Select Edit, System, Channel tab. Also show the channel's Edit Layer dialog box, Film Cal. tab.

Start deposition of the single material. This can be accomplished by manually controlling your deposition source, or the Manual Power function of the EIES software. Set the power to achieve a rate near the maximum deposition rate you want to measure. This can be determined from previous experience with the power supply setting, or by measuring the true rate with a QCM. It is not important that the value be exact, just near the upper range of the desired deposition rate.

On the Edit Layer dialog box, adjust the PMT voltage until the % Current reading on the Edit System dialog box shows 50% to 70%. Typical PMT voltage values are 500V to 700V. The 50% to 70% value may seem low, but some headroom may be necessary when other materials are being codeposited.

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6.3.3 Zero Calibration

The EIES detector may read a residual gas signal, even when no deposition is occurring.

To remove this error term, in the EIES software create a layer that uses the desired material (film). Show the channel's Edit Layer dialog box, Film Cal. tab. Verify that the film's Unit Multiplier setting is 1 and Unit Offset is 0. Also verify that the Cal Gain setting is 1 and the Cal Zero setting is 0. This assures that the detector reading displayed is detector current in nA.

With the EIES sensor enabled, but with no deposition, observe the channel readings. Enter the reading into the Cal. Zero field of the Edit Layer dialog box and press <Enter>. The channel reading will now show zero.

6.3.4 Gain Calibration – Test Run

Gain calibration matches the EIES detector's relative rate/thickness measurement to a known rate/thickness measurement. This can be done by completing a trial deposition on a substrate whose thickness can be measured by some other means, such as a QCM, interferometer, profilometer, or weight.

Record the EIES thickness reading at the end of the deposition and correct the value by entering a Cal Gain:

Cal. Gain = Measured Thickness / EIES Total

This method of EIES gain calibration is both time-consuming and prone to error.

6.3.5 Gain Calibration - QCM

A Quartz Crystal Monitor (QCM) provides an accurate means of calibrating EIES detector gain. While it can be used in the manner described above, INFICON's SQM-242 or Q-pod provides an automated approach.

Show the channel's Edit Layer dialog box, FilmCal. tab. Select the QCM input you wish to use in the Cal. QCM # dropdown. Enter the Density and Z Factor for the material being calibrated. If you don't know the Z Factor, use a new crystal and set ZFactor = 1. Set Cal. Accuracy to 100% for now, and Cal. Interval = 0. Set Cal. Sample to a value that will give adequate measurement time – maybe 10 seconds.

Start deposition of only the material you want to calibrate, under PID control. When deposition reaches a stable value, click Calibrate Start. The QCM shutter will open, then after 5 seconds the calibration sample will begin. When calibration is done, the Cal. Gain value will be updated so that the EIES channel reading matches the CQM reading.

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For automatic QCM calibration, enter a Cal. Interval. During deposition, the EIES software will automatically calibrate for Cal. Sample time each Cal. Interval during deposition.

The algorithm used for QCM calibration is:

1. Open the crystal shutter.
2. Wait 5 seconds for thermal stabilization.
3. Measure rate and thickness of EIES and QCM.
4. Verify that stability of rate signals are within Cal. Accuracy value.
5. Measure rate and thickness until the end of Cal. Sample time.
6. Verify that EIES and QCM thickness are >=100A.
7. Calculate Cal. Gain = QCM Thickness / EIES Thickness.

6.3.6 Cross Channel Calibration

The EIES detector may detect optical emission from background gases or other materials. This is particularly true if the emission wavelengths of other materials are near the wavelength of the material being measured. To compensate for this effect, you need to measure, and subtract the interfering (cross channel) rate(s).

In the EIES software, create a codeposition layer for the materials to be calibrated. Show the channel's Edit Layer dialog box, Film Cal. tab. With no deposition on the selected channel, start deposition on the interfering channel. When the interfering channel rate stabilizes, calculate the percent of the interfering channel's rate reading that shows in the channel you are calibrating. Select the interfering channel in the First xChan dropdown box and enter the percent value in the First xChan% cell. You can repeat this procedure with a second, third, or fourth interfering channel.

An example will be helpful. Let's say that you are codepositing copper (Cu) on Channel 1 and cadmium (Cd) on channel 2. The wavelength for Cu is 3261, for Cd the wavelength is 3247. It is unlikely that either of these filters will adequately reject the other material's signal.

While not depositing copper on channel 1, start depositing cadmium on channel 2, near the desired rate. Let's say the channel 2 rate (Cd) is 1 A/s, and with no copper being deposited channel 1 measures .1 A/s. Then for channel 1, you would enter First xChan = 2 and xChan% = 10. This will calibrate the channel 1 reading to show 0 A/s, the true Cu reading.

Repeat this procedure while depositing Cu on channel 1, and no Cd deposition on channel 2. Assume that the channel 1 rate (Cu) is 20 A/s and channel 2 measures 1 A/s. On the channel 2 Edit Layer dialog box, enter 1st xChan = 1 and 1st xChan% = 5%.

This procedure can compensate for three other materials. In each case, deposit no material on the channel you are calibrating, and calibrate for the other channels.

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Chapter 7 - Communications

7.0 Introduction

The computer interface capabilities of the EIES program allow operation from an external computer via Ethernet or RS-232 serial communications using a simple ASCII command set. Programs running on the same computer can control the EIES program using ActiveX and the same ASCII command set. Or, you can control the EIES Guardian controller directly using ASCII commands.

7.1 Serial Interface

Connect a serial cable from the EIES computer's serial port to the control 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 EIES program select the Edit menu, System dialog box, then the Comm tab. Set the External Comm Port to match the serial port that is connected to the control computer. Set the baud rate to match the baud rate of the control computer that will be connected to the EIES computer. Communications format is No Parity, 8 bits, 1 stop bit.

7.2 Ethernet Interface

Connect a cable from the Ethernet card to your Ethernet network. In the EIES program select the Edit menu, System dialog box, then the Comm tab. Set the External 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.

7.3 ActiveX (COM) Interface

Any program that supports Microsoft's COM (Active X) interface (i.e. LabView, Wonderware, etc.) can communicate with the EIES program. A small ActiveX interface program, SQS242X.EXE, provides receive data and transmit data entry points to the global cComm242 class. The naming is odd because this program was originally developed for our SQS-242 deposition control software. It works equally well as an interface to the EIES software.

The EIES Comm demo program discussed in the next section provides a Visual Basic example of using another program to control the EIES program. Contact INFICON for examples in other languages and detailed technical information.

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7.4 EIES Comm Program

EIES Comm (found in the Comm sub-directory of the EIES program) is a simple Windows® program to demonstrate EIES communications concepts. With EIES Comm you can easily send commands and read the responses returned by the EIES program. EIES Comm is written in Visual Basic and the source code is included as an example of programming concepts for computer interfacing.

Setup for RS-232 or Ethernet:

In the EIES program, select Edit, System and set the RS-232 or Ethernet settings as detailed in the previous sections.

Load the EIES Comm program on a computer (the host) and connect an Ethernet or RS-232 cable between the host and the computer running the EIES 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).

Setup for Active X Control:

Load the EIES Comm program on the same computer that is running the EIES program. Start the Comm program and select Active X on the Utility tab. Start the EIES program also.

Communicating with the EIES Program:

In the EIES Comm program, Utility tab, click the Version. Click Send to send the query to the EIES program.

The response from the EIES program should show in the Comm program Response window. A typical response is @QU;ACK;2.0.0;39, which indicates software version 2.00. The next section describes the Query/Update and Response strings in detail.

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7.5 EIES Program Protocol

EIES program commands fall into two categories:

Query commands that request data from the EIES program and
Update commands that update a setting or instruct the program to take an action.

Query Command Format:
@<command>;<param1>;…;<paramn>;<Chksum><CR>

Example: Software Version Query
@QU;11;44<CR>
where:

@	Message start character
QU	Query Utility command
;	Separator
11	Parameter 11 (EIES Software Version)
;	Separator
0	Optional parameter (not used for this query)
;	Separator
4F	Checksum (see section that follows on checksums)
<CR>	Carriage Return (ASCII 13)

Example: Response to Software Version Query
@QU;<ACQ>;2.1.6;4B<CR> (Response to Software Version query)
where:

@;QU;<ACQ>;	Query Acknowledged (ASCII 06)
2.0.0	Message (Software Version)
;	Separator
4B	Checksum (actual checksum varies with different versions)
<CR>	Carriage Return (ASCII 13)

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Update Command Format:
@<command>;<param1>;...;<paramn>;<data>;<Chksum><CR>

Example: Set Process Update
@UP;01;MyProcess;44<CR>
where:

@;UP;	Update Process command
;	Separator
01	Parameter 01 (Set Process)
;	Separator
MyProcess	Data
;	Separator
??	Checksum
<CR>	Carriage Return (ASCII 13)

Example Response: Set Process Update Succeeded
@UP;<ACQ>;??<CR>

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

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.*

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7.6 EIES Program Command Summary

Query Process: @QP;<param1> where <param1> is:

01 Process Name
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 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

06 Phase Time (mm:ss)
07 Run #
08 All Process Names (comma delimited list)
09 Number of Process layers
1n Source Shutter Status, n=1 to 8 (0=Open, 1=Close)
2n Sensor Shutter Status , n=1 to 8 (0=Open, 1=Close)
30 Emission 1 Status (0=Off, 1=On) Legacy, see Query Sensor for new command
32 Emission 2 Status (0=Off, 1=On) Legacy, see Query Sensor for new command
34 DataLog Status (0=Off, 1=On)
36 DataLog FileName
37 DataLog Interval
38 DataLog Type (0=Overwrite, 1=Append, 2=Run#)
4n Power Mode Channel n (1 to 8), 1 = PID, 0= Manual Power
71 Emission SetPt 1 Legacy, see Query Sensor for new command
72 Emission SetPt 2 Legacy, see Query Sensor for new command
73 Leakage SetPt 1 Legacy, see Query Sensor for new command
74 Leakage SetPt 2 Legacy, see Query Sensor for new command

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Update Process: @UP;<param1>;<data> where <param1> is:

Note: *Update commands 01, 07, and 09 are only valid in Stop Mode.*

01 Set Active Process (data = process name)
02 Start Process
03 Stop Process
04 Start Layer
05 Stop Layer
06 Reset
07 Set Run #
08 Next Layer
09 Set Active Layer #
30 Emission 1 Off
31 Emission 1 On
32 Emission 2 Off
33 Emission 2 On
34 DataLog Off
35 DataLog On
36 DataLog FileName
37 DataLog Interval
38 DataLog Type (0=Overwrite, 1=Append, 2=Run#)
4n Channel n (1 to 8) to Auto Power
49 Set all active channels to Auto Power
5n Channel n (1 to 8) to Manual Power (<Data> = % Power)
59 Set all active channels to Manual Power (<Data> = % Power)
6n Zero channel n (1 to 8) total
69 Zero all totals
71 Emission SetPt 1
72 Emission SetPt 2
73 Leakage SetPt 1
74 Leakage SetPt 2

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Query/Update Layer: **@QL;<param1>;<layer>;<channel>**
@UL<param1>;<layer>;<channel>

***Note**: A <layer> value of zero sets/returns data on the current layer.*

where <param1> is:

01	Film Name
02	Rate Setpoint (A/s)
03	End Thickness (kA)
04	Time SetPt (mm:ss)
05	Thickness SetPt (kA)
06	Start Mode (0/1)
09	Start Prompt (250 characters or less)
10	Phase of the requested channel (query only)
11	Ramp 1 Start Thickness
12	Ramp 2 Start Thickness
21	Ramp 1 Ramp Time
22	Ramp 2 Ramp Time
31	Ramp 1 New Rate
32	Ramp 2 New Rate
61	xChan1 #
62	xChan2 #
63	xChan3 #
64	xChan4 #
71	xChan1 %
72	xChan2 %
73	xChan3 %
74	xChan4 %

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Query/Update Film: **@QF;<param1>;<layer>;<channel>**
@UF;<param1>;<layer>;<channel>;<value>

***Note**: A <layer> value of zero sets/returns data on the current layer.*

where <param1> is:

01 P Term
02 I Term
03 D Term
05 Shutter Timeout
06 Shutter Accuracy
07 Error Action (0/1/2)
08 Control Accuracy
10 QCM Sample Accuracy
11 QCM Sample Time
12 QCM Sample Interval
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
25 Indexer 1 Pocket
26 Max Power
27 Slew Rate
28 QCM Density
29 QCM Tooling
30 QCM Z-Factor
31 Input Type
32 PMT Voltage
33 Cal Gain
34 Cal Zero
35 User Units
36 User Multiplier
37 User Offset
38 Exponent
39 Integer Digits
40 Decimal Digits
41 Filter
42 QCM Cal Number

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Query Sensor: @QS;<param1>

where <param1> is:

01	Sensor 1 Status (0=Off, 1=On)	
03	Sensor 2 Status (0=Off, 1=On)	
05	Gas 1 Status (0=Off, 1=On)	
07	Gas 2 Status (0=Off, 1=On)	
1n	Sensor n Emission SetPt (mA)	1=Sens1, 2=Sens2, 3=Gas1, 4=Gas2
2n	Sensor n Maximum Leakage (mA)	1=Sens1, 2=Sens2, 3=Gas1, 4=Gas2
3n	Sensor n Gas Calibration	1=Sens1, 2=Sens2

Update Sensor: @US;<param1>;<value>

where <param1> is:

01	Sensor 1 Off	
02	Sensor 1 On	
03	Sensor 2 Off	
04	Sensor 2 On	
05	Gas1 Off	
06	Gas1 On	
07	Gas 2 Off	
08	Gas 2 On	
1n	Sensor n Emission SetPt (mA)	1=Sens1, 2=Sens2, 3=Gas1, 4=Gas2
2n	Sensor n Maximum Leakage (mA)	1=Sens1, 2=Sens2, 3=Gas1, 4=Gas2
3n	Sensor n Gas Calibration	1=Sens1, 2=Sens2

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Query/Update Utility: **@QU;<param1>**
@UU;<param1>;<Param1>

02 Simulate Mode (0/1)
06 Front Panel Disable
Param 1 is sum of these disable values:

1	Start Buttons	32	Zero
2	Emission 1	64	Manual Power
4	Emission 2	128	File Menu
8	DataLog	256	Edit Menu
16	Chan Edit	512	Graph Setup

For example: <Param1> = 9 would disable Start Buttons and DataLog
07 Application Visible (0/1)
11 EIES Software Version (Query only)
12 EIES Computer Operating System (Query only)
13 EIES Computer Name (Query only)
14 EIES On Top (0/1, Update only)

Query Measurement: **@QM;<param1>**

01	Sensor 1 Emission Current (mA)	Legacy, see 51-54 for new command
02	Sensor 2 Emission Current (mA)	Legacy, see 51-54 for new command
03	Sensor 1 Leakage Current (mA)	Legacy, see 55-58 for new command
04	Sensor 2 Leakage Current (mA)	Legacy, see 55-58 for new command
05	Sensor 1 Power (Watts)	Legacy, see 61-64 for new command
06	Sensor 2 Power (Watts)	Legacy, see 61-64 for new command
07	Sensor 1 Fail (0 OK, 1 Fail)	Legacy, see 65-68 for new command
08	Sensor 2 Fail (0 OK, 1 Fail)	Legacy, see 65-68 for new command
1n	Channel n Power (n=1 to 8)	
2n	Channel n Rate	
3n	Channel n Thickness	
4n	Channel n Deviation	
5n	Sensor n Emission Current (mA)	1=Sens1, 2=Sens2, 3 = Gas1, 4=Gas2
5n	Sensor n Leakage Current (mA)	5=Sens1, 6=Sens2, 7 = Gas1, 8=Gas2
6n	Sensor n Power (watts)	1=Sens1, 2=Sens2, 3 = Gas1, 4=Gas2
6n	Sensor n Fail (0 OK, 1 Fail)	5=Sens1, 6=Sens2, 7 = Gas1, 8=Gas2
7n	Sensor n Filament Current (A)	1=Sens1, 2=Sens2, 3 = Gas1, 4=Gas2
7n	Sensor n Bias Voltage (V)	5=Sens1, 6=Sens2, 7 = Gas1, 8=Gas2

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7.7 Guardian Controller Command Summary

The EIES program is a turnkey deposition control program for the EIES Guardian controller. The EIES program uses these ASCII commands to communicate with the Guardian controller. You can create your own deposition control program using these same commands.

Command Summary (# is channel, V is value)

@ Returns Guardian Controller version, X.XX

A Get active channels

B#,V Version 1.XX
Set channel update (V is rdgs)
B#,V,G Version 2.XX
Set channel update (V is rdgs, G is gas sensor used (1) or not (0))

C Set bias current (LoCal = 100 nA, HiCal & Normal = 2000 nA)

D Version 1.XX
Get Dual Sensor Status (Leak1, Emis1, Leak2, Emis2, Pwr2, Pwr1, Unk, Unk, Status)
Status: "0" OK, "1" Sensor1 Err, "8" Sensor2 Err, "9" Sensor 1&2 Err
D Version 2.XX
Get GC Sensor Status (Emis1, Leak1, Pwr1, FillCur1, BiasV1, Emis2, Leak2, Pwr2, FillCur2, BiasV2, EmisGas1, LeakGas1, PwrGas1, FillCurGas1, BiasVGas1, EmisGas2, LeakGas2, PwrGas2, FillCurGas2, BiasVGas2
Status: "0" AOK, "1" Sensor1Err, "2" Gas1Err, "4" Sensor2Err, "8" Gas2Err, "?" AllErr (value encoded 0x30 to 0x3F, 0x33 indicates Sensor1 and Gas1 error)

E#,V Start integrator calibrate (V is packets)

F Reading ready? 0 = No, 1 = Yes

G Version 1.XX
Get readings SamplesOn, DataOn, SamplesBkg, DataBkg;;;;;;;;
'G Version2.XX
Get readings SamplesOn, DataOn, SamplesBkg, DataBkg, SamplesGas, DataGas;;;;;;;;

H#,V Set PMT# Voltage (V is 0 to 1250 volts)

I Cal done?

J# Get integrator cal readings

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K#,V Set output voltage 0 to 5 (V is counts, 0V = 32767)

L Read hand controller, Start(0/1), Delta counts

M Read digital inputs X,X,X,X,X,X,X,X,X,X,X,X
' Bit 13 (1 based) is handcontroller start/stop pushed

N,V Set relays (V is X,X,X,X,X,X,X,X,X,X,X,X)

O#,V Set filter #, (V is 1 to 4)

P# Read filter # (returns 0 Busy, 1 Home, 2 Error)

S#,V Version 1.XX
Emission 1/2 On/Off (1/0)
S#,V Version 2.XX
Emission 1 to 4, On/Off (1/0) #1/3 are normal sensors, 2/4 gas sensors

T# Get power (mainly used for hand controller)

U#,V Version 1.XX
HandController (V is Cts FS) # = 0 is controller off
U#,V Version 2.XX
Set emission current (100 cts/mA) #1/3 are normal sensors, 2/4 gas sensors

W#,V Set output voltage 7 & 8 (# is 0/1) (V is counts, 0V = 32767)

Z#,V Simulate chan # on/off (1/0)

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7.8 Guardian Controller Communications Parameters

All Guardian controllers can communicate by RS-232. Versions 2.01 and later can also communicate by Ethernet.

To communicate by RS-232, set your communication program to:

Baud Rate:	115,200
Data Bits:	8
Parity:	None
Stop Bits:	1
Flow Control:	None

To communicate by Ethernet, connect to

Address:	192.168.1.200
Port:	23

The Ethernet connector on the Guardian controller has two status LEDs:

Top Left (yellow)	Link Status	Off: Link not detected On: Link detected
Top Right (green)	Data Status	Off: No data Blink: Data being transmitted or received

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Appendix

A. Material Optical Parameters

Note: Items in parenthesis indicate additional lines for a material (2), or lines that overlap other materials Au (Co).

Material	Symbol	Wave-length	½ Band width (Å)
Aluminum	Al	3961	12
Argon	Ar	4596	25
Barium	Ba	3072	40
Barium	Ba(2)	3500	30
Boron	B	2496	35
Cadmium	Cd	3261	18
Calcium	Ca	4226	15
Carbon Dioxide	CO_2	2890	25
Chromium	Cr	3605	15
Cobalt	Co/(Au)	2428	35
Copper	Cu	3247	20
Europium	Er	4008	20
Gallium	Ga	4170	30
Germanium	Ge/(Ta)	2650	32
Gold	Au	2676	15
Gold	Au(2)/(Co)	2428	35
Hafnium	Hf/(Zr)	2983	15
Helium	He	5016	25
Indium	In	4511	20
Iron	Fe	3720	18
Lanthanum	La/(Sm)	4422	20
Lead	Pb/(Ti)	3937	25
Manganese	Mn	2796	20
Molybdenum	Mo	3133	20

Material	Symbol	Wave-length	½ Band width (Å)
Nickel	Ni	3415	15
Niobium	Nb/(U238)	3582	20
Nitrogen	N_2	3914	25
Oxygen	O_2	2594	30
Palladium	Pd	2455	35
Platinum	Pt	2659	25
Rhenium	Re	2275	30
Samarium	Sm/(La)	4422	20
Scandium	Sc	4020	20
Silicon	Si	2520	45
Silver	Ag	3281	20
Strontium	Sr/(Ar)	4596	25
Tantalum	Ta/(Ge)	2650	32
Tin	Sn	3175	18
Titanium	Ti/(Pb)	3637	25
Titanium	Ti(2)	3982	25
Tungsten	W	2551	25
Uranium	U238/(Nb)	3582	20
Vanadium	V	3184	16
Water	H_2O	3100	40
Yttrium	Y	4077	20
Zinc	Zn	2025	50
Zirconium	Zr/(Hf)	2985	15

B. Material QCM Parameters

Material	Density	ZFactor
Aluminum	2.73	1.08
Aluminum Oxide	3.97	1
Antimony	6.62	0.768
Arsenic	5.73	0.966
Barium	3.5	2.1
Beryllium	1.85	0.543
Bismuth	9.8	0.79
Bismuth Oxide	8.9	1
Boron	2.54	0.389
Cadmium	8.64	0.682
Cadmium Selenium	5.81	1
Cadmium Sulfide	4.83	1.02
Cadmium Teluridium	5.85	0.98
Calcium	1.55	2.62
Calcium Fluoride	3.18	0.775
Carbon Diamond	3.52	0.22
Carbon Graphite	2.25	3.26
Cerium Fluoride	6.16	1
Cerium Oxide	7.13	1
Chromium	7.2	0.305
Chromium Oxide	5.21	1
Cobalt	8.71	0.343
Copper	8.93	0.437
Copper Sulfide	4.6	0.82
Copper Sulfide B	5.8	0.67
Copper Sulfide A	5.6	0.69
Dysprosium	8.54	0.6
Erbium	9.05	0.74
Gadolinium	7.89	0.67
Gallium	5.93	0.593
Gallium Arsenide	5.31	1.59
Germanium	5.35	0.516
Gold	19.3	.381
Hafnium	13.1	0.36
Hafnium Oxide	9.63	1
Holmium	8.8	0.58
Indium	7.3	0.841
Indium Intimnide	5.76	0.769
Indium Oxide	7.18	1
Iridium	22.4	0.129
Iron	7.86	0.349
Lanthanum	6.17	0.92
Lanthanum Fluoride	5.94	1
Lanthanum Oxide	6.51	1
Lead	11.3	1.13
Lead Sulfide	7.5	0.566
Lithium	0.53	5.9
Lithium Fluoride	2.64	0.774
Magnesium	1.74	1.61

Material	Density	ZFactor
Magnesium Fluoride	3	1
Manganese	7.2	0.377
Manganese Sulfide	3.99	0.94
Mercury	13.46	0.74
Molybdenum	10.2	0.257
Neodymium Fluoride	6.506	1
Neodymium Oxide	7.24	1
Nickel	8.91	0.331
Niobium	8.57	0.493
Niobium Oxide	4.47	1
Palladium	12	0.357
Platinum	21.4	0.245
Potassium Chloride	1.98	2.05
Rhenium	21.04	0.15
Rhodium	12.41	0.21
Samarium	7.54	0.89
Scandium	3	0.91
Selenium	4.82	0.864
Silicon	2.32	0.712
Silicon Dioxide	2.2	1.07
Silicon Oxide	2.13	0.87
Silver	10.5	0.529
Silver Bromide	6.47	1.18
Silver Chloride	5.56	1.32
Sodium	0.97	4.8
Sodium Chloride	2.17	1.57
Sulfur	2.07	2.29
Tantalum	16.6	0.262
Tantalum Oxide	8.2	0.3
Tellurium	6.25	0.9
Terbium	8.27	0.66
Thallium	11.85	1.55
Thorium Fluoride	6.32	1
Tin	7.3	0.724
Titanium	4.5	0.628
Titanium Oxide	4.9	1
Titanium Oxide IV	4.26	0.4
Tungsten	19.3	0.163
Tungsten Carbide	15.6	0.151
Uranium	18.7	0.238
Vanadium	5.96	0.53
Ytterbium	6.98	1.13
Yttrium	4.34	0.835
Yttrium Oxide	5.01	1
Zinc	7.04	0.514
Zinc Oxide	5.61	0.556
Zinc Selenide	5.26	0.722
Zinc Sulfide	4.09	0.775
Zirconium Oxide	5.6	1.001

C. 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."

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.

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.

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(A/s) above 0 is shown. Again, verify that the power supply output agrees with the 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.

Determine Open Loop Gain: Slowly adjust the control knob until the Rate(A/s) reading approximately matches your Initial Rate setting. Record the Power(%) reading as PWR_{DR} (power @ desired rate). Slowly lower the power until the Rate(A/s) reading is just at (or near) zero. Record the zero rate Power(%) reading as PWR_{0R}.

Determine Open Loop Response Time: Calculate 1/3 of your desired rate ($RATE_{1/3}$), and 2/3 of the desired rate ($RATE_{2/3}$) for this layer. Slowly increase the power until Rate(A/s) matches $RATE_{1/3}$. Get ready to record the loop's response to an input change. Quickly adjust Power(%) to PWR_{DR}. Measure the time for the Rate (A/s) reading to reach $RATE_{2/3}$. 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, $TIME_{SR}$. $TIME_{SR}$ is typically .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:

Set PID Values: In the Edit Process, Deposition tab set P=25, I= $TIME_{SR}$, D=0. Assure that all Conditioning values are set to zero. Save the values and close the Edit Process dialog box. Press Start Process and observe the Power graph. The power should rise from 0%, and stabilize near PWR_{DR} with little ringing or overshoot. If there is more than about 10% overshoot, lower the P Term. If the time to reach PWR_{DR} 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.

Set Preconditioning: The power level you recorded as PWR_{0R} is the power where deposition just begins. That's a good value for Ramp 1 power. PWR_{DR}, 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

D. Specifications

Sensor

Type	Single filament hot cathode or Dual filament gas compensating
Sensor Materials	304 SS, Tungsten, Ceramic
Filament Life (typical)	~1000 hours @ 1 x 10^{-5} Torr
Filament Material	Yttrium coated Iridium
Filament Current	2 to 4 amps
Emission Current	2 to 10 ma, programmable
Bias Voltage	180 Volts
Operating Pressure	<5 x 10^{-4} Torr
Operating/Bakeout Temperature	450º C maximum
Size	¾" x 1¼" x 1¾" (19 x 32 x 45 mm)
Mounting	2 ¾" CF (NW35CF) with sapphire viewport
Optical Path	Rigid SS tube from 7" to 16" (175 to 405mm) Optional fiber optic bundle
InVac Wiring	18 ga polyimid coated Copper Optional UHV compatible wiring
External Wiring	6 conductor, 16ga, 50' (15m) maximum

Detector

Photmultiplier Tube (PMT)	Hamamatsu R7518 or equivalent
Spectral Response	185 to 730 nm
Detection Limit	>5 fW of optical input power
PMT Gain	10^3 to 10^7, programmable
Resolution	20 bits
Mounting	1.035" x 40 threads per Compatible with Omega SM1 series
Filter Holder	1" (25mm) diameter x .2" (5mm) thick filters
Size	2" x 5½" x 2¾" (50 x 140 x 70 mm)
Weight	1.7 lbs (.8 kg)
Wiring	DB9 Male/Female, 50' (15m) maximum

Controller

Sensors	1, 2 optional
Detectors	8
Source Control Outputs	8 outputs, 0 to ±10 VDC programmable
Digital I/O	12 relays (30VDC, 3A), 12 inputs (5-12VDC)
Communications	RS-232 or Ethernet static IP address
Power	100-240 V~ ±10% nominal, 50/60Hz, 110W
Fuse	250V 1.6A T
Size	19” x 3 ½” x 12” (483 x 89 x 305 mm)
Weight	8.5 lbs (3.9 kg)
Computer	Windows 2000/XP/Vista, user supplied
Operating Environment	0°C to 40°C 0 to 80% RH non-condensing 0 to 2,000 meters Indoor Use Only Class 1 Equipment (Grounded Type) Suitable for Continuous Operation Ordinary Protection (not protected against harmful ingress of moisture) Pollution Degree 2 Installation (Overvoltage) Category II for transient overvoltages
Storage Environment	-40°C to 40°C

E. EC Declaration of Conformity

Manufacturer's Name: Sigma Instruments

Manufacturer's Address: 120 Commerce Drive, Unit 1

Fort Collins, CO 80524 USA

declares that the product:

Product Name: EIES Guardian

Product Model: EIES Guardian

Product Options: All Options

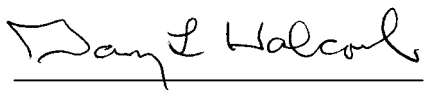
conforms to the following Directives:

73/23/EEC (93/68/EEC)	Low Voltage Directive
89/336/EEC	Electromagnetic Compatibility Directive

uses the following standards:

EN 61010-1	Safety of Electrical Equipment for Measurement, Control, and Laboratory Use
EN 55011	Radiated and Conducted Emissions, 2007 Class A, Group 1
EN 61326	EMC Requirements, 1997 Measurement, Control, and Laboratory Use A1: 1998 + A2: 2001 + A3: 2003 Part 1 - General Requirements

And complies with the Essential Health and Safety Requirements.



Gary L. Halcomb President

Fort Collins, Colorado, USA **May 2008**

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