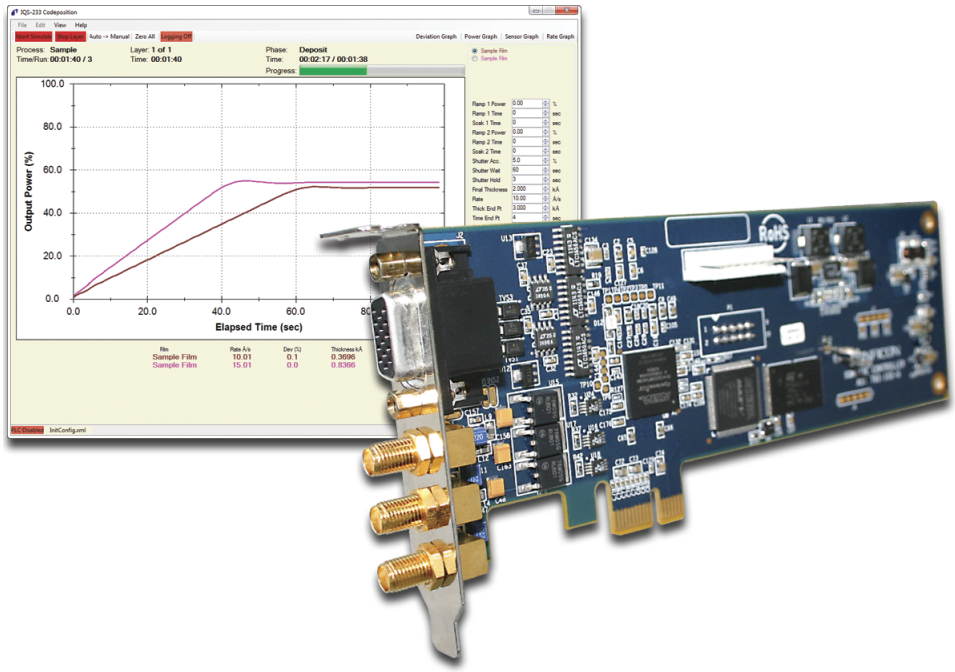
O P E R A T I N G M A N U A L



IQS-233™

Codeposition Software

IPN 074-585-P1A

INFICON

O P E R A T I N G M A N U A L

IQS-233™

Codeposition Software

IPN 074-585-P1A

INFICON Instruments for Intelligent Control®

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NOTE: These instructions do not provide for every contingency that may arise in connection with the installation, operation or maintenance of this equipment. Should you require further assistance, please contact INFICON.

Table Of Contents

IPN 074-585-P1A

IPN 074-585-P1A

IPN 074-585-P1A

IPN 074-585-P1A

Chapter 1
Introduction

1.1 Introduction

IQS-233 Codeposition software works with INFICON IQM-233 or SQM-242 cards to provide a powerful, Windows computer-based, thin film deposition controller. See Figure 1-1.

Figure 1-1 IQS-233 Codeposition software display

1.1.1 IQS-233 Codeposition Software Features

- Supports up to two IQM-233 cards
  - Measures up to six quartz crystal sensors simultaneously
  - Controls up to six deposition source power supplies simultaneously for codeposition.
- Supports up to two SQM-242 cards (SAM-242 card not supported)
  - Measures up to eight quartz crystal sensors simultaneously
  - Controls up to four deposition source power supplies simultaneously for codeposition
- Allows multi-layer processes
- Provides preconditioning, multiple rate ramps, and feed/idle phases
- Provides graphs of deposition rate, rate deviation, or power output
- Stores process, film and material parameters.
- Can be controlled remotely from another computer using the RS-232 or Ethernet command protocol
- Provides flexible and reliable digital I/O using an external Programmable Logic Controller (PLC)
  - Easy PLC integration for event selectable relay commands and shutter control

  NOTE: PLC is not provided by INFICON.

1.1.2 Hardware Supported by IQS-233 Codeposition Software

IQS-233 Codeposition software supports IQM-233 or SQM-242 cards (see Figure 1-2 and Figure 1-3). Up to two IQM-233 or up to two SQM-242 cards can be installed in the same computer with IQS-233 Codeposition software.

NOTE: If IQM-233 and SQM-242 cards are installed in the same computer, IQS-233 Codeposition software will automatically select IQM-233 card(s) and ignore SQM-242 card(s).

Refer to the IQM-233 or SQM-242 operating manuals for detailed information on installing and using IQM-233 and SQM-242 cards.

IPN 074-585-P1A

Figure 1-2 IQM-233 card

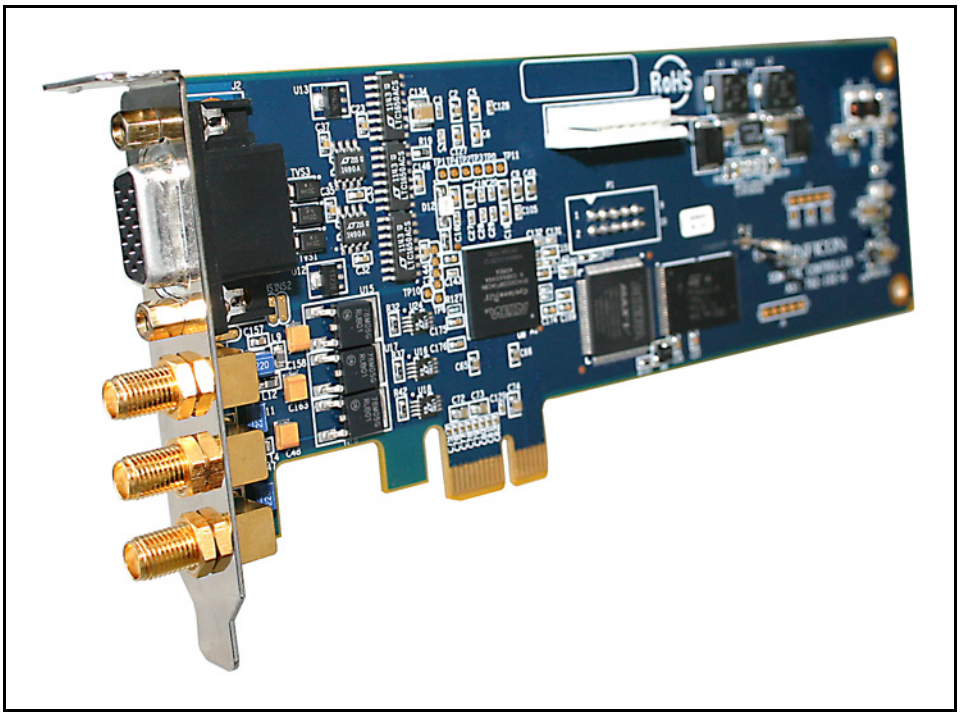
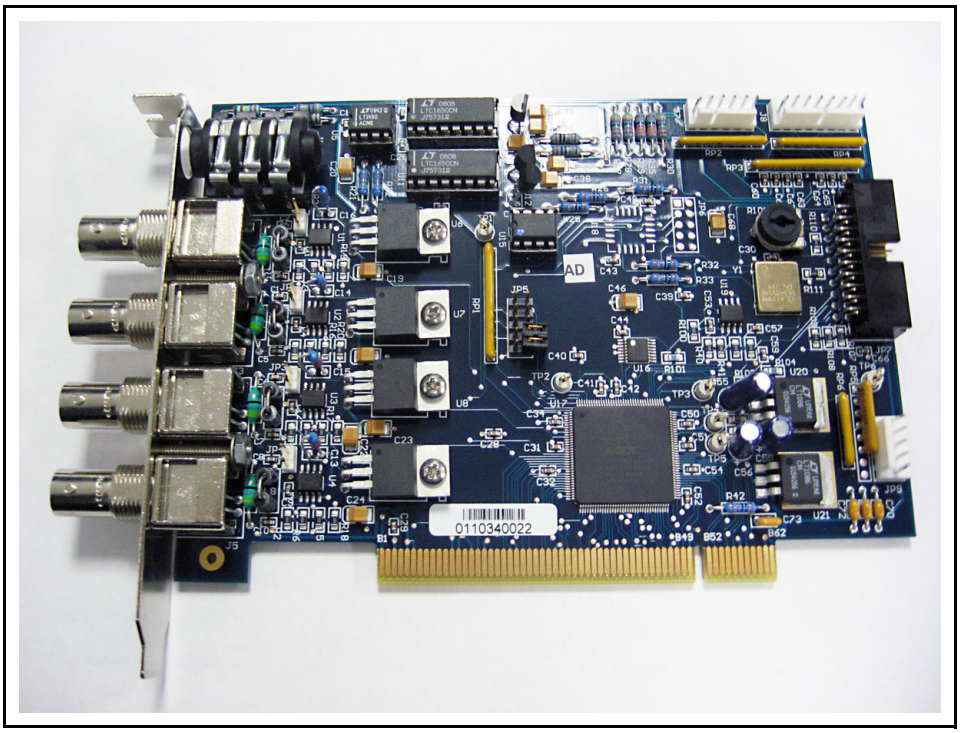


Figure 1-3 SQM-242 card



1.1.2.1 Digital I/O Capability

IQM-233 and SQM-242 cards do not provide the digital inputs and outputs needed to automatically control source and sensor shutters, rotate source pockets, etc. However, digital I/O capability can be added by interfacing an external, Programmable Logic Controller (PLC) with IQS-233 Codeposition software. The PLC is not provided by INFICON. See Chapter 3, Digital I/O.

1.1.3 Computer Requirements

Processor	1.5 GHz CPU minimum
RAM	2 GB RAM minimum
Memory	200 MB hard disk space minimum
Operating System	Windows XP SP3, Windows 7 32/64-bit, Windows 8 32/64-bit
Screen Resolution	800 x 600 minimum
Case (IQM-233 Card)	Standard or Small Form Factor
Case (SQM-242 Card)	Standard
Bus Interface (IQM-233 Card)	PCI Express x1, x4, x8, x16
Bus Interface (SQM-242 Card)	PCI
Communication Interface	RS-232C when interfacing an external PLC
RS-232C Baud Rate	4800, 9600, 19200, 38400, 57600, 115200

1.1.4 Related Operating Manuals

Operating manuals can be downloaded from www.inficon.com

074-584	IQM-233 Operating Manual
074-549	SQM-242 Operating Manual

IPN 074-585-P1A

1.2 How To Contact INFICON

Worldwide customer support information is available under **Contact >> Support Worldwide** at www.inficon.com:

- Sales and Customer Service
- Technical Support
- Repair Service

If you are experiencing a problem with your IQS-233 Codeposition software, please have the following information readily available:

- The Sales Order or PO number of the software purchase.
- The version of IQS-233 Codeposition software. See Figure 2-54 on page 2-72.
- The version of Windows operating system.
- A description of the problem.
- An explanation of any corrective action that you may have already attempted.
- The exact wording of any error messages that you may have received.

1.3 Software Specifications

1.3.1 Display

Graphs	Rate, Deviation (Rate %), Power (%), Sensors (Rate)
Readouts	Rate Å/s, Dev (%), Thickness kÅ, Power (%), Frequency (MHz), Life (%), Process name, Film name, Layer number, Phase, Process Time, Layer Time, Phase Time

1.3.2 Process Parameters

Processes	Unlimited number of processes
Process Name	15 characters maximum
Sensors	IQM-233: 1 to 6 (1 to 3 Dual) SQM-242: 1 to 8 (1 to 4 Dual)
Outputs	IQM-233: 1 to 6 SQM-242: 1 to 4
Layers	Unlimited number of layers
Film	Any defined film
Outputs	IQM-233: 1 to 6 SQM-242: 1 to 4

IPN 074-585-P1A

Input	Sensor(s), Timed Power
Setpoint Å/s	-999.90 to 999.90 Å/s
Setpoint % Pwr	0.00 to 100.00% Power
Final Thickness	0.000 to 999.900 kÅ
Thickness Endpoint	0.000 to 999.900 kÅ
Time Endpoint	0.00 to 30000.00 s
Start Mode	Manual Start, Auto Start, Skip Pre Cond
Source Indexers	IQM-233: 6 SQM-242: 4
Index Pockets	0 to 15
Timeout	0 to 3000 s
Substrate Indexer	1
Index Pockets	0 to 4
Timeout	0 to 3000 s
User Indexers	2
Index Pockets	0 to 15
Timeout	0 to 3000 s
Rate Ramps	Unlimited number of Rate Ramps
Start Thickness	0.000 to 999.900 kÅ
Ramp Time	0.00 to 30000 s
Setpoint Å/s	-999.90 to 999.90 Å/s
Setpoint % Pwr	0.00 to 100.00% Power

1.3.3 Film Parameters

Films	Unlimited number of films
Film Name	15 characters maximum
P Term	0 to 9999
I Term	0.0 to 999.9 s
D Term	0.00 to 99.90 s
Shutter Delay Accuracy	0.0 to 30.0%
Shutter Delay Wait	0.00 to 30000 s
Shutter Delay Hold	0.00 to 30000 s

IPN 074-585-P1A

Rate Sampling	Continuous, Accuracy Based, Time Based
Accuracy Based	0.00 to 100.00%
Time Based Sample	0.00 to 100.00 s
Time Based Hold	0.00 to 100.00 s
Ramp (1, 2) Power	0.00 to 100.00%
Ramp (1, 2) Time	0.00 to 30000 s
Soak (1, 2) Time	0.00 to 30000 s
Feed Power	0.00 to 100.0%
Feed Ramp Time	0.00 to 100 s
Feed Time	0.00 to 100 s
Idle Power	0.00 to 100.0%
Idle Ramp Time	0.00 to 100 s
Material	Any defined material
Max Power	0.00 to 100.00%
Slew Rate	0.0 to 100.0%
Sensor Tooling	IQM-233: 1 to 6, 0.0 to 999.0% SQM-242: 1 to 8, 0.0 to 999.0%
On Error	Ignore, Stop Layer, Timer Power
Control Error %	0 to 30%
Control Error sec	0 to 99 s
Crystal Fail Counts	0 to 99
Crystal Quality %	0 to 50%
Crystal Quality Counts	0 to 99
Crystal Stability Single	25 to 9999 Hz
Crystal Stability Total	25 to 9999 Hz

1.3.4 Material Parameters

Name	24 characters maximum
Density	0.40 to 99.99 g/cm^3
Z-Factor	0.100 to 9.999

IPN 074-585-P1A

1.3.5 System Parameters

Outputs	IQM-233: 1 to 6 SQM-242: 1 to 4
Full Scale Out	-10.0 to 10.0 V (dc)
Sensors	IQM-233: 1 to 6 (1 to 3 Dual) SQM-242: 1 to 8 (1 to 4 Dual)
Control	Rate, Thickness
Relays (PLC required)	16
Relay Events	Source Shutter (1 to 6), Source Active (1 to 6), Sensor Shutter (1 to 8), Process Stopped, Process Running, Layer Stopped, Layer Running, Deposit Phase, Pre-Cond Phase, Soak Hold Phase, Process Active, Manual Mode, Max Power, Time Setpoint, Thickness Setpoint, Final Thickness, All Crystals Good, All Crystals Fail
Inputs (PLC required)	12
Input Events	Start Process, Abort Process, Start Layer, Stop Layer, Next Layer, Force Final Thickness, Zero Thickness, Zero Time (NA), Soak 2 Hold, Soak 2 Release
Card Type	IQM-233, SQM-242
Period	0.10, 0.25, 0.50, 1.00, 2.00 s
Maximum Frequency	4.002000 to 6.100000 MHz
Initial Frequency	4.001000 to 6.099000 MHz
Minimum Frequency	4.000000 to 6.098000 MHz
Computer Interface	RS-232, Ethernet, Windows Communication Foundation
RS-232 Baud	4800, 9600, 19200, 38400, 57600, 115200
Filter Readings	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Last Output Displayed	1 to 6
Units	Thickness, Mass
Graph X Axis Width	0 to 100
Graph Y Axis Height	0 to 10000

IPN 074-585-P1A

1.3.6 Security

User Name . . . . . 10 characters maximum

Password . . . . . 10 characters maximum

Access Levels 3

IPN 074-585-P1A

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IPN 074-585-P1A

Chapter 2
IQS-233 Codeposition Software

2.1 Introduction

This chapter covers the installation and operation of IQS-233 Codeposition software. Refer to the IQM-233 or SQM-242 operating manual for installation instructions of an IQM-233 card or SQM-242 card.

2.2 Installing IQS-233 Codeposition Software

IQS-233 Codeposition software supports up to two IQM-233 cards or up to two SQM-242 cards.

CAUTION

If IQM-233 and SQM-242 cards are installed together in the same computer, IQS-233 Codeposition software will communicate with up to two IQM-233 cards and ignore the SQM-242 card(s).

IQM-233 card(s) must be removed to use IQS-233 Codeposition software with SQM-242 card(s).

The required Dynamic Link Library (DLL), device driver, and WinDriver are installed by the **IQM233 DLL** or the **SQM242 with IQM DLL** setup file. To install the DLL, device driver, and WinDriver, see section 2.2.1.

CAUTION

IQM233 DLL and SQM242 with IQM DLL cannot be installed together on the same computer.

NOTE: IQS-233 Codeposition software and the **IQM233 DLL** or **SQM242 with IQM DLL** may be installed before or after the installation of the IQM-233 or SQM-242 card(s). Refer to the IQM-233 or SQM-242 operating manual for card installation instructions.

IPN 074-585-P1A

2.2.1 Installing the DLL, Device Driver, and WinDriver

1. If the operating system is Windows 7 or 8, click **Start >> Control Panel >> System**. Note the operating system size (32-bit or 64-bit) displayed under **System type**.

   If the operating system is Windows XP, click **Start >> Settings >> Control Panel >> System >> System Properties >> General** tab. Determine the operating system size from the operating system name displayed under **System**:

   - Windows XP Home, Windows XP Media Center Edition, and Windows XP Professional are 32-bit operating systems.
   - Windows XP Professional x64 Edition is a 64-bit operating system.

   NOTE: The operating system size will generally match the performance capabilities of the computer processor. However, it is possible to have a 64-bit processor and a 32-bit operating system. In this case, the 64-bit installation is required.

2. Insert the **IQS-233 Codeposition Operating Manual CD** into the computer's CD drive.
3. Click **Windows Explorer** or **File Explorer >> Computer >> (CD drive letter:) IQS-233 >> IQM-233 Drivers**.
4. If IQS-233 Codeposition software is to be used with an IQM-233 card:

   - For a 32-bit operating system, double-click **IQM233 DLL x86 v x.x.x.x Setup.exe**
   - For a 64-bit operating system, double-click **IQM233 DLL x64 v x.x.x.x Setup.exe**

   If IQS-233 Codeposition software is to be used with an SQM-242 card:

   - For a 32-bit operating system, double-click **SQM242 with IQM DLL x86 v x.x.x.x Setup.exe**
   - For a 64-bit operating system, double-click **SQM242 with IQM DLL x64 v x.x.x.x Setup.exe**

IPN 074-585-P1A

CAUTION

IQM233 DLL and SQM242 DLL can be installed in the same computer.

However, when IQM-233 and SQM-242 cards are installed in the same computer, IQS-233 Codeposition software will interface only with IQM-233 card(s) and ignore the SQM-242 card(s).

IQM-233 card(s) must be removed for IQS-233 Codeposition software to communicate with SQM-242 card(s).

5 The **InstallShield Wizard** window will display.

6 Click **Next**.

7 Read the license agreement.

8 If it is acceptable, click **I accept the terms in the license agreement**.

9 Click **Next**.

10 Type the requested information into the **User Name** and **Organization** boxes.

11 Click **Next**.

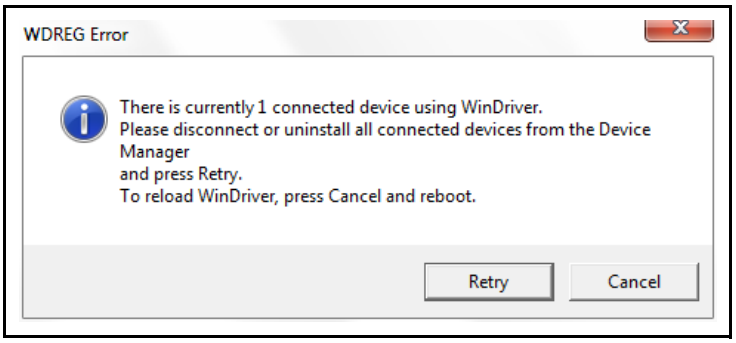
12 Click **Install** to start the installation of the device driver and the DLL.

13 When **Install Wizard Completed** is displayed, click **Finish** to close the InstallShield Wizard.

2.2.1.1 Troubleshooting the DLL Installation

If the **WDREG Error** window appears (see Figure 2-1), an existing version of WinDriver is preventing the installation of the DLL.

Figure 2-1 WDREG Error



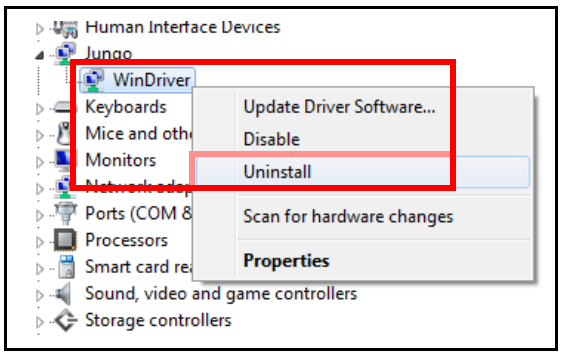
To remove the existing WinDriver and install the required WinDriver:

1 In **Windows Device Manager**, click the expansion button (▷) next to **Jungo** to display **WinDriver**. See Figure 2-2.

Figure 2-2 Jungo and WinDriver

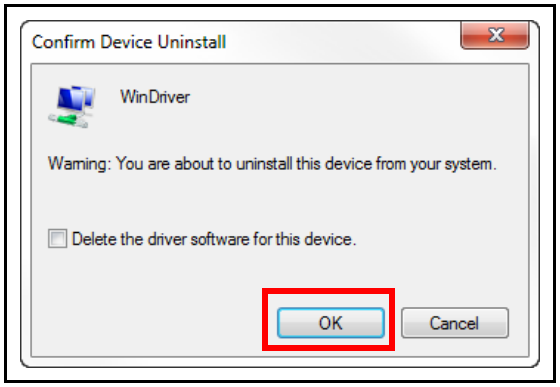
2 Right-click **WinDriver** and click **Uninstall**. See Figure 2-3.

Figure 2-3 Uninstall WinDriver



3 When the **Confirm Device Uninstall** window appears, click **OK** to uninstall WinDriver. See Figure 2-4.

Figure 2-4 Confirm Device Uninstall

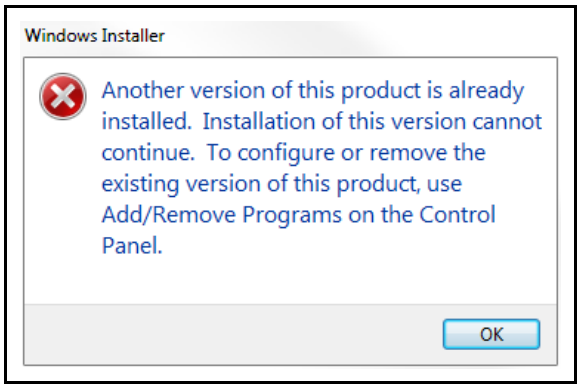


4 In the **WDREG Error** window, click **Retry** to continue with the DLL installation. Refer to Figure 2-1.

If the **Windows Installer** window appears (see Figure 2-5), another DLL (**IQM233 DLL** or **SQM242 with IQM DLL**) is already installed. **IQM233 DLL** and **SQM242 with IQM DLL** cannot be installed together on the same computer.

IPN 074-585-P1A

Figure 2-5 Windows Installer window



4a Click **OK** to keep the previously installed DLL, or

4b To remove the previously installed DLL and install a different DLL:

- ***4b1*** Click **OK** to close the Windows Installer window.
- ***4b2*** Click **Control Panel >> Programs** to display a list of installed programs.
- ***4b3*** Select the **IQM233 DLL** or the **SQM242 with IQM DLL** from the list.
- ***4b4*** Click **Uninstall** to remove the selected DLL.
- ***4b5*** Install the DLL again. Refer to section 2.2.1 on page 2-2.

IPN 074-585-P1A

2.2.2 Installing IQS-233 Codeposition Software

NOTE: To update an existing installation of IQS-233 Codeposition software to a newer version, see section 2.2.3.

1. Click **Windows Explorer** or **File Explorer >> Computer >> (CD drive letter:) IQS-233**.
2. Double-click **IQS-233 SETUP.EXE**.
3. The **InstallShield Wizard** will display.
4. Click **Next**.
5. Read the license agreement.
6. If it is acceptable, click **I accept the terms in the license agreement**.
7. Click **Next**.
8. Type the requested information into the **User Name** and **Organization** boxes.
9. Click **Next**.
10. Click **Install** to start the software installation.
11. When **Install Wizard Completed** is displayed, click **Finish** to close the **InstallShield Wizard** window.

2.2.3 Updating IQS-233 Codeposition Software

To update an existing installation of IQS-233 Codeposition software to a newer version:

1. Click **Control Panel >> Programs**.
2. If the IQS-233 Codeposition software was used with an IQM-233 card, select **IQM233 DLL x86** or **IQM233 DLL x64**.

   If the IQS-233 Codeposition software was used with an SQM-242 card, select **SQM242 with IQM DLL x86** or **SQM242 with IQM 233 DLL x64**.
3. Click **Uninstall** to remove **IQM233 DLL** or **SQM242 with IQM DLL**.
4. In **Programs**, select **IQS-233 Codeposition**.
5. Click **Uninstall** to remove the previous version of IQS-233 Codeposition software.
6. Install the latest version of IQM233 DLL or SQM242 with IQM DLL, as appropriate. Refer to section 2.2.1 on page 2-2.
7. Install the latest version of IQS-233 Codeposition software. Refer to section 2.2.2.

IPN 074-585-P1A

2.3 Using IQS-233 Codeposition Software

2.3.1 Starting IQS-233 Codeposition Software

2.3.1.1 Starting the Software in Windows XP or Windows 7

1. Click **Start >> All Programs >> INFICON >> IQS-233 Codeposition**.
2. The **User Login** window will display. See Figure 2-6.

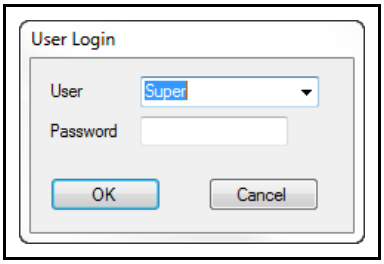
2.3.1.2 Starting the Software in Windows 8

1. In the **Start** window, click the **IQS-233 Codeposition** icon.
2. If the icon cannot be found:
   - **2a** Click **Search >> Apps**.
   - **2b** Type **IQS-233** in the **Search** text box.
   - **2c** Click the **IQS-233 Codeposition** icon.

2.3.2 Logging On to the Software

On the initial login, the **User Login** window will display **Super** as the default **User** name. See Figure 2-6.

Figure 2-6 User Login window



A **Password** is not required to log on to a user session with the default **User** name. Click **OK** to close the **User Login** window and display the **IQS-233 Codeposition** window. See Figure 2-7.

NOTE: If security settings are changed from the default values, a different **User** name and **Password** may be required. See section 2.3.3.7 on page 2-61.

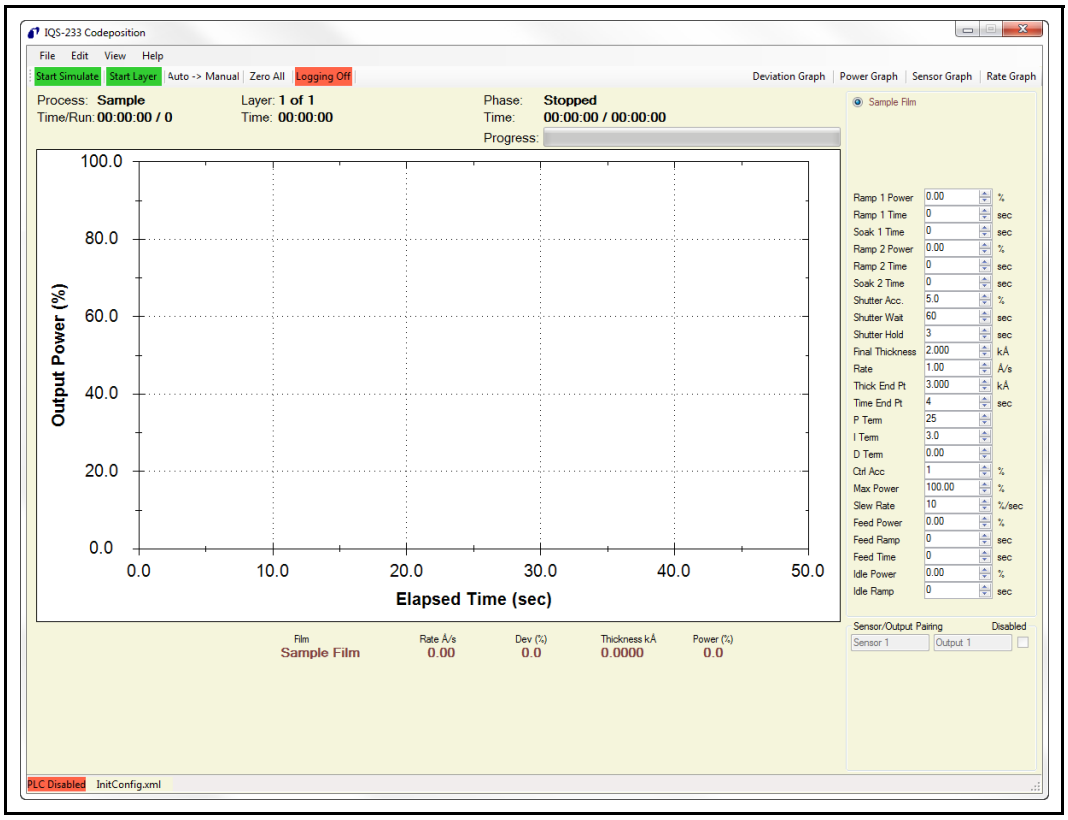
IPN 074-585-P1A

2.3.3 IQS-233 Codeposition Window

The **IQS-233 Codeposition** window displays readouts for Film, Rate, Deviation, Thickness and Power simultaneously for each active output. This window also provides Process, Layer, Phase, Run, and Time for each active output as well as customizable process parameters, graphical information, and access to File, Edit, View, and Help menus. See Figure 2-7.

NOTE: The Rate, Deviation, and Thickness readings displayed represent an average of the sensors assigned to each film.

Figure 2-7 IQS-233 Codeposition window



NOTE: To zoom in the graph pane, click in the graph pane on the IQS-233 Codeposition window and drag to draw a box over the data needing to be enlarged. To further zoom in, or to zoom out, rotate the wheel button up or down, respectively, with the pointer in the graph pane.

- **File**, see section 2.3.3.1
- **Edit**, see section 2.3.3.5 on page 2-17
- **View**, see section 2.3.4.1 on page 2-66
- **Help**, see section 2.3.5.1 on page 2-73

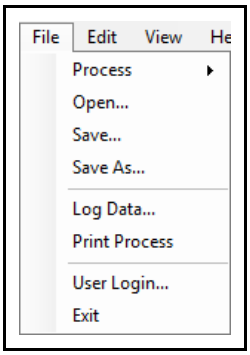
IPN 074-585-P1A

2.3.3.1 File

Click **File** to display the list of File commands. See Figure 2-8.

NOTE: File commands are not available once a process is started or while a process is running.

Figure 2-8 File commands



- **Process**, see section 2.3.3.1.1
- **Open**, see section 2.3.3.1.2 on page 2-11
- **Save**, see section 2.3.3.1.3 on page 2-12
- **Save As**, see section 2.3.3.1.4 on page 2-12
- **Log Data**, see section 2.3.3.1.5 on page 2-14
- **Print Process**, see section 2.3.3.2 on page 2-16
- **User Login**, see section 2.3.3.3 on page 2-16
- **Exit**, see section 2.3.3.4 on page 2-17

IPN 074-585-P1A

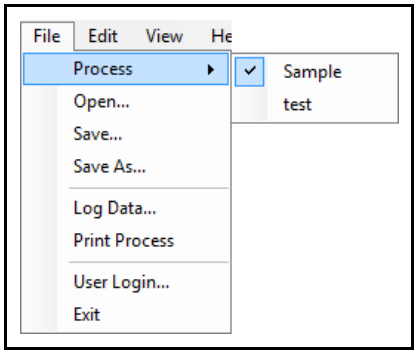
2.3.3.1.1 Process

Click **File >> Process** to display a list of saved process configurations (see Figure 2-9). A check mark next to the current process name indicates that the process configuration has been loaded for that process name.

NOTE: The current process name is also displayed in the **IQS-233 Codeposition** window (refer to Figure 2-7 on page 2-8).

The process configuration consists of all of the parameters in the **Process** window (see Figure 2-16 on page 2-18). System and security parameters are not included in the process configuration. System parameters are contained in the .xml configuration file. A different set of system parameters can be selected by loading a previously saved configuration file (see section 2.3.3.1.2).

Figure 2-9 Process list



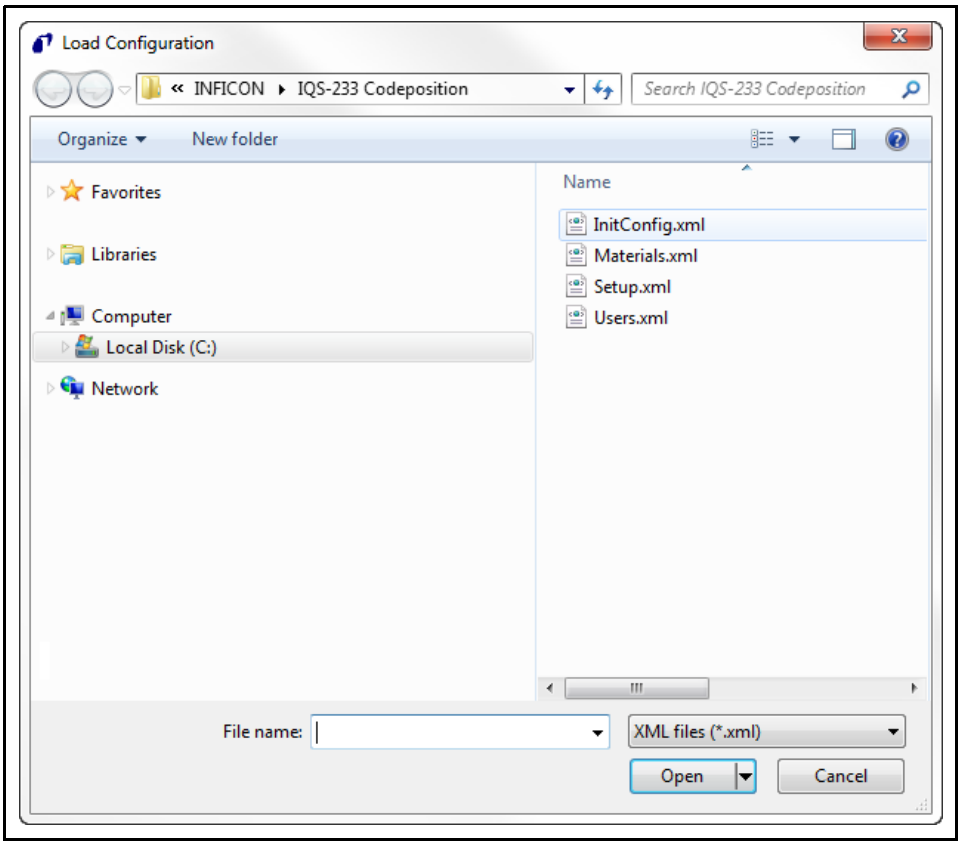
IPN 074-585-P1A

2.3.3.1.2 Open

Click **File >> Open** to display the **Load Configuration** window (see Figure 2-10) where a previously saved configuration file containing a set of parameters used for a previous deposition can be selected and loaded.

Configuration files are in .xml format. **InitConfig.xml** is loaded when IQS-233 Codeposition software is started. Once the software is running, a different configuration file can be selected and loaded. Another process can be selected without altering the system parameters loaded by the configuration file (refer to section 2.3.3.1.1).

Figure 2-10 Load Configuration window



CAUTION

Do not delete or alter the InitConfig.xml, Materials.xml, Setup.xml, or Users.xml files located in the C:\ProgramData\INFICON\IQS-233 Codeposition folder.

Do not move these files to another folder.

2.3.3.1.3 Save

Click **File >> Save** to save the current Process and System parameter values to the configuration filename displayed in the message pane on the IQS-233 Codeposition window.

If the default configuration filename, InitConfig.xml, is displayed, the default parameters loaded when IQS-233 Codeposition software is started will be overwritten by any changes made to the Process and System parameters.

2.3.3.1.4 Save As

Click **File >> Save As** to save the current Process and System configuration under a different name. Configuration files are saved in .xml format. The default folder for saving a configuration file is **C:\ProgramData\INFICON\IQS-233 Codeposition**; however, the configuration file may be saved to another folder location if desired (see Figure 2-11).

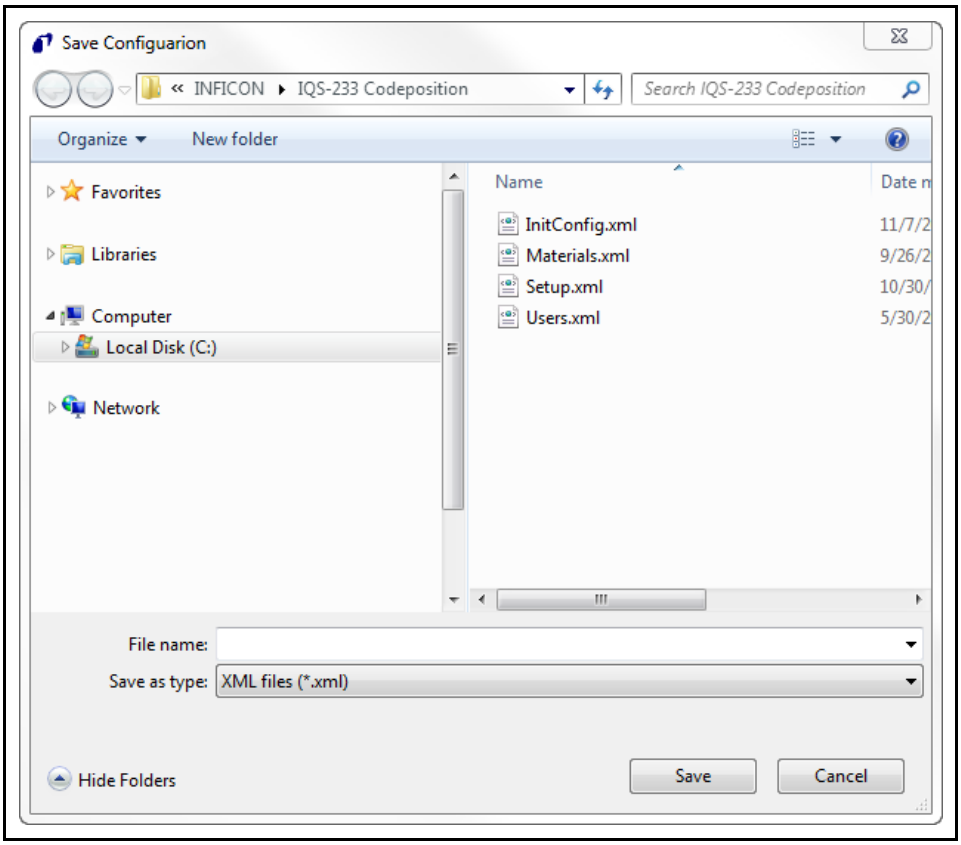
CAUTION

Do not delete or alter the InitConfig.xml, Materials.xml, Setup.xml, and Users.xml files located in the C:\ProgramData\INFICON\IQS-233 Codeposition folder.

Do not move these files to another folder.

IPN 074-585-P1A

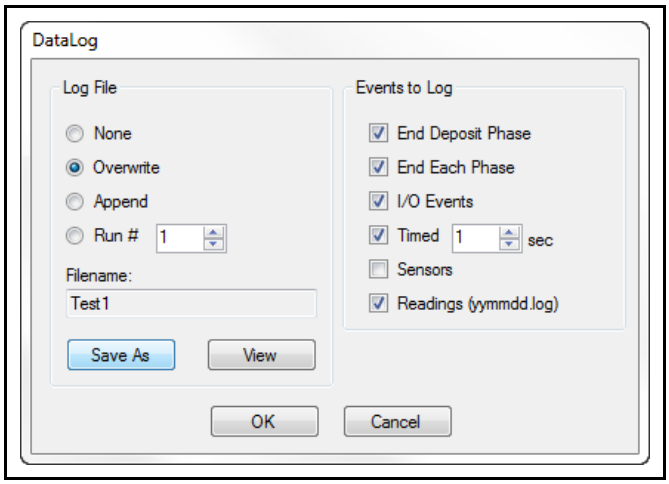
Figure 2-11 Save Configuration window



2.3.3.1.5 Log Data

Click **File >> Log Data** to display the **DataLog** window where data log preferences can be configured and saved to a .csv format data log file (see Figure 2-12).

Figure 2-12 DataLog window



When data logging is activated, data is recorded for the following parameters:

- Process Name
- Run Number
- Date Time
- Event
- Layer
- Process Time
- Layer Time
- Deposit Time
- Output Number
- Film
- Thickness
- Rate
- Rate Deviation
- Power
- Sensor Number
- Sensor Rate
- Sensor Thickness
- Frequency

NOTE: The parameters recorded in the data log file depend on the parameter selections in the **Events to Log** pane of the **DataLog** window.

IPN 074-585-P1A

Log File pane

None . . . . . Data logging is unavailable.

Filename . . . . . Displays the name of the file to which process data will be saved.

Overwrite . . . . . Each process run is saved to the file name displayed in the Filename box.

NOTE: Subsequent process runs will overwrite previous data in this file.

Append . . . . . Data logged for the current process run is added on to the end of any previously logged data in the file displayed in the Filename box.

Run # . . . . . Each process run is saved as a separate file with the format filename_#.csv, where # is a number that increments with each new run.

Save As . . . . . Displays the Save As window, where process data can be saved as a .csv format file. The name of this file will be displayed in the Filename box.

View . . . . . Displays the default Log folder where data log files are stored. Click a data log file to display a preview of the file contents or double-click the file to open it in Microsoft® Excel®.

IPN 074-585-P1A

Events to Log pane

End Deposit Phase . . . . . Data is recorded at the end of each layer's deposit phase.

End Each Phase . . . . . Data is recorded at the end of all phases.

I/O Events . . . . . Data is recorded each time an external digital input or output changes state.

Timed . . . . . Data is recorded at the selected time interval.

Sensors . . . . . Data is recorded for individual sensors in addition to the normally recorded data.

Readings (yymmdd.log) . . . . . When the Readings check box is selected, the following data from individual sensors is recorded and saved in a separate file: Timer, Run Time, Sensor #, Rate, Thickness, and Frequency. The file is saved in the format of yymmdd.csv (for example, data saved on January 15, 2014 will be saved to a file named 140115.csv).

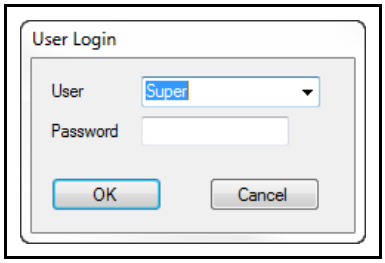
2.3.3.2 Print Process

Click **File >> Print Process** to print the configuration parameters for the current Process to the default printer.

2.3.3.3 User Login

Click **File >> User Login** to display the **User Login** window (see Figure 2-13) allowing a different user to log on to IQS-233 Codepostion software. When a different **User** name and its associated **Password** are entered, the current session is ended and the security access levels change to that of the new user. See section 2.3.3.7 on page 2-61 for more information.

Figure 2-13 User Login window

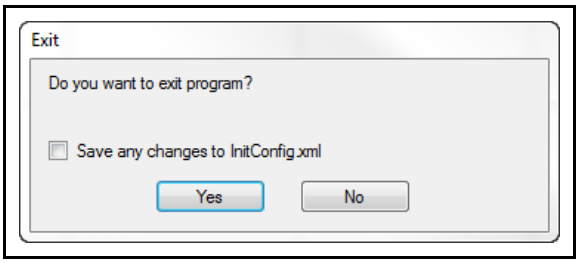


IPN 074-585-P1A

2.3.3.4 Exit

Click **File >> Exit** to display the **Exit** window (see Figure 2-14). When exiting the software, changes made to the current Process, Film, and System parameters can be saved to the configuration filename displayed in the **Exit** window by selecting the **Save any changes to (name).xml** check box and clicking **Yes**. Refer to section 2.3.3.1.4 on page 2-12 to save parameter changes to a different configuration filename.

Figure 2-14 Exit window

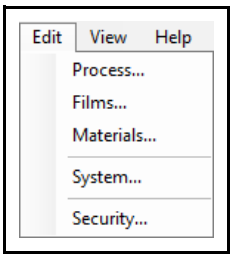


2.3.3.5 Edit

Click **Edit** to display the list of Edit commands. See Figure 2-15.

NOTE: The Edit commands are not available once a process is started or while a process is running.

Figure 2-15 Edit items list



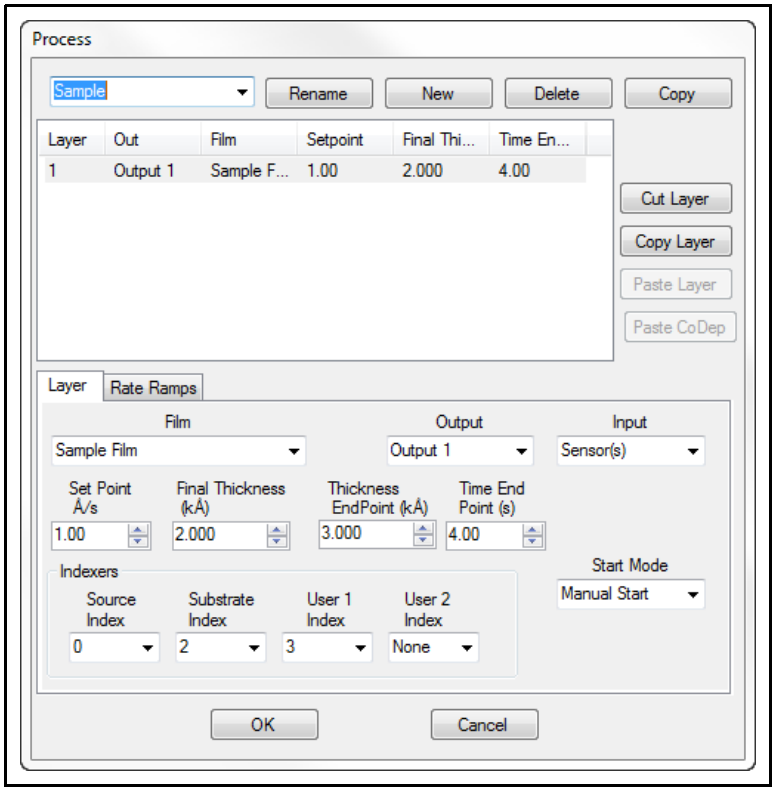
- **Process**, see section 2.3.3.5.1
- **Films**, see section 2.3.3.5.6 on page 2-28
- **Materials**, see section 2.3.3.5.12 on page 2-42
- **System**, see section 2.3.3.6 on page 2-44
- **Security**, see section 2.3.3.7 on page 2-61

IPN 074-585-P1A

2.3.3.5.1 Process

Click **Edit >> Process** to display the **Process** window. The **Process** window provides the commands needed to develop a thin film deposition process consisting of one or more Layers. See Figure 2-16.

Figure 2-16 Process window



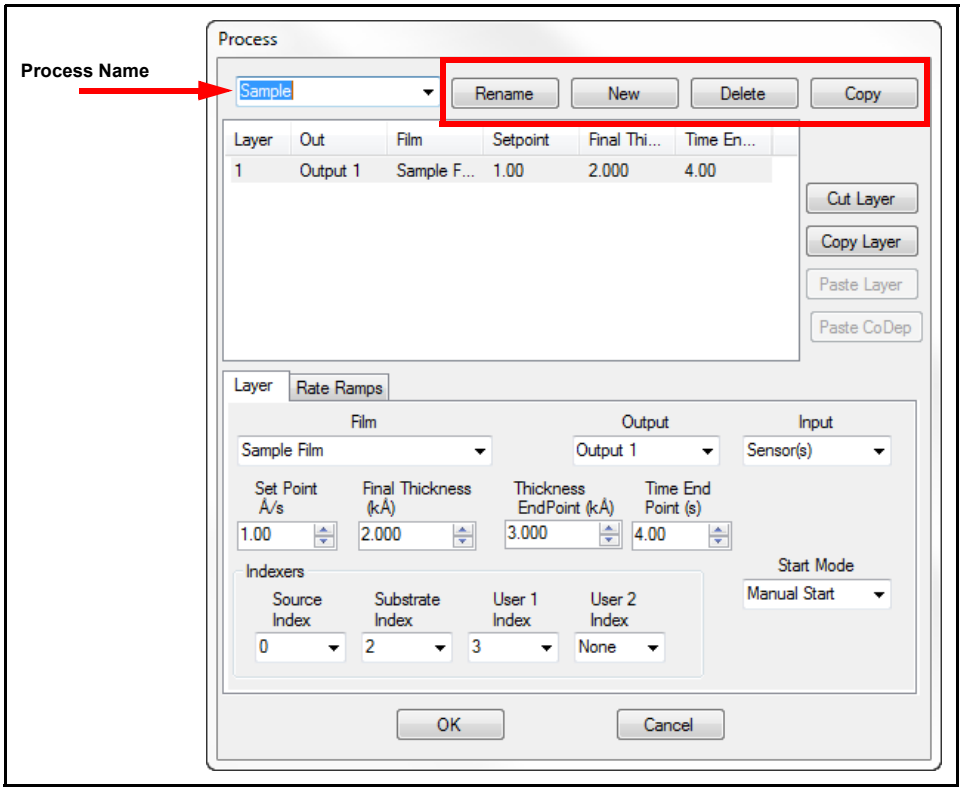
- **Process** name and edit commands, see section 2.3.3.5.2
- **Layer** tab, see section 2.3.3.5.4 on page 2-23
- **Rate Ramps** tab, see section 2.3.3.5.5 on page 2-26

IPN 074-585-P1A

2.3.3.5.2 Process Name and Edit Commands

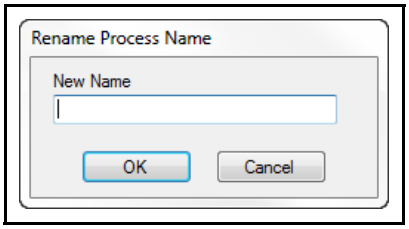
Process name box . . . . . Select a name from a list of previously saved Process names to load the configuration for that Process. See Figure 2-17.

Figure 2-17 Process window - Process name and edit commands



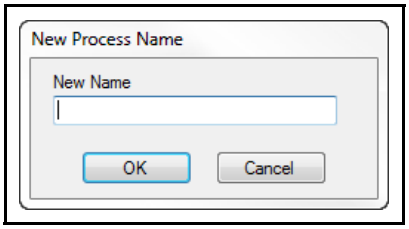
Rename . . . . . Displays the Rename Process Name window where the name of the current Process can be changed. The original Process name is replaced. See Figure 2-18.

Figure 2-18 Rename Process Name window



New . . . . . Displays the New Process Name window where the name for a new Process configuration can be entered. When the New Process Name window is closed (by clicking OK), the name for the new Process is displayed in the Process name box and the default Process configuration is displayed. The original Process name is not deleted. See Figure 2-19.

Figure 2-19 New Process Name window



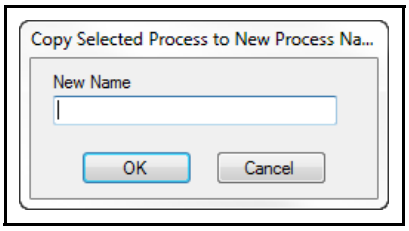
Delete . . . . . Deletes the current Process configuration from the database of Process configurations.

CAUTION

Delete cannot be undone.

Copy . . . . . Displays the Copy Selected Process to New Process Name window where a duplicate of the current Process configuration can be named and saved. See Figure 2-20.

Figure 2-20 Copy Selected Process to New Process Name window

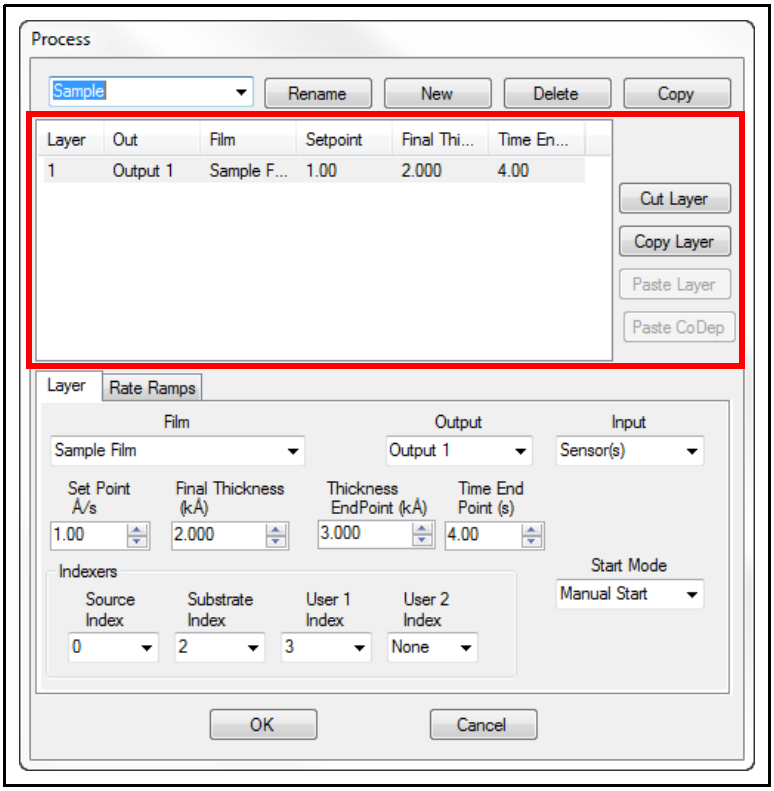


IPN 074-585-P1A

2.3.3.5.3 Layer Information and Edit Commands

A Process consists of the Layer(s) displayed in the **Layer** information pane (see Figure 2-21). A Layer consists of the parameters configured in the **Layer** tab (see Figure 2-22 on page 2-23) and **Rate Ramps** tab (see Figure 2-23 on page 2-26).

Figure 2-21 Process window - Layer information and edit commands



Layer . . . . . Click the number of the desired Layer to display the parameters in the Layer and Rate Ramps tabs pertaining to that Layer.

NOTE: All related Codeposition Layers have the same Layer number, but each Codeposition Layer must use a different Output.

Out . . . . . The name of the source Output mapped to a physical source output connection on the IQM-233 or SQM-242 card. Refer to the IQM-233 or SQM-242 operating manual for information about the source output connection. The Output name is selected in the Layer tab (see Figure 2-22 on page 2-23). The relationship between the Output name and the physical output connection on the IQM-233 or SQM-242 card is configured in the Outputs tab of the System Setup window (see Figure 2-37 on page 2-45).

Film . . . . . The Film name selected in the Layer tab.

Setpoint . . . . . The Setpoint value selected in the Layer tab.

Final Thickness . . . . . The Final Thickness value selected in the Layer tab.

Time Endpoint . . . . . The Time Endpoint value selected in the Layer tab.

Cut Layer . . . . . Deletes the selected Layer from the Layer information pane and moves that Layer to the Clipboard.

Copy Layer . . . . . Copies the selected Layer to the Clipboard.

Paste Layer . . . . . Inserts a Layer from the Clipboard directly below the selected Layer. The Layer number increments for each new Layer. Any Layers below the selected Layer are shifted downward and their Layer numbers are incremented accordingly. Click Paste repeatedly to insert multiple Layers. The parameters for the new Layer(s) in the Layer and Rate Ramps tabs can then be changed as needed.

Paste CoDep . . . . . Pastes a Layer from the Clipboard directly below a selected Layer. The selected Layer and pasted Layer will become Codeposition Layers with the same Layer number. Any Layers below the pasted Layer will be shifted downward and their Layer numbers incremented accordingly.

To create Codeposition Layers

1. Click an existing Layer and click **Copy Layer**.
2. Change the **Output** in the **Layer** tab (see Figure 2-22) of the existing layer.
3. Click **Paste CoDep** to paste the cut Layer directly below the selected Layer. The Codeposition Layers will have the same Layer number.

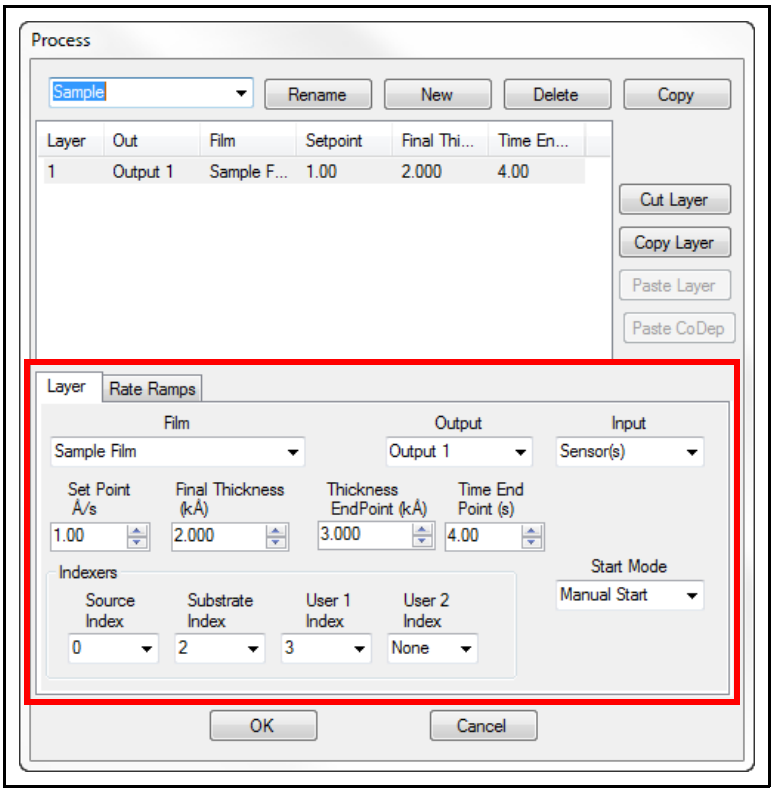
NOTE: Each Codeposition Layer must use a different Output.

IPN 074-585-P1A

2.3.3.5.4 Layer Tab

The **Layer** tab (see Figure 2-22), used to configure a Layer, consists of the following parameters:

Figure 2-22 Process window - Layer tab



Film . . . . . Select the Film name to be used for the selected Layer. A Film consists of the parameters configured in the Film Edit window (see Figure 2-24 on page 2-28).

Output . . . . . Select the name of the source Output to be used for the selected Layer. The relationship between the Output name and the physical output connection on the IQM-233 or SQM-242 card is configured in the Outputs tab of the System Setup window (see Figure 2-36 on page 2-44). Refer to the IQM-233 or SQM-242 operating manual for information about the physical source output connection.

Input. . . . . Sensor(s), Timed Power

The Input selection determines the control method used during the deposition phase.

Sensor(s):

Setpoint Å/s . . . . . -999.90 to 999.90 Å/s

When Sensor(s) is selected, the Setpoint (Å/s) box is displayed where a value for the deposition rate (or the initial deposition rate if rate ramps are used) is selected.

Timed Power:

Setpoint % Pwr . . . . . 0.00 to 100.00%

When Timed Power is selected, the Setpoint % Pwr box is displayed where a value equal to a percentage of the full scale source Output voltage is selected. The source Output Power will remain at this constant level during the deposition phase. The deposition phase ends when the Final Thickness value is reached, or the Time Endpoint value is reached, whichever occurs first.

Final Thickness (kÅ) . . . . . 0.000 to 999.900 kÅ

When this value is reached, deposition ends and the postcondition phases start. The postcondition phases are configured in the Condition tab of the Film Edit window (see Figure 2-30 on page 2-34).

Thickness Endpoint (kÅ) . . 0.000 to 999.900 kÅ

When this value is reached, the Thickness Setpoint relay will be activated if selected in the I/O tab of the System Setup window. See Figure 2-40 on page 2-52.

NOTE: The IQM-232 and SQM-242 cards do not contain relays. A PLC is required to provide the relays. See Chapter 3, Digital I/O.

Time Endpoint (s) . . . . . 0.00 to 30000.00 s

When this value is reached, the Time Setpoint relay will be activated if selected in the I/O tab of the System Setup window.

NOTE: IQM-232 and SQM-242 cards do not contain relays. A PLC is required to provide the relays. See Chapter 3, Digital I/O.

Start Mode . . . . . Manual Start, Auto Start, Skip Pre Cond, Continuous

IPN 074-585-P1A

Manual Start . . . . . The previous layer ends at its idle power. In the IQS-233 Codeposition window, click Start Layer to start the next Layer.

Auto Start . . . . . Starts the next Layer automatically upon completion of the previous Layer.

Skip Pre Cond . . . . . Skips the precondition phases.

NOTE: The **Start Mode** selection must be the same for all related Codeposition Layers.

Indexers pane

NOTE: A Programmable Logic Controller (PLC) is required to provide the relays needed for control of an Indexer. See Chapter 3, Digital I/O.

Source Index. . . . . None, 0 to 15

The Source Indexer pocket used by the selected Layer. This value is sent to the PLC at the start of the Layer.

Substrate Index . . . . . None, 0 to 4

The Substrate Indexer pocket used by the selected Layer. This value is sent to the PLC at the start of the Layer.

User 1 Index . . . . . None, 0 to 15

The index value used by the selected Layer. This value is sent to the PLC at the start of the Layer for use as needed. A common application is to select external equipment configurations.

User 2 Index . . . . . None, 0 to 15

The index value used by the selected Layer. This value is sent to the PLC at the start of the Layer for use as needed. A common application is to select external equipment configurations.

NOTE: To change the name of the User 1 and User 2 Index as it appears in IQS-233 Codeposition software, open the InitConfig.xml file located at C:\ProgramData\INFICON\IQS-233, and change the name of the indexer in quotation marks located on lines 23 and 24 of the document. Save the document.

```
<LayerIdx Name="User 1" Timeout="30" Done="False" End="15" Start="0">2</LayerIdx>
<LayerIdx Name="User 2" Timeout="30" Done="false" End="15" Start="0">3</LayerIdx>
```

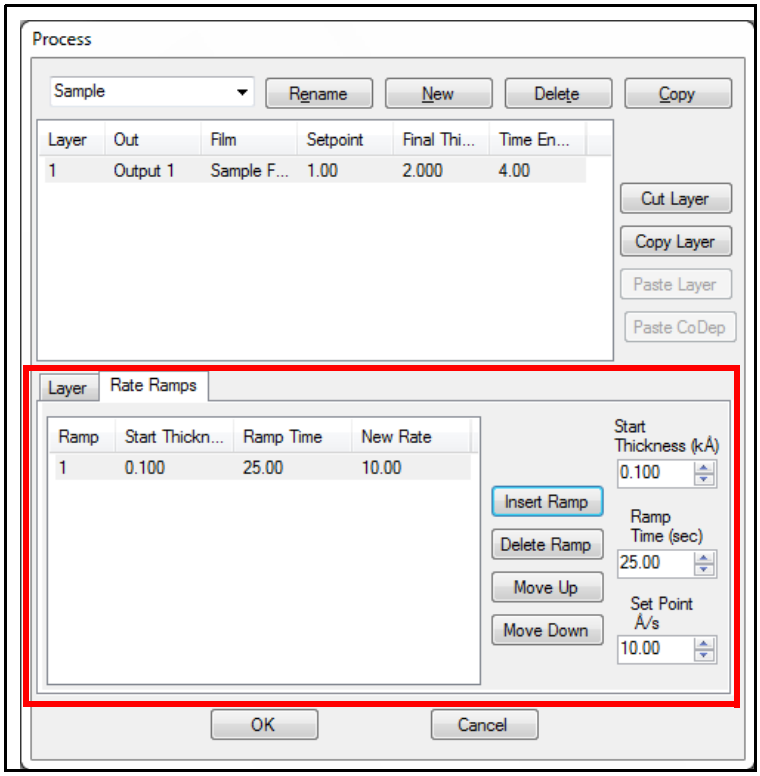
Do not change any other portion of the document. Doing so may cause IQS-233 Codeposition software not to operate properly.

IPN 074-585-P1A

2.3.3.5.5 Rate Ramps Tab

Click the **Rate Ramps** tab to display the Rate Ramp parameters (see Figure 2-23). Rate Ramps allow for more than one deposition rate during the deposition phase. Each Layer of a Process can have an unlimited number of Rate Ramps. Each Rate Ramp consists of a Start Thickness value that initiates ramping to the Setpoint value of a new rate, and a Ramp Time value for the time required to ramp to the new rate Setpoint value.

Figure 2-23 Process window - Rate Ramps tab



Start Thickness (kÅ) . . . . . 0.000 to 999.900 kÅ

The value that, when reached, initiates a timed ramp to a new rate. The Start Thickness value should be greater for each subsequent ramp and less than the Final Thickness of the Layer; otherwise, the Rate Ramp is ignored.

Ramp Time (sec). . . . . 0.00 to 30000 s

The time in seconds required to achieve the new rate Setpoint value.

Setpoint (Å/s) . . . . . -999.90 to 999.90 Å/s

Setpoint (Å/s) is displayed instead of Setpoint % Pwr when Sensor(s) is selected in the Input box on the Layer tab. Setpoint (Å/s) is the value of a new rate.

IPN 074-585-P1A

Setpoint % Pwr . . . . . 0.00 to 100.00%

Setpoint % Pwr is displayed instead of Setpoint (Å/s) when Timed Power is selected in the Input box of the Layer tab. Setpoint % Pwr is the value of constant Output Power used until the next Rate Ramp is initiated or Final Thickness is reached. This value is equal to a percentage of the full scale source Output voltage.

Insert Ramp . . . . . Inserts a new rate ramp configuration for the selected Layer, at the selected position in the rate ramps list. Existing rate ramps are shifted downward.

Delete Ramp . . . . . Deletes the selected rate ramp.

Move Up . . . . . Shifts the selected rate ramp up one position.

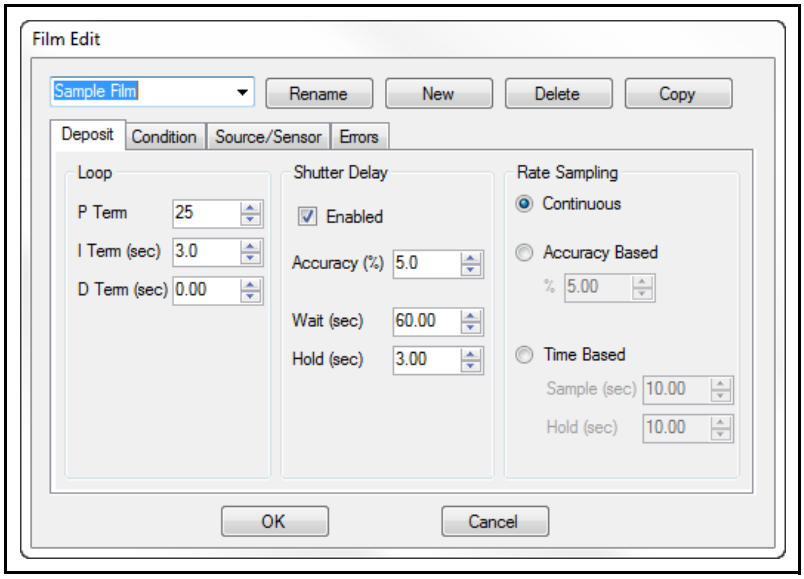
Move Down . . . . . Shifts the selected rate ramp down one position.

IPN 074-585-P1A

2.3.3.5.6 Films

Click **Edit >> Films** to display the **Film Edit** window where the configuration for a new Film can be created and an existing Film can be renamed, copied, or deleted. See Figure 2-24.

Figure 2-24 Film Edit window

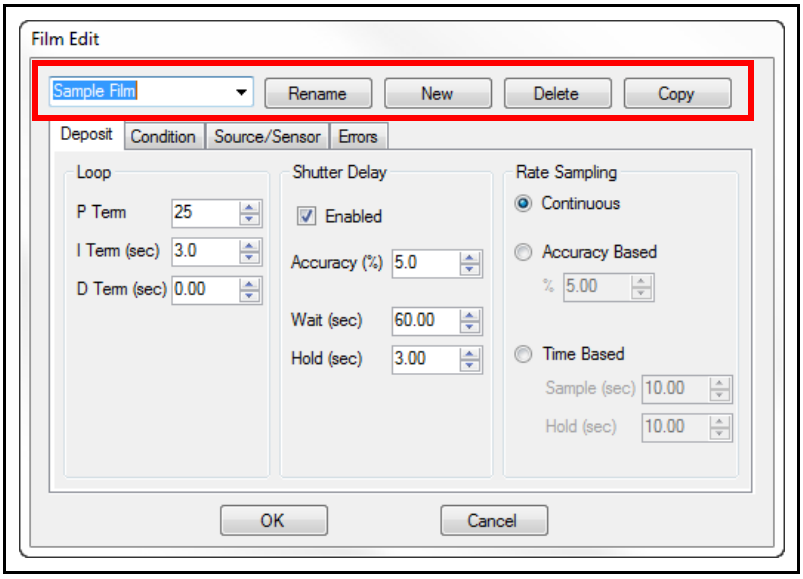


- **Edit commands**, see section 2.3.3.5.7
- **Deposit tab**, see section 2.3.3.5.8 on page 2-31
- **Condition tab**, see section 2.3.3.5.9 on page 2-34
- **Source/Sensor tab**, see section 2.3.3.5.10 on page 2-36
- **Errors tab**, see section 2.3.3.5.11 on page 2-37

IPN 074-585-P1A

2.3.3.5.7 Edit Commands

Figure 2-25 Film Edit window - edit commands

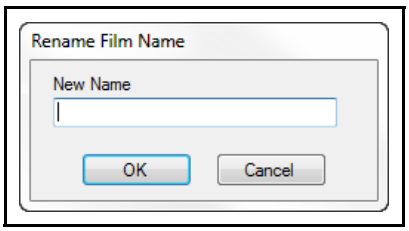


NOTE: Edits to a Film will affect any Process with Layers using that Film.

Film box . . . . . Displays a list of previously saved Film names. Select a name from the list to display the parameters for that Film in the Deposit, Condition, Source/Sensor, and Errors tabs.

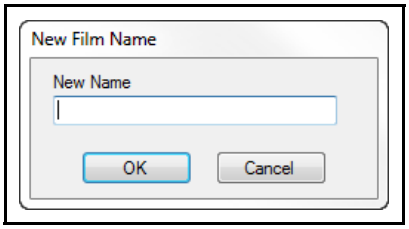
Rename . . . . . Displays the Rename Film Name window where a new name for the current Film name can be entered (see Figure 2-26). The original Film name is replaced.

Figure 2-26 Rename Film Name window



New . . . . . Displays the New Film Name window where a name for a new set of Film parameters can be entered. When a new name is entered and the New Film Name window is closed by clicking OK, the new name is displayed in the Film box and the default Process configuration is displayed in the Deposit, Condition, Source/Sensor, and Errors tabs. These Film parameters can then be changed as needed and saved under the new name. The original Film name is not deleted from the list of Film names. See Figure 2-27.

Figure 2-27 New Film Name window



Delete . . . . . Deletes the currently displayed Film name from the list of Film names.

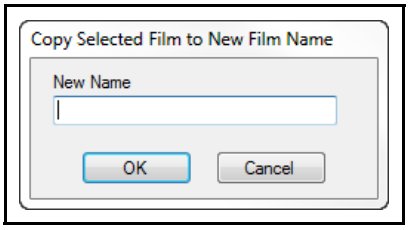
NOTE: If the Film to be deleted is used in a Process, a message will display the name of any Process where the Film is used. The Film must be deleted from any Process where the Film is used before the Film can be deleted from the list of Film names.

CAUTION

Delete cannot be undone.

Copy . . . . . Displays the **Copy Selected Film to New Film Name** window where a duplicate of the currently displayed Film parameters can be named and saved. See Figure 2-28.

Figure 2-28 Copy Selected Film to New Film Name window

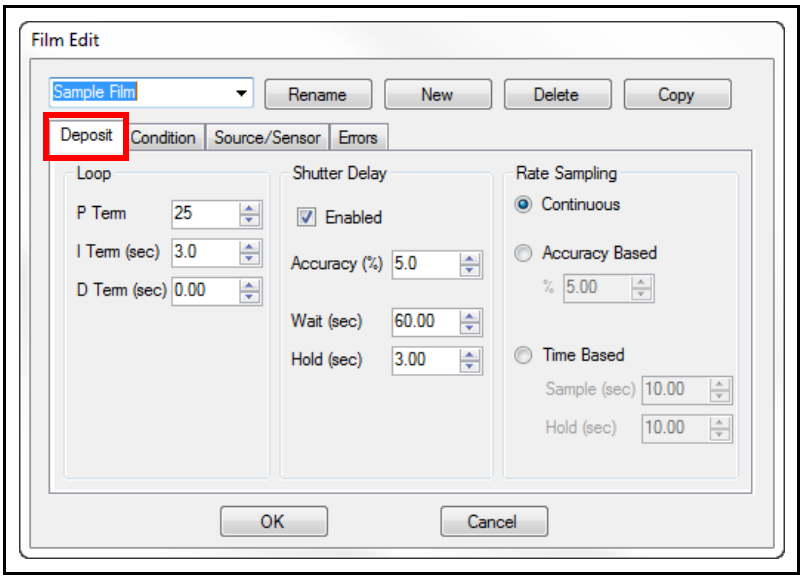


IPN 074-585-P1A

2.3.3.5.8 Deposit Tab

PID loop control, Shutter Delay, and Rate Sampling are configured in the Deposit tab. See Figure 2-29.

Figure 2-29 Film Edit window - Deposit tab



Loop pane

P Term . . . . . 0 to 9999

P is the proportional term that sets the gain of the control loop. A value of 0 makes this command unavailable. Enter a higher gain for a faster responding (but potentially unstable) control loop, and a lower gain for a slower responding control loop. Enter a value of 25, and then gradually increase or decrease the value to respond as desired to rate step changes.

I Term (sec) . . . . . 0.0 to 999.9 s

I is the integral term that controls the time constant of the loop. A value of 0 makes this command unavailable. Enter a small I Term, such as 0.5 to 1 second, to smooth the response and minimize overshoot to rate step changes.

D Term (sec) . . . . . 0.00 to 99.90 s

D is the derivative term that determines how quickly the control loop responds to changes. A value of 0 makes this command unavailable. Enter 0 or a very small value to avoid rate oscillations, especially with fast sources, such as electron beam guns. Slow sources, such as resistively heated sources, may require a large D value.

NOTE: For detailed information about determining the PID values, see section 4.5, Tuning the Control Loop, on page 4-5.

Shutter Delay pane

Shutter Delay allows a stable rate to be achieved before the source shutter opens exposing the substrate to the deposition source.

Enabled . . . . . Select the check box to active Shutter Delay.

Accuracy (%) . . . . . 0.0 to 30.0 %

A percentage of the desired deposition rate that must be reached within a specified time period (Wait) and not exceeded for a specified time period (Hold). If the Accuracy (%) value is not achieved within the Wait time, or is exceeded before the Hold time elapses, the layer is halted and the message Failed to reach and hold n% control during shutter delay time on (name) film is displayed.

Wait (sec) . . . . . 0.00 to 30000.00 s

Maximum time allowed to achieve the Accuracy (%) value.

Hold (sec) . . . . . 0.00 to 30000.00 s

Time period that must elapse without the percentage of desired rate being exceeded.

Rate Sampling pane

Rate sampling can extend the life of crystals. With rate sampling, the deposition rate is sampled by a sensor during the Sample time and the average Output Power required to maintain the rate during the Sample time is determined. The sensor shutter is then closed and the Output Power is held at a constant value during the Hold time. When the Hold time elapses, the sensor shutter is opened and the deposition rate is sampled again. This sample and hold cycle continues until the desired Final Thickness value is reached.

Continuous . . . . . Rate Sampling is unavailable and the sensor shutter remains open during deposition.

IPN 074-585-P1A

Accuracy Based . . . . . Used in conjunction with the Time Based parameter. If the Rate does not exceed the % value when the Time Based Sample value elapses, the shutter will be closed for the Time Based Hold time, with Output Power held at a constant level during that time; otherwise, the shutter will remain open until the rate is equal to or less than the **%** value. The **%** value is a ± percentage of the desired deposition rate (± sign is not entered before the value).

% . . . . . 00.0 to 100.00 %

Time Based . . . . . When deposition starts, the sensor shutter will be opened for the Sample (sec) time, and then the shutter will be closed for the Hold (sec) time, with source power held at a constant level during that time.

Sample (sec) . . . . . 00.0 to 100.00 s

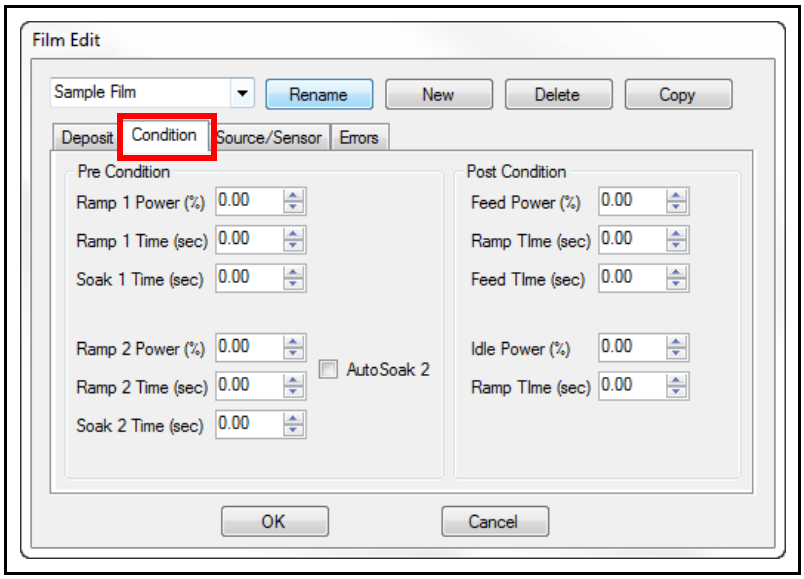
Hold (sec) . . . . . 00.0 to 100.00 s

IPN 074-585-P1A

2.3.3.5.9 Condition Tab

Preconditioning and postconditioning phases are configured in the **Condition** tab. See Figure 2-30.

Figure 2-30 Film Edit window - Condition tab



Pre Condition pane

Before the deposition phase starts, it is often necessary to precondition the source material, especially when using a thermal source. At the end of the precondition phase, the power level should be at or near the power required for deposition.

Ramp 1 Power (%) . . . . . 0.00 to 100.00%

The output Power at the end of the Ramp 1 Time phase. This value is a percentage of the full scale output (Full Scale Out) selected in the Outputs tab of the System Setup window.

Ramp 1 Time (sec) . . . . . 0.00 to 30000 s

The length of time to change the output power from the initial power level to the Ramp 1 Power level.

Soak 1 Time (sec) . . . . . 0.00 to 30000 s

The length of time the output Power remains at the Ramp Power level.

Ramp 2 Power (%) . . . . . 0.00 to 100.00%

Same command as Ramp 1 Power. Typically, the Ramp 2 Power value is set to approximately the power level required to achieve the desired initial deposition rate.

IPN 074-585-P1A

Ramp 2 Time (sec) . . . . . 0.00 to 30000 s

Same command as Ramp 1 Time.

Soak 2 Time (sec) . . . . . 0.00 to 30000 s

Same command as Soak 1 Time.

Auto Soak 2 . . . . . When the check box is selected, a power value based on the power level used during the deposition phase is used for the Ramp 2 Power value during the next run of the selected Layer.

Post Condition pane

Feed parameters are used with systems that provide wire-fed material to the source. The Feed phase starts immediately after the deposition phase ends. If the Feed parameters are at 0, the Feed phase is skipped and the Idle phase starts.

Feed Power (%). . . . . 0.00 to 100.0%

The Power level reached at the end of the Ramp Time. This value is a percentage of the full scale output (Full Scale Out) selected in the Outputs tab on the System Setup window.

Ramp Time (sec). . . . . 0.00 to 30000 s

The amount of time required to reach the Feed Power level after the deposition phase ends.

Feed Time (sec) . . . . . 0.00 to 30000 s

The time that Output Power stays at the Feed Power value before the Idle phase starts.

The Idle phase follows the Feed phase. If the Feed parameters are at 0, the Feed phase is skipped and the Idle phase starts immediately after the deposition phase ends.

Idle Power (%). . . . . 0.00 to 100.0%

The Power level reached at the end of the Ramp Time. This value is a percentage of the full scale output (Full Scale Out) selected in the Outputs tab of the System Setup window.

Ramp Time (sec). . . . . 0.00 to 30000 s

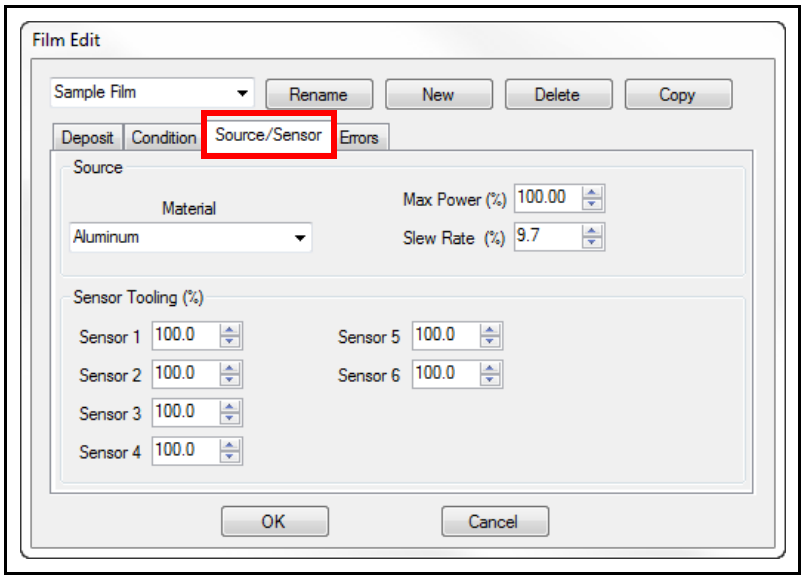
The time required to reach the Idle Power level after the Feed phase ends (or the Deposition phase ends, if Feed parameters are at 0).

IPN 074-585-P1A

2.3.3.5.10 Source/Sensor Tab

Max Power, Slew Rate, and Sensor Tooling are configured in the Source/Sensor tab, and the material to be deposited is selected in this tab. See Figure 2-31.

Figure 2-31 Film Edit window - Source/Sensor tab



Source pane

Material . . . . . Select the material to be deposited from a list of material names. The Density and Z-Ratio values for that material are displayed in the Materials window (see Figure 2-33 on page 2-42) where these values can be edited if desired.

Max Power (%) . . . . . 0.00 to 100.00%

The maximum Output Power allowed, as a percentage of the Full Scale Out value in the Outputs tab on the System Setup window (see Figure 2-37 on page 2-45). For example, if the Full Scale Out value is -10 and the Max Power value is 75, the Output Power will not exceed 75%, and therefore the output voltage to the source will not exceed –7.5 V.

Slew Rate (%) . . . . . 0.0 to 100.0%

The maximum allowed change per second of Output Power, for an Output using PID loop control, as a percentage of the Full Scale Out value in the Outputs tab on the System Setup window.

IPN 074-585-P1A

Sensor Tooling (%) pane

Compensates for differences due to sensor and substrate geometry of the Thickness measured by the sensor and the actual Thickness of material deposited on the substrate (see section 4.3 on page 4-2). A value of 0.0 makes a sensor unavailable.

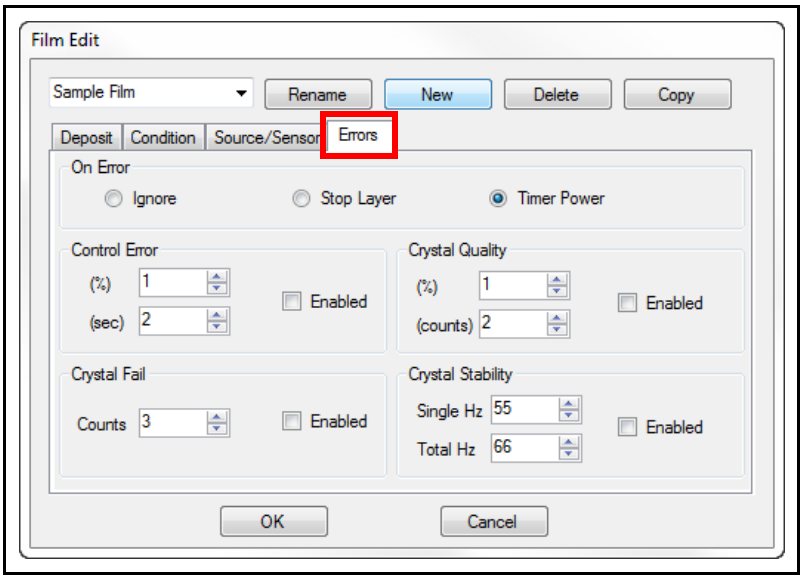
Sensor 1 to 6 (IQM-233) . . . 0.0 to 999.0%

Sensor 1 to 8 (SQM-242) . . 0.0 to 999.0%

2.3.3.5.11 Errors Tab

Error detection and the action to occur upon the error are configured in the Errors tab. See Figure 2-32.

Figure 2-32 Film Edit window - Errors tab



HINT: Until the stability and repeatability of the Process has been established, the **Enabled** check boxes for **Control Error**, **Crystal Quality**, and **Crystal Stability** should be cleared, and the check box for Crystal Fail be selected.

On Error pane

The selected action is initiated if an error condition occurs as determined by the Control Error pane selections. The possible actions are:

Ignore . . . . . All error conditions are ignored. The PID loop attempts to control the rate until the deposition phase is completed.

Stop Layer . . . . . Stops the deposition phase and sets source output power to zero. This allows the cause of the error to be corrected before continuing the deposition phase, or allows the deposition phase to be completed using manual control.

Timer Power . . . . . A constant power level, based on the last "good" rate measurements before the error occurs, is used to complete the deposition phase.

NOTE: A good rate is defined as a rate not exceeding the Control Error % value (if Control Error is selected), or not exceeding ±10% rate deviation (if Control Error is cleared).

Control Error pane

If the PID control loop cannot achieve a deposition rate within a specified percentage of the desired rate for a specified time period, the action selected in the On Error pane is initiated.

HINT: Shutter Delay can ensure adequate rate control before the deposition phase starts. Refer to section 2.3.3.5.8 on page 2-31.

Enabled . . . . . Select the check box to activate the Control Error command

(%) . . . . . 0 to 30%

The ± percentage (the sign is not entered before the value) of deviation from the desired rate that when exceeded for a specified time (sec) initiates the On Error selection.

(sec). . . . . 0 to 99 s

The period of time the rate must exceed the (%) value before the On Error selection is initiated.

IPN 074-585-P1A

Crystal Fail pane

A Crystal Fail error occurs if the crystal frequency of any Sensor used by the Film is invalid for a specified number of measurements.

Enabled . . . . . Select the check box to activate the Crystal Fail command.

Counts . . . . . 0 to 99

The quantity of invalid crystal frequency measurements. If this value is exceeded the On Error action is initiated and the message Xtal Fail: Sensor x Freq is displayed. An invalid frequency measurement is defined as no frequency, or a frequency above the Max. Freq value or below the Min. Freq value in the Card tab of the System Setup window.

CAUTION

If Ignore is selected as the On Error action and a Crystal Fail occurs, Output Power can increase to maximum. Selecting the Crystal Fail Enabled check box in conjunction with selecting Stop Layer or Timed Power as the On Error action is recommended.

CAUTION

When using a dual sensor, the Crystal Fail Enabled check box must be selected for the Dual sensor shutter to open if a Crystal Fail error occurs.

IPN 074-585-P1A

Crystal Quality pane

A Crystal Quality error occurs if the deposition rate exceeds a percentage of the desired rate for a specified number of measurements.

Enabled . . . . . Select the check box to activate the Crystal Quality command.

(%) . . . . . 0 to 50%

The ± percentage (sign is not entered before the value) of deviation from the desired rate that when exceeded increments a counter or when not exceeded decrements the counter. The % parameter is used in conjunction with the (counts) parameter.

(counts) . . . . . 0 to 99

During the deposition phase, each rate measurement exceeding the (%) value increments a counter. Each rate measurement not exceeding the (%) value decrements the counter to a minimum count of 0. If the quantity of measurement counts exceeds the (counts) value, the On Error action is initiated and the message Xtal Fail: Sensor x Qual is displayed.

IPN 074-585-P1A

Crystal Stability pane

When material is being deposited, crystal frequency normally decreases. However, near the end of crystal life, the crystal frequency may briefly "mode hop" to higher frequencies. Other causes of a frequency increase include thermal effects, material stress, and e-beam arcing. A Crystal Stability error will occur if the specified magnitude of positive frequency increase is exceeded or the specified sum of positive frequency increases is exceeded.

Enabled . . . . . Select the check box to activate the Crystal Stability command.

Single Hz . . . . . 25 to 9999

The largest single frequency increase allowed during the deposition phase. If this value is exceeded, the On Error action is initiated and the message Xtal Fail: Sensor x Stab is displayed.

Total Hz . . . . . 25 to 9999

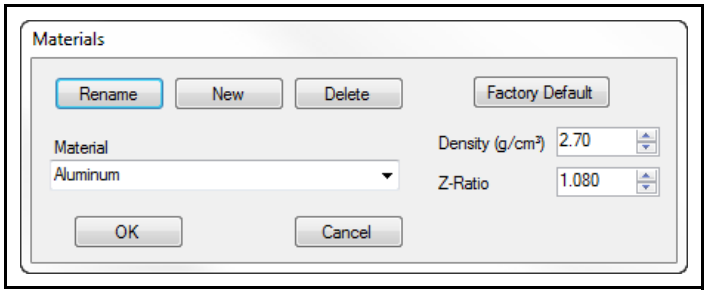
The maximum sum allowed for frequency increase events occurring during the deposition phase, If this value is exceeded, the On Error action is initiated and the message Xtal Fail: Sensor x Stab is displayed.

IPN 074-585-P1A

2.3.3.5.12 Materials

Click **Edit >> Materials** to display the **Materials** window where the Density and Z-Ratio values can be edited and saved, and the name of the material can be edited and saved. See Figure 2-33.

Figure 2-33 Materials window

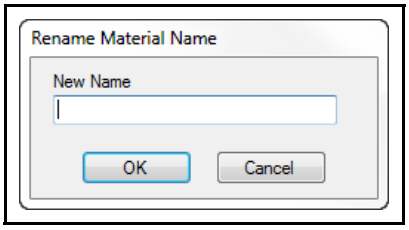


Material . . . . . Select a Material from the Material library list to display the Density and Z-Ratio for that material. The Density and Z-Ratio values can be edited and the new values can be saved under the existing Material name. An existing Material name can be renamed or a new Material name can be created.

Rename . . . . . Displays the Rename Material Name window where the currently displayed name can be changed and saved to the Material library (the original name is removed from the library).

NOTE: If the renamed material is used by a Film, the material name displayed in the Source/Sensor tab of the Film Edit window will automatically change to the new name.

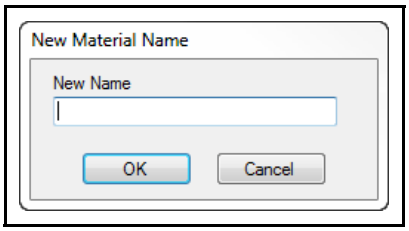
Figure 2-34 Rename Material Name window



IPN 074-585-P1A

New . . . . . Displays the New Material Name window where a name for a new material can be entered and saved to the Material library. To display the new material name, select the new name from the Material library list. The Density and Z-Ratio values for that material can then be edited and saved under the new name.

Figure 2-35 New Material Name window



Delete . . . . . Deletes the currently displayed material name from the material library.

CAUTION

Delete cannot be undone.

Factory Default . . . . . Restores the Material Name, Density, and Z-Ratio values to the factory default values for all Materials.

CAUTION

Any custom changes or added materials will be lost.

Density (g/cm^3) . . . . . 0.40 to 99.99 g/cm^3

The density of the material to be deposited (see Appendix A, Material Table). The Density value has a significant effect on the measured Thickness.

Z-Ratio . . . . . 0.100 to 9.999

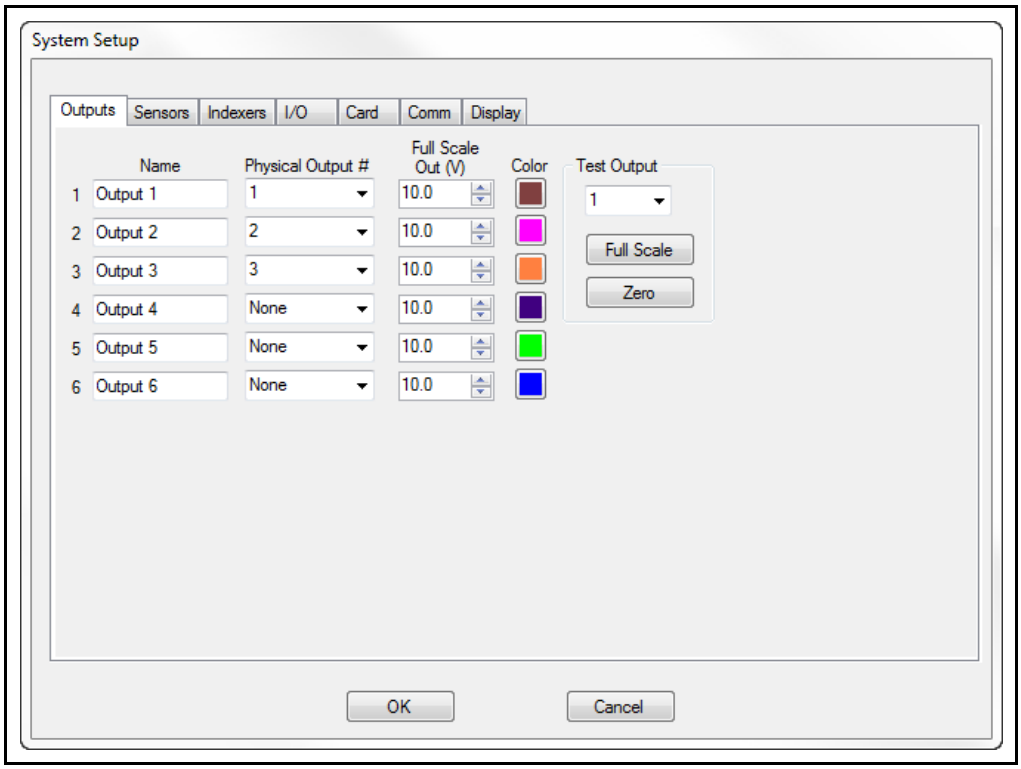
A value specific to the material being deposited that compensates for the mechanical elasticity of the material to the quartz crystal (see Appendix A, Material Table). The Z-Ratio has a minimal effect on the measured Thickness when the crystal is new and a greater effect on Thickness as the deposited coating on the crystal becomes thicker.

IPN 074-585-P1A

2.3.3.6 System

Click **Edit >> System** to display the **System Setup** window where system hardware and IQS-233 Codeposition software displays can be configured. See Figure 2-36.

Figure 2-36 System Setup window



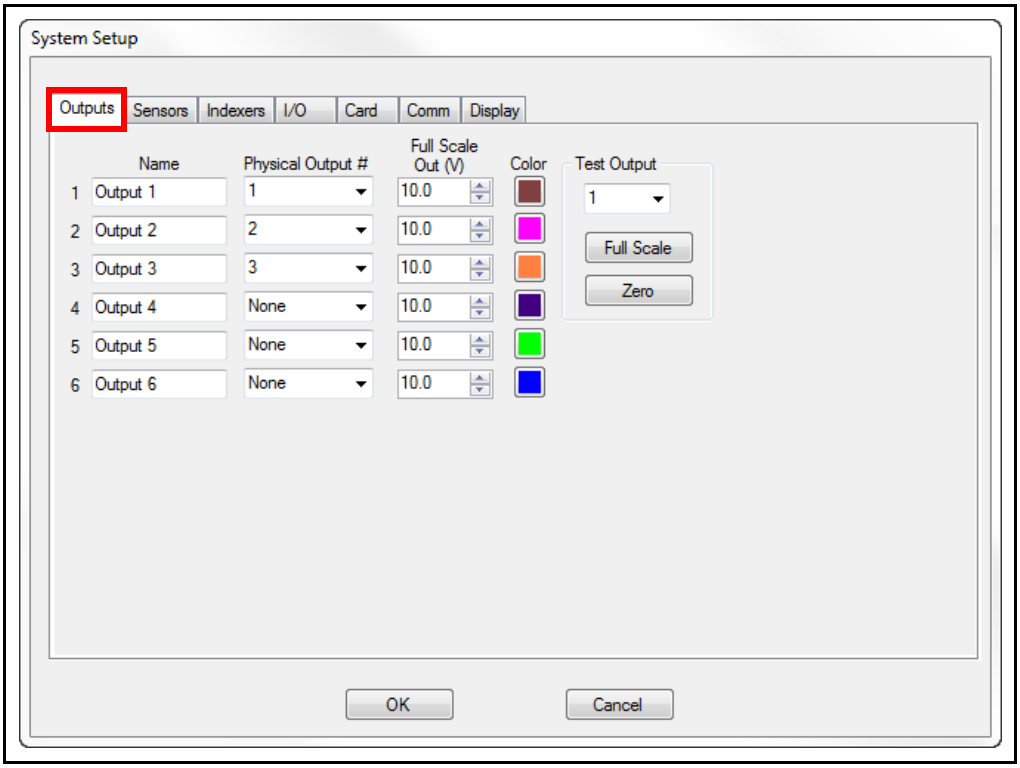
- **Outputs** tab, see section 2.3.3.6.1
- **Sensors** tab, see section 2.3.3.6.2 on page 2-47
- **Indexers** tab, see section 2.3.3.6.3 on page 2-50
- **I/O** tab, see section 2.3.3.6.4 on page 2-52
- **Card** tab, see section 2.3.3.6.5 on page 2-56
- **Comm** tab, see section 2.3.3.6.6 on page 2-58
- **Display** tab, see section 2.3.3.6.7 on page 2-60

IPN 074-585-P1A

2.3.3.6.1 Outputs Tab

The source Outputs are configured in the **Outputs** tab. See Figure 2-37.

Figure 2-37 System Setup window - Outputs tab



Name . . . . . Outputs 1 to 6 (IQM-233 cards)
Outputs 1 to 4 (SQM-242 cards)

A new name for an Output can be entered in the Name box.

NOTE: Output 1 to Output 3 are displayed if one IQM-233 card is installed. Output 1 and Output 2 are displayed if one SQM-242 card is installed.

Physical Output # . . . . . None, 1 to 6 (IQM-233 cards)
None, 1 to 4 (SQM-242 cards)

The Physical Output number mapped to the same numbered source output connection on the IQM-233 or SQM-242 card. Refer to the IQM-233 or SQM-242 operating manual for information about the source output connections.

Full Scale Out (V) . . . . . 0.0 to ±10.0

Enter the desired value for the source output voltage at 100% Power. This value can be from -10.0 to +10.0 (the + sign is not required), but must not exceed the maximum input voltage allowed for the equipment connected to the source output on the IQM-233 or SQM-242 card.

Color . . . . . Click the Color box corresponding to an Output and select a color from the color palette to be used for the corresponding Output Power, Rate, and Deviation graph. The Color also changes the color of the Film, Rate, Deviation, Thickness, and Power values on the IQS-233 Codeposition window (see Figure 2-54 on page 2-72).

Test Output . . . . . 1 to 6

Select the number of the Physical Output to be tested. Use the Full Scale and Zero commands to test the selected Physical Output. Verify with a digital multimeter.

Full Scale . . . . . Forces the selected Physical Output to its Full Scale Out value.

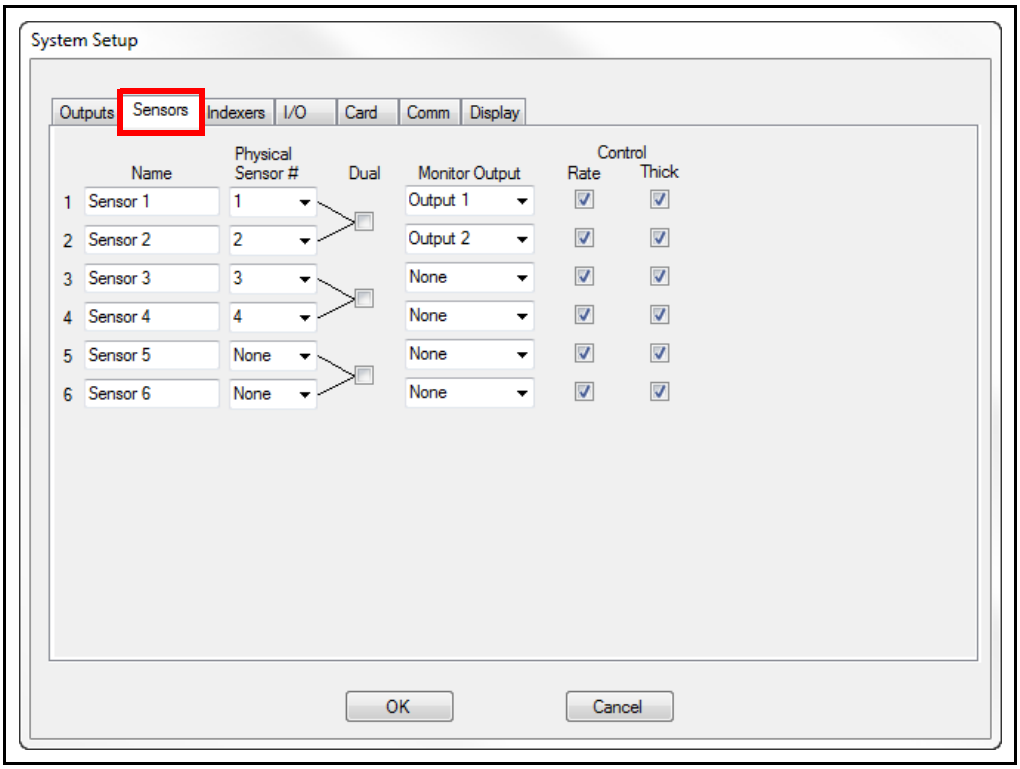
Zero . . . . . Zeroes the selected Physical Output.

IPN 074-585-P1A

2.3.3.6.2 Sensors Tab

Sensor assignments, Output-Sensor mapping, and Sensor/Output control method are configured in the Sensors tab. See Figure 2-38.

Figure 2-38 System Setup window - Sensors tab



Name . . . . . Sensor 1 to 6 (IQM-233 cards)
Sensor 1 to 8 (SQM-242 cards)

A new name for a Sensor can be entered in the Name text box.

NOTE: Sensor 1 to Sensor 3 are displayed if one IQM-233 card is installed. Sensor 1 to Sensor 4 are displayed if one SQM-242 card is installed.

Physical Sensor # . . . . . None, 1 to 6 (IQM-233 cards)
None, 1 to 8 (SQM-242 cards)

The Physical Sensor numbers 1 to 3 or 1 to 4 correspond to the same numbered sensor connection on the IQM-233 or SQM-242 card, respectively. The Physical Sensor numbers 4 to 6 or 5 to 8 correspond to the sensor connections 1 to 3 or 1 to 4 on the second IQM-233 or SQM-242 card, respectively. Refer to the IQM-233 or SQM-242 operating manual for information about the sensor connections.

NOTE: When two cards are installed, computers may vary in which PCI express slot corresponds to card 1 (Physical Sensor numbers 1 to 3 or 1 to 4).

Dual . . . . . Select the Dual check box to select the corresponding sensor pair as the primary and secondary channels of a dual sensor. If a crystal fail occurs for the primary channel, the dual sensor shutter exposes the secondary crystal and the secondary channel is used for measurement. A PLC is required to provide the relay for the dual sensor shutter (see Chapter 3, Digital I/O).

Monitor Output . . . . . None, Output 1 to 6 (IQM-233 cards)
None, Output 1 to 4 (SQM-242 cards)

Select the name of an Output to map to the corresponding sensor. Multiple sensors may be mapped to the same Output name for sensor rate averaging.

IPN 074-585-P1A

Control. . . . . Rate, Thick

Select the Rate check box to use the corresponding sensor for PID control of the mapped output and contribute to rate averaging if other sensors are mapped to the same output.

Select the Thick check box to have the corresponding sensor provide a Thickness reading in the Reading window (View >> Sensor Readings) and contribute to the aggregate Thickness reading in the IQS-233 Codeposition window.

Clear the Rate and Thick check boxes for the corresponding sensor to monitor a deposition with no PID control of the mapped output. This sensor will be removed from rate averaging if other sensors are mapped to the same output. The deposition phase will not stop when the Final Thickness value is reached assuming no other sensors being used have the Thick check box selected.

IPN 074-585-P1A

2.3.3.6.3 Indexers Tab

Source Indexers, a Substrate Indexer, and User Indexers are configured in the Indexers tab. See Figure 2-39.

NOTE: A Programmable Logic Controller (PLC) is required to provide the I/O required to control indexers.

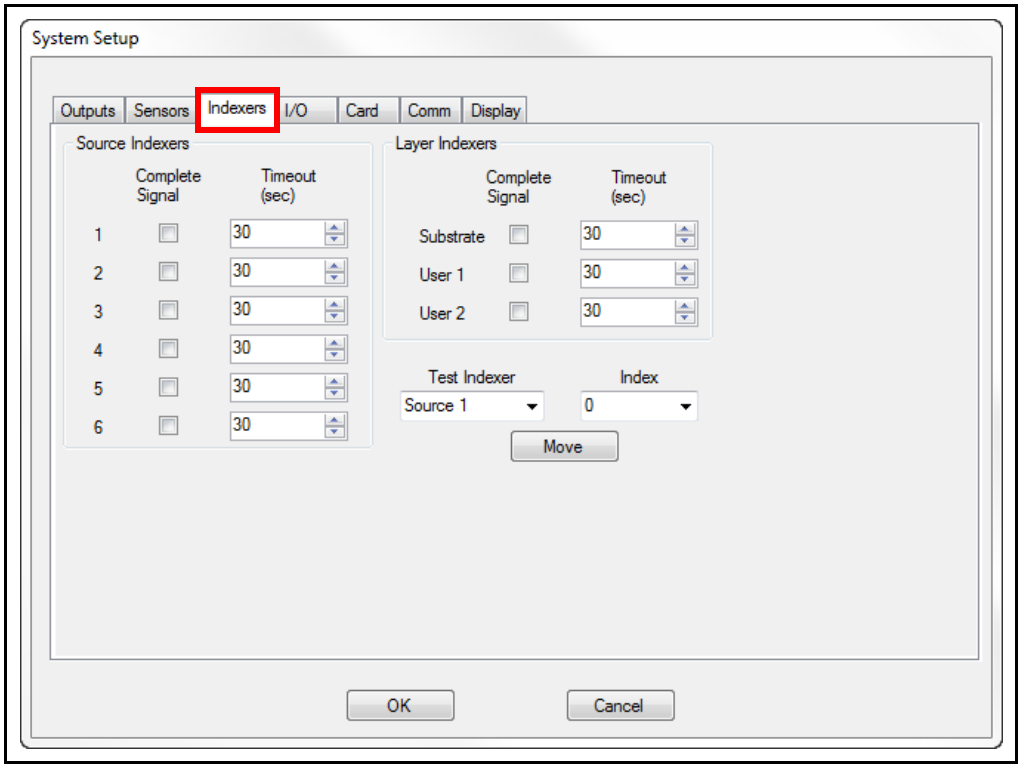
A unique Source Indexer is available for each source Output. The Source Indexer will move to the Index number it is assigned to at the start of each Layer.

The Substrate Indexer and User Indexers will move to the Index number they are assigned to at the start of each Layer.

User Indexers are useful for controlling external equipment.

Any of the indexers can be tested from within the Indexer tab without having to start a Process.

Figure 2-39 System Setup window - Indexers tab



IPN 074-585-P1A

Complete Signal . . . . . If an indexer provides an in-position signal used to indicate when it is in the selected position, select the Complete Signal check box corresponding to the Source, Substrate, or User Indexer. An external means for detecting the in-position signal must be provided (IQS-233 Codeposition software does not have an Input Event that can be used with a PLC for detecting the in-position signal). The Source Indexer Done command must be sent to the IQS-233 Codeposition software when the in-position signal is true. If this command is not received before the Timeout (sec) value elapses, the Layer will stop.

Timeout (sec) . . . . . 0 to 3000 s

The command of this parameter depends on the status of the Complete Signal check box:

- If the Complete Signal check box is selected, the Layer will start if the Source Indexer Done command is received by the software before the Timeout (sec) time period elapses.
- If the Complete Signal check box is clear, the Layer will start when the Timeout (sec) time period elapses.

Test Indexer. . . . . Source 1 to 6, Substrate, User 1 to 2

An indexer can be tested without starting a Process by selecting the name of the indexer, selecting the Index number, and clicking Move.

Index . . . . . 0 to 15

Select the indexer position to move to at the start of the Layer to access the pocket material for that layer.

Move . . . . . Moves the indexer to the selected Index position.

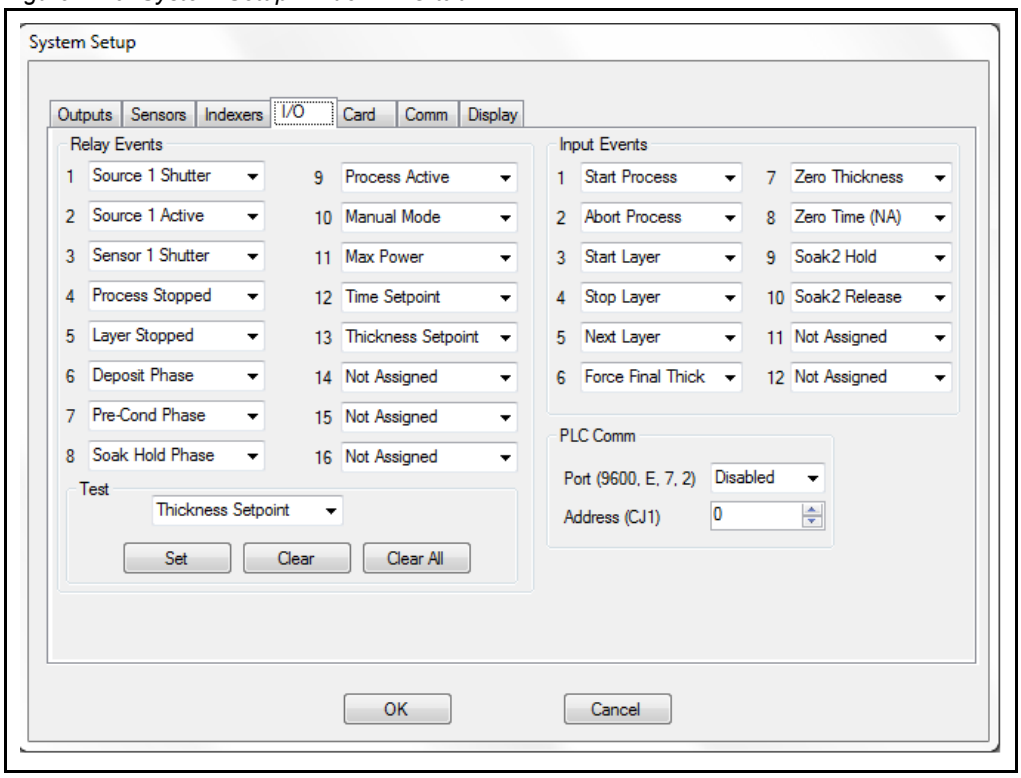
IPN 074-585-P1A

2.3.3.6.4 I/O Tab

Various events can be assigned in the I/O tab (see Figure 2-40) to correspond to the relays and inputs of an external Programmable Logic Controller (PLC). IQM-233 and SQM-242 cards do not provide digital I/O. The PLC can provide the relays and inputs needed for automatic control of source and sensor shutters, rotation of source indexer pockets, etc.

NOTE: Programmable Logic Controllers use relay and input addressing. Relay addresses correspond to relays 1 to 16 in the Relay Events pane. Input addresses correspond to inputs 1 to 12 in the Input Events pane. (Refer to the PLC operating manual for addressing.)

Figure 2-40 System Setup window - I/O tab



Relay Events pane

Selecting an event in a Relay Events box will activate the corresponding PLC relay when the event is true and deactivate the relay when the event is false.

Not Assigned . . . . . The corresponding PLC relay cannot be activated.

Source Shutter (1 to 6) . . . The relay controlling the deposition source shutter will activate at the start of the deposition phase and deactivate at the start of the postconditioning phase.

IPN 074-585-P1A

Sensor Shutter (1 to 8) . . . This relay controls the sensor shutter. The relay command depends on whether the sensor is single or dual:

- for a single sensor configuration, the relay will activate at the start of Shutter Delay (if selected) or the start of the deposition phase and deactivate at the start of the postconditioning phase.
- for a dual sensor configuration, the relay is activated when a Crystal Fail condition occurs.

NOTE: Crystal Fail must be selected (refer to section 2.3.3.5.11 on page 2-37) for the relay to command the Dual sensor configuration (refer to section 2.3.3.6.2 on page 2-47).

Process Stopped . . . . . The relay will activate when Abort Process is selected and deactivate when Start Process is selected.

Process Running . . . . . The relay will activate when Start Process is selected and deactivate when Abort Process is selected.

Layer Stopped . . . . . The relay will activate when Stop Layer is selected and deactivate when Start Layer is selected.

Layer Running . . . . . The relay will activate when Start Layer is selected and deactivate when Stop Layer is selected.

Deposit Phase . . . . . The relay will activate at the start of the deposition phase and deactivate at the start of the postconditioning phase.

Pre-Cond Phase . . . . . The relay will activate at the start of the preconditioning phase and deactivate at the start of deposition phase.

Soak Hold Phase . . . . . The relay will activate at the start of the Auto Soak 2 (if selected) phase and deactivate at the start of the Shutter Delay (if selected) or deposition phase.

Process Active . . . . . The relay will activate if a Process is temporarily halted for any reason (for example, if a Layer is waiting for a Manual Start) and deactivate when the Process is active again.

Manual Mode . . . . . The relay will activate when Manual mode is active and deactivate when Auto mode is active.

IPN 074-585-P1A

Max Power . . . . . The relay will activate when the Output Power is equal to the Max Power value and deactivate when the Output Power is below the Max Power value.

Time Setpoint . . . . . The relay will activate when the Time End Point value is reached.

Thickness Setpoint . . . . . The relay will activate when the Thickness End Point value is reached.

Final Thickness . . . . . The relay will activate when the Final Thickness value is reached.

All Crystals Good . . . . . The relay will activate when all activated sensors have valid frequency readings.

All Crystals Fail . . . . . The relay will activate when none of the activated sensors has a valid frequency reading.

Test pane

The PLC relays can be tested without starting a Process. Select a relay event in the **Test** box that matches the relay event assigned to the relay to be tested. Use the Set, Clear, and Clear All commands to test the relay.

Set . . . . . Activates the relay(s) corresponding to the selected event.

Clear . . . . . Deactivates the relay(s) corresponding to the selected event.

Clear All . . . . . Deactivates all activated relays.

Input Events pane

Selecting an event from an **Input Events** box will initiate this event when the corresponding PLC input is activated.

Not Assigned . . . . . Activating the corresponding PLC input has no effect on events.

Start Process . . . . . Starts the current Process.

Abort Process . . . . . Aborts the current Process.

Start Layer . . . . . Starts the current Layer.

Stop Layer. . . . . Stop the current Layer.

Next Layer. . . . . Skips the current Layer and starts the next Layer.

Force Final Thick . . . . . Same effect as reaching the Final Thickness value.

Zero Thickness. . . . . Zeroes the Thickness reading.

Zero Time (NA) . . . . . This event is not available.

IPN 074-585-P1A

Soak2 Hold . . . . . Power stays at the Ramp 2 Power value indefinitely.

Soak2 Release . . . . . Deposition phase begins when the Soak 2 Time value elapses.

PLC Comm pane

The communication settings required by the PLC are configured here.

Port (9600, E, 7, 2) . . . . . Disabled, COM#

Select the Comm serial port used to communicate with the PLC, or select Disabled to disable communications with the PLC (has same effect as selecting Not Assigned for all Relay Events and Input Events). The fixed communication parameters are: Baud Rate = 9600, Parity = E, Data Bits = 7, Stop Bits = 2.

Address (CJ1) . . . . . 0 to 100

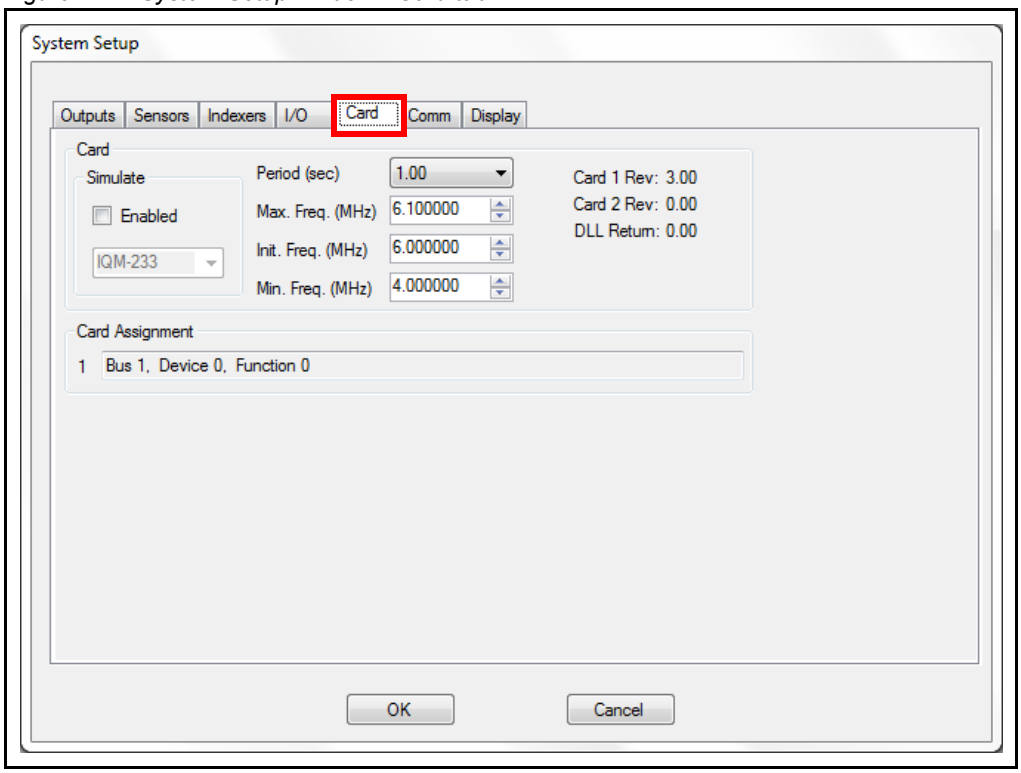
A single PLC will usually use Address 0. Multiple PLCs can be controlled from a single computer serial port by connecting their expansion ports. The unique slave address of each PLC is usually selected by a rotary or DIP switch (refer to the PLC operating manual).

IPN 074-585-P1A

2.3.3.6.5 Card Tab

Measurement properties are configured in the Card tab, and Simulate mode can be selected in this tab. Computer assignments for the IQM-233 or SQM-242 cards, card firmware revision, and DLL revision are displayed. See Figure 2-41.

Figure 2-41 System Setup window - Card tab



Card box . . . . . Select the card type (IQM-233 or SQM-242) to be simulated.

NOTE: The Card box selections are available only when the Enabled check box is selected.

Simulate Enabled . . . . . Select the check box to activate Simulate mode, allowing a deposition process to be developed and tested without the need for an IQM-233 or SQM-242 card to be installed or sensors to be connected to the installed card. The check box is automatically selected when no cards are installed.

Period (sec). . . . . 0.10, 0.25, 0.50, 1.00, 2.00 s

Indicates the time period needed for one measurement. Enter a longer measurement period to provide higher resolution, especially in low rate applications.

IPN 074-585-P1A

Max. Freq (MHz) . . . . . 4.002000 to 6.100000 MHz

Enter the highest possible frequency of a new crystal. Frequencies above this value will cause a Crystal Fail error to occur.

Init. Freq (MHz) . . . . . 4.001000 to 6.099000 MHz

Enter the nominal frequency of a new crystal; usually 5 MHz or 6 MHz.

Min. Freq (MHz). . . . . 4.000000 to 6.098000 MHz

Enter the lowest desired crystal frequency. Frequencies below this value will cause a Crystal Fail error to occur.

NOTE: The Max. Freq value must be at least 0.001 MHz higher than the Init. Freq value, and the Init. Freq value must be at least 0.001 MHz higher than the Min. Freq value.

Card Assignment . . . . . Displays the computer Bus, Device, and Command assignments for up to two installed IQM-233 or SQM-242 cards. If IQM-233 and SQM-242 cards are installed, only the Bus, Device, and Command assignments for up to two IQM-233 cards will be displayed.

NOTE: SQM-242 cards are not detected if IQM-233 cards are installed.

Card 1 Rev . . . . . The firmware revision of the IQM-233 or SQM-242 card automatically interfaced to the IQS-233 Codeposition software.

Card 2 Rev . . . . . The firmware revision of the second card automatically interfaced to the IQS-233 Codeposition software if two IQM-233 or SQM-242 cards are installed.

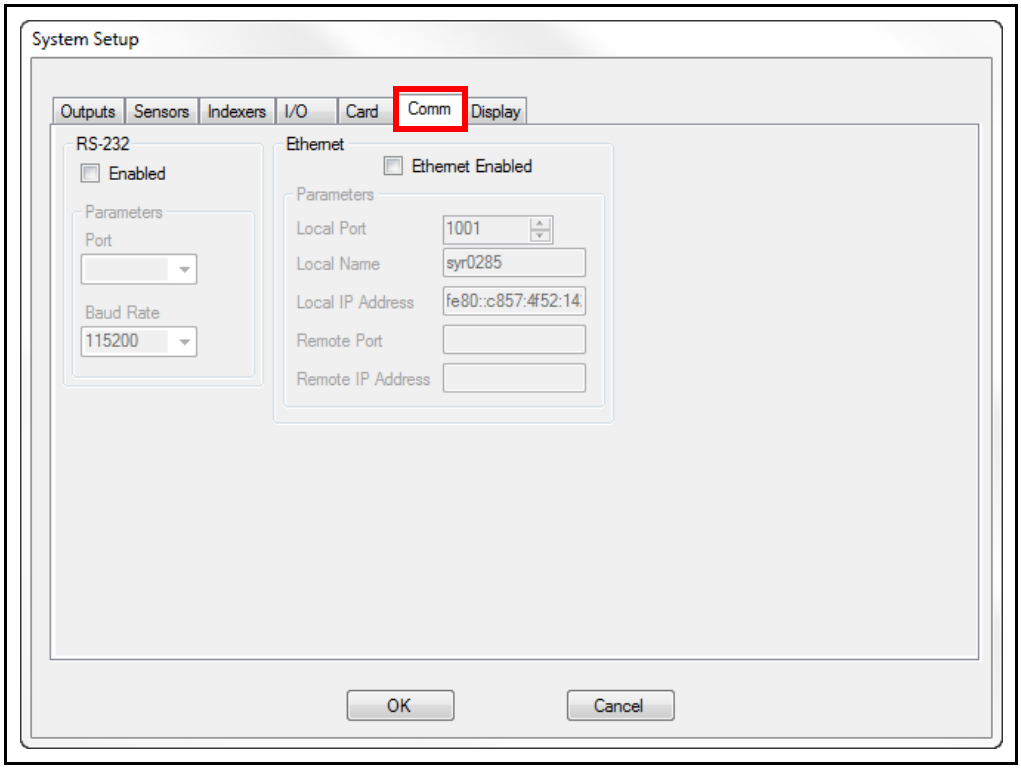
DLL Return . . . . . The firmware version of the installed Dynamic Link Library (DLL) used by the IQS-233 Codeposition software.

IPN 074-585-P1A

2.3.3.6.6 Comm Tab

When controlling the IQS-233 Codeposition software from a remote computer, the RS-232 or Ethernet communications are configured in the Comm tab. See Figure 2-42.

Figure 2-42 System Setup window - Comm tab



RS-232 pane

Enabled . . . . . Select the Enabled check box to activate RS-232 communications.

Port . . . . . COM#

Select the detected serial communication port to be used for the RS-232 communications with another computer.

Baud Rate 4800, 9600, 19200, 38400, 57600, 115200

Select the Baud Rate to be used for RS-232 communications.

IPN 074-585-P1A

Ethernet pane

Ethernet Enabled . . . . . Select the Ethernet Enabled check box to activate Ethernet communications.

Ping Enabled . . . . . Select the Ping Enabled check box to detect that the connected computer can send/receive messages without error.

Local Port . . . . . 0 to 65536

Select the TCP/IP port to be used by the IQS-233 Codeposition software for Ethernet communications (1001 is a typical value, use -1 for no Ethernet).

Local Name . . . . . Displays the names of the local and remote computers.

Local IP Address . . . . . Displays the IP address (xxx.xxx.xxx.xxx) of the local computer.

Remote Port . . . . . Displays the TCP/IP port of the remote computer.

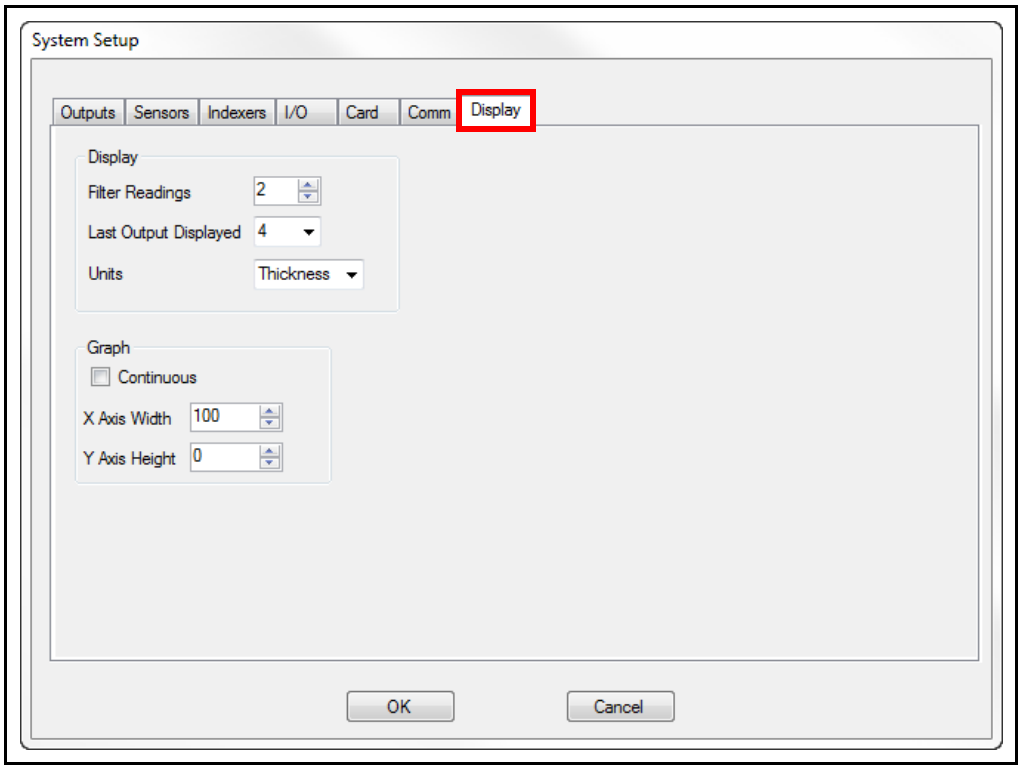
Remote IP Address . . . . . Displays the IP address (xxx.xxx.xxx.xxx) of the remote computer.

IPN 074-585-P1A

2.3.3.6.7 Display Tab

The IQS-233 Codeposition software display properties are configured in the **Display** tab. See Figure 2-43.

Figure 2-43 System Setup window - Display tab



Display pane

Filter Readings . . . . . 1 to 10

Select the number of desired readings between display updates. A value of 1 updates the display as fast as possible, while a higher value provides greater filtering of graphed data between display updates. Filter Readings only filters readings for Power and Thickness on the display.

NOTE: The IQM-233 card resolution for PID control is unchanged.

Last Output Displayed . . . . 1 to 6 (IQM-233 card)
1 to 4 (SQM-242 card)

Select the maximum number of displayed Output readouts.

IPN 074-585-P1A

Units . . . . . Thickness, Mass

Select Thickness or Mass as the displayed unit of measurement.

Graph pane

Continuous . . . . . Select the check box to display continuous data for the preconditioning, deposition, and postconditioning phases. Clear the check box to refresh the graph at the end of the preconditioning, deposition, and postconditioning phases.

X Axis Width . . . . . 0 to 100

Select the time in seconds required for data to scroll the width of the graphs. Select a value of 0 to activate auto scaling for scroll time.

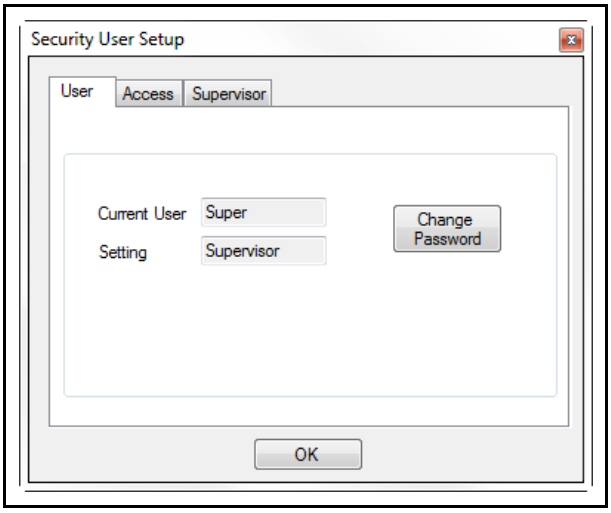
Y Axis Height . . . . . 0 to 10000

Select the maximum displayed value for the Rate graph and Sensors graph. Select a value of 0 to activate auto scaling for the Rate graph and Sensors graph.

2.3.3.7 Security

Click **Edit >> Security** to display the **Security User Setup** window where access levels when logging on to the IQS-233 Codeposition software can be assigned for different users. See Figure 2-44.

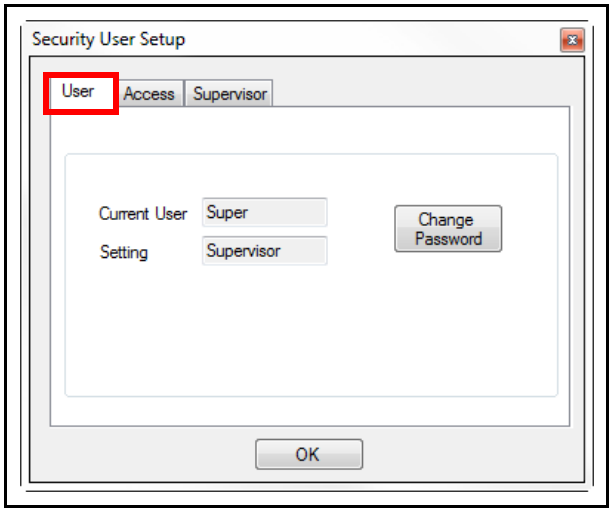
Figure 2-44 Security User Setup window



NOTE: The Security User Setup window is available only to users with Supervisor Access.

2.3.3.7.1 User Tab

Figure 2-45 Security User Setup window - User tab

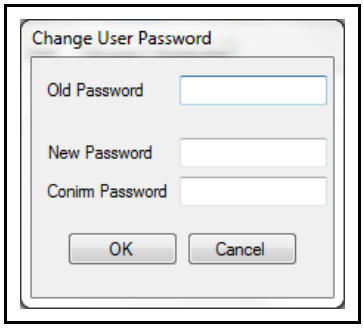


Current User . . . . . Displays the user currently logged in.

Setting . . . . . Displays the access level of the current user: Supervisor, Technician, or User.

Change Password . . . . . Allows the current user to change the password. When Change Password is clicked, a second display will prompt the current user to enter the Old Password, New Password, and Confirm Password. If the New Password box is left blank, no Password is needed for the current user to login. See Figure 2-46).

Figure 2-46 Change User Password window



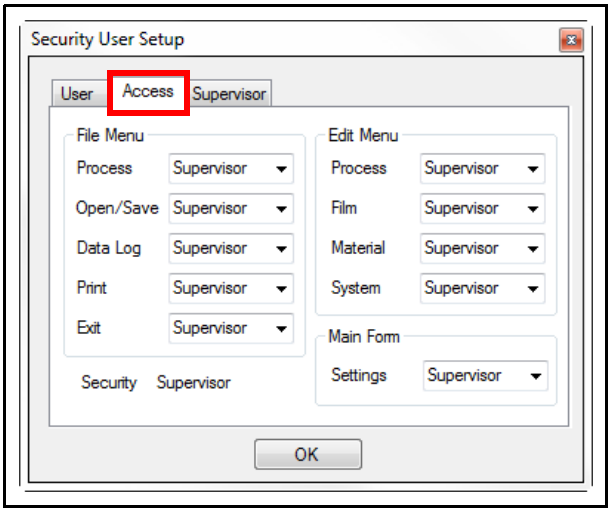
NOTE: User names and passwords may contain A-Z, 0-9, space, and special characters. Passwords are a maximum of 10 characters.

IPN 074-585-P1A

2.3.3.7.2 Access Tab

Supervisor is the highest level of security access that can be assigned. Technician is the intermediate level and User is the lowest level of security access that can be assigned.

Figure 2-47 Security User Setup window - Access tab



The **Access** tab allows Supervisors to assign which program commands are available to each of the three Access Levels. When a program command is assigned to a particular access level, it is automatically available to higher access levels. Figure 2-47 shows Supervisor access for each File Menu, Edit Menu, and Main Form program command.

NOTE: Users having access below the assigned access level for any program command can select and run processes, but cannot edit process parameters or access program commands.

File Menu pane

Process . . . . . Supervisor, Technician, User

Permits assigned access level and above to have access to the Process option from the File menu.

Open/Save . . . . . Supervisor, Technician, User

Permits assigned access level and above to have the ability to open and save configuration files.

Data Log . . . . . Supervisor, Technician, User

Permits assigned access level and above to have access to the Log Data option from the File menu.

Print . . . . . Supervisor, Technician, User

Permits assigned access level and above to have access to the Print option from the File menu.

Exit. . . . . Supervisor, Technician, User

Permits assigned access level and above to have access to the Exit option from the File menu.

Edit Menu pane

Process . . . . . Supervisor, Technician, User

Permits assigned access level and above to have access to the Process option from the Edit menu.

Film . . . . . Supervisor, Technician, User

Permits assigned access level and above to have access to the Film option from the Edit menu.

Material . . . . . Supervisor, Technician, User

Permits assigned access level and above to have access to the Material option from the Edit menu.

System . . . . . Supervisor, Technician, User

Permits assigned access level and above to have access to the System option from the Edit menu.

Main Form Settings

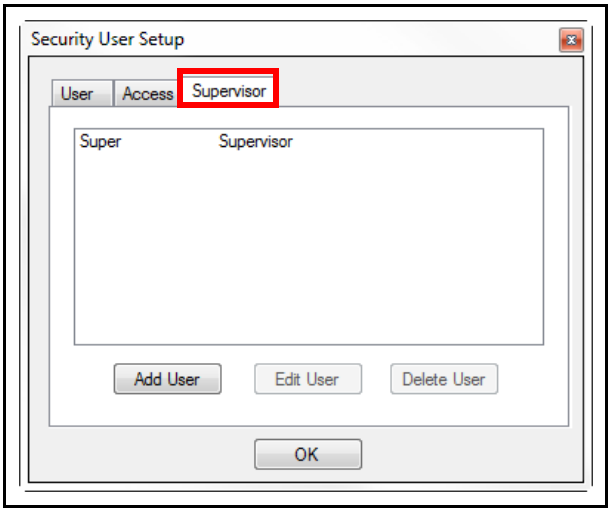
Use the drop down menu to select level of access: Supervisor, Technician, User. This controls access to the parameters along the right side of the IQS-233 Codeposition window. See Figure 2-51 on page 2-67. These settings can be viewed by any user, but values can only be edited by the assigned access level or higher access.

Security . . . . . Displays level of access of current user.

IPN 074-585-P1A

2.3.3.7.3 Supervisor Tab

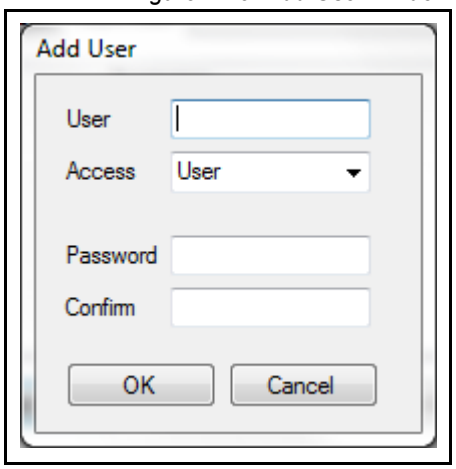
Figure 2-48 Security User Setup window - Supervisor tab



The **Supervisor** tab allows Supervisors to add, edit, and delete users.

Add User . . . . . Click Add User to display the Add User window as seen in Figure 2-49. This window allows for new users to be added, access for that user to be assigned, and a user password to be created and confirmed. Click OK to save user.

Figure 2-49 Add User window



Edit User . . . . . Select the user from the Supervisor tab (refer to Figure 2-48) and click Edit User to reassign an access level to that user. Click OK to save changes.

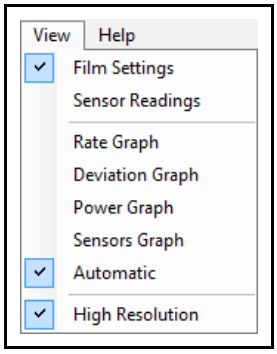
Delete User . . . . . Select the user from the Supervisor tab (refer to Figure 2-48) and click Delete User to remove that user from having access to IQS-233 Codeposition software.

IPN 074-585-P1A

2.3.4 View

Click **View** on the menu bar to display the list of items related to informational readouts (see Figure 2-50). From this list, various graphs and readouts can be selected for display, frequently accessed Process parameters can be displayed or hidden, and standard or high resolution can be selected for the Rate and Thickness readouts.

Figure 2-50 View list



- **Film Settings**, see section 2.3.4.1
- **Sensor Readings**, see section 2.3.4.2 on page 2-69
- **Rate Graph**, see section 2.3.4.3 on page 2-71
- **Deviation Graph**, see section 2.3.4.4 on page 2-71
- **Power Graph**, see section 2.3.4.5 on page 2-71
- **Sensors Graph**, see section 2.3.4.6 on page 2-71
- **Automatic**, see section 2.3.4.7 on page 2-71
- **High Resolution**, see section 2.3.4.8 on page 2-72

2.3.4.1 Film Settings

Displays or hides a pane of frequently used Layer parameters. The displayed parameter values are for the active Layer of a Process and these values are updated at the start of the Layer.

- If Auto mode is selected, parameters used for PID loop source control are displayed (see Figure 2-51).
- If Manual mode is selected, parameters used for manual source control are displayed (see Figure 2-52 on page 2-68).

Parameter values can be edited whether a Process is started or stopped. Changing the value of a parameter also changes the value of the same parameter residing in another location.

When the process is stopped, additional parameters can be accessed from the Edit item list (refer to section 2.3.3.5 on page 2-17).

IPN 074-585-P1A

For a sequential Layer, the name of the Film used in the Layer is displayed at the top of the pane.

For a Codeposition Layer, the names of the Films used in the Layers comprising the Codeposition Layer are displayed at the top of the pane.

- The name displayed at the top of the name list corresponds to the Layer using the lowest numbered physical output.
- The name at the bottom of the list corresponds to the Layer using the highest numbered physical output.

  NOTE: The physical output number for an Output name is configured in the Outputs tab of the System Setup window.

Select the Film name corresponding to a particular Layer of the Codeposition Layer to display the frequently used parameters for that Layer.

Figure 2-51 IQS-233 Codeposition window - frequently used Layer parameters for PID loop control

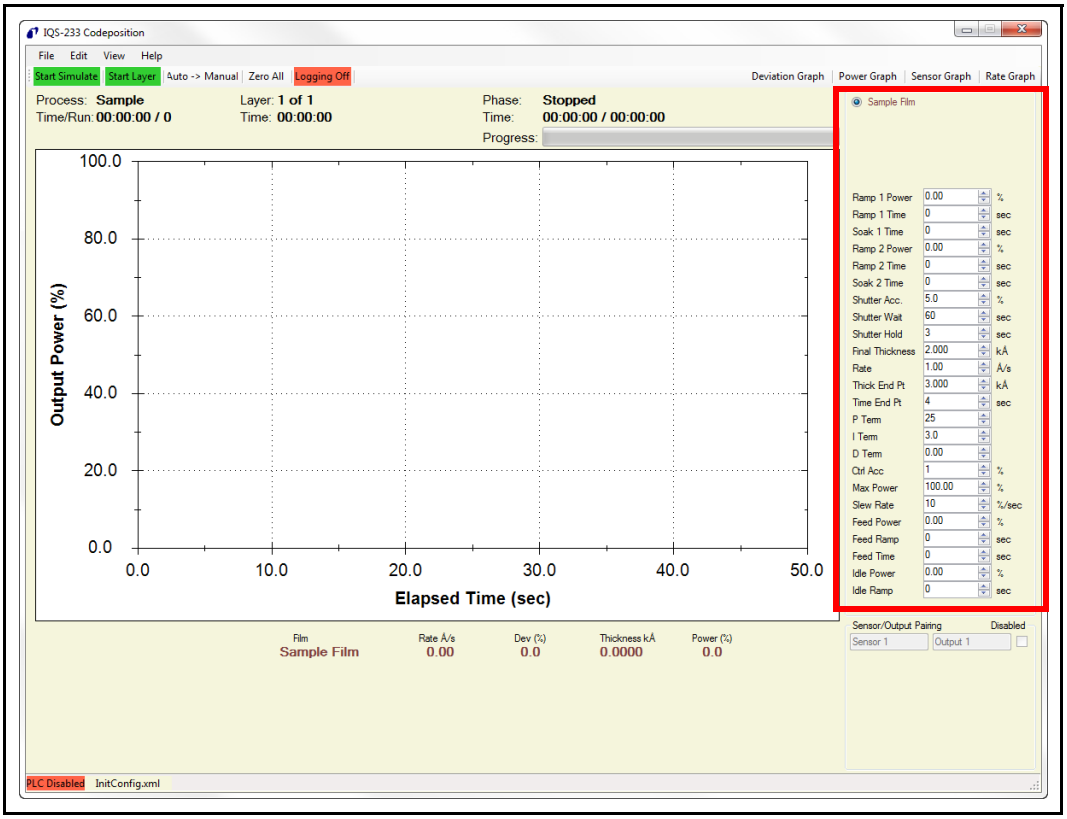
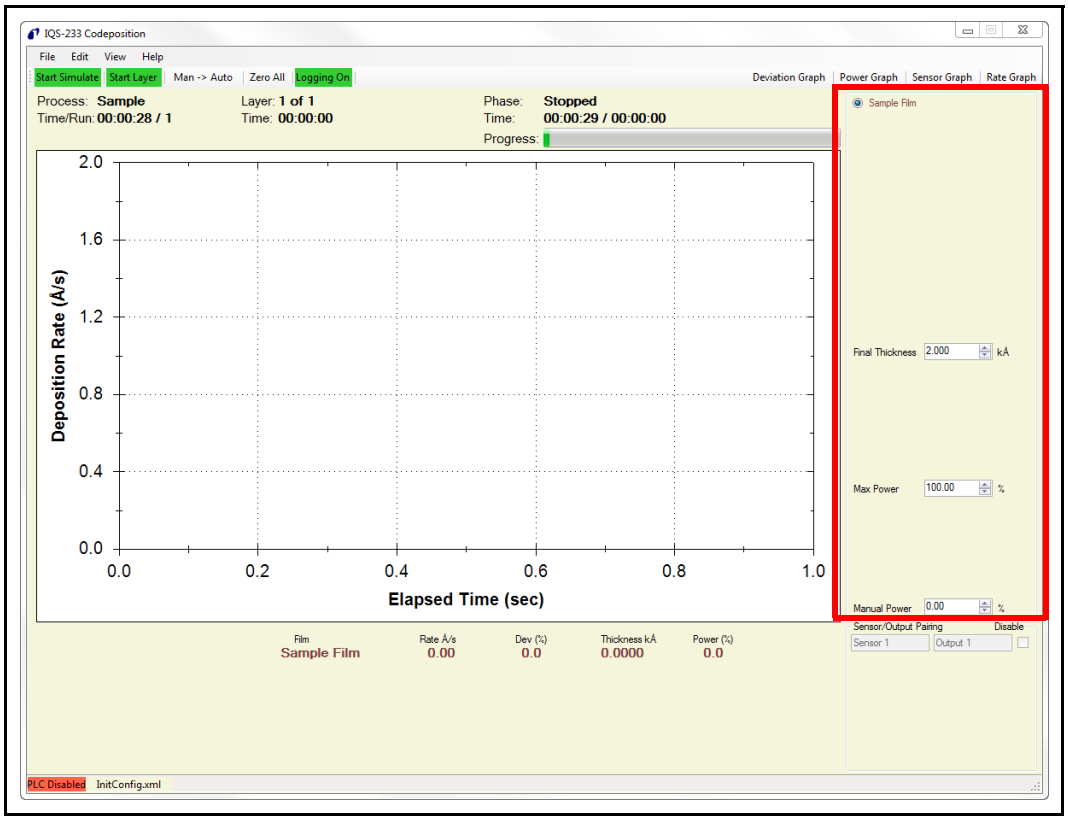


Figure 2-52 IQS-233 Codeposition window - frequently used Layer parameters for manual control



Frequently Used Parameters—Auto Mode

Ramp 1 Power . . . . . 0 to 100%

Ramp 1 Time . . . . . 0 to 30000 sec

Soak 1 Time . . . . . 0 to 30000 sec

Ramp 2 Power . . . . . 0 to 100.00%

Ramp 2 Time . . . . . 0 to 30000 sec

Soak 2 Time . . . . . 0 to 30000 sec

Shutter Acc . . . . . 0.0 to 30.0%

Shutter Wait . . . . . 0 to 30000 sec

Shutter Hold . . . . . 0 to 30000 sec

Final Thickness . . . . . 0.000 to 999.900 kÅ

Rate . . . . . -999.90 to 999.90 Å/s

Thick End Pt . . . . . 0.000 to 999.900 kÅ

Time End Pt . . . . . 0 to 3000 sec

P Term . . . . . 0 to 9999

IPN 074-585-P1A

I Term . . . . . 0.0 to 999.9

D Term . . . . . 0.00 to 99.90

Ctrl Acc . . . . . 0 to 30%

Max Power . . . . . 0.00 to 100.00%

Slew Rate . . . . . 0 to 100%/sec

Feed Power . . . . . 0.00 to 100.00%

Feed Ramp . . . . . 0 to 30000 sec

Feed Time . . . . . 0 to 30000 sec

Idle Power . . . . . 0.00 to 100.00%

Idle Ramp . . . . . 0 to 30000 sec

Frequently Used Parameters—Manual Mode

Final Thickness . . . . . 0.000 to 999.900 kÅ

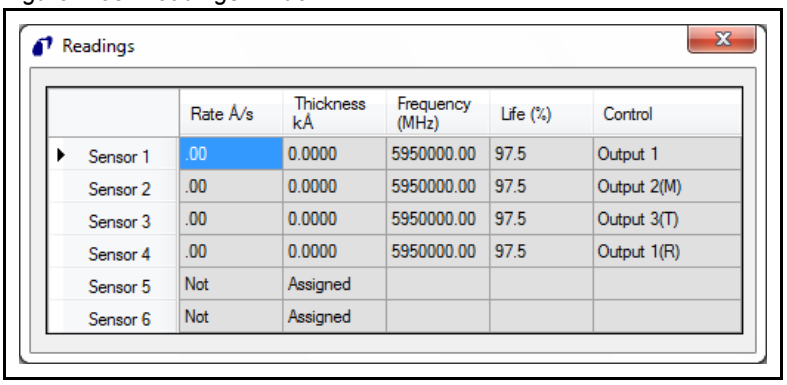
Max Power . . . . . 0 to 100%

Manual Power . . . . . 0.00 to 100.00%

2.3.4.2 Sensor Readings

Click **View >> Sensor Readings** to display the **Readings** window where Rate, Thickness, and Frequency raw data for individual Sensors, the calculated remaining Life of each crystal, and the Control method used for each Sensor are displayed. See Figure 2-53.

Figure 2-53 Readings window



Sensor . . . . . Sensor 1 to 6 (IQM-233)
Sensor 1 to 8 (SQM-242)

The Sensor number corresponds to the Sensor connections on the IQM-233 or SQM-242 card(s). Refer to the IQM-233 or SQM-242 operating manual for information about the Sensor connections.

NOTE: Sensor 1 to Sensor 3 are displayed if one IQM-233 card is installed. Sensor 1 to Sensor 4 are displayed if one SQM-242 card is installed.

Rate Å/s, **Thickness kÅ** . . . Rate and Thickness are displayed only for Sensors that are mapped to an Output used by the active Layer. Outputs are mapped to Sensors in the Sensors tab on the System Setup window (refer to Figure 2-38 on page 2-47).

Frequency (MHz), **Life (%)** . . Displayed for all Physical Sensors assigned to a Sensor name in the Sensors tab on the System Setup window.

Control . . . . . The control method used is displayed for all Physical Sensors assigned to a Sensor name. The control method is selected in the Sensors tab on the System Setup window (refer to Figure 2-38 on page 2-47)

- (Output name): Sensor is mapped to the named Output and is used for PID Rate and Thickness End Point control.
- None: Sensor is not mapped to an Output.
- P: Sensor is the primary sensor channel of a dual sensor
- S: Sensor is the secondary sensor channel of a dual sensor.
- (Output name) (M): Sensor is used to monitor the deposition with no PID Rate control.
- (Output name) (R): Sensor is used for PID Rate control.
- (Output name) (T): Sensor is used for Thickness End Point control.

IPN 074-585-P1A

2.3.4.3 Rate Graph

Click **View >> Rate Graph** to display a graph of Deposition Rate as the main graph on the IQS-233 Codeposition window. This graph is useful during shutter delay, rate ramp, and deposition.

2.3.4.4 Deviation Graph

Click **View >> Deviation Graph** to display a graph of Rate Deviation as the main graph on the IQS-233 Codeposition window. This graph is useful for fine tuning PID control loop. See Chapter 4, Calibration Procedures.

2.3.4.5 Power Graph

Click **View >> Power Graph** to display a graph of Output Power as the main graph on the IQS-233 Codeposition window. This graph is useful during the preconditioning, Feed, and Hold phases. It can also be useful during the deposition phases to detect error conditions, which cause oscillations.

2.3.4.6 Sensors Graph

Click **View >> Sensors Graph** to display the rate readings from each individual, assigned sensor as the main graph on the IQS-233 Codeposition window. It is a graphical display of the **Rate** column of the Sensor Readings window (refer to section 2.3.4.2 on page 2-69).

2.3.4.7 Automatic

Click **View >> Automatic** to display a graph of the most pertinent information for each phase as the main graph on the IQS-233 Codeposition window.

- The Power Graph is displayed during preconditioning.
- The Rate Graph is displayed during shutter delay, rate ramps, and deposition.
- The Power Graph is displayed during the Feed and Hold phases.

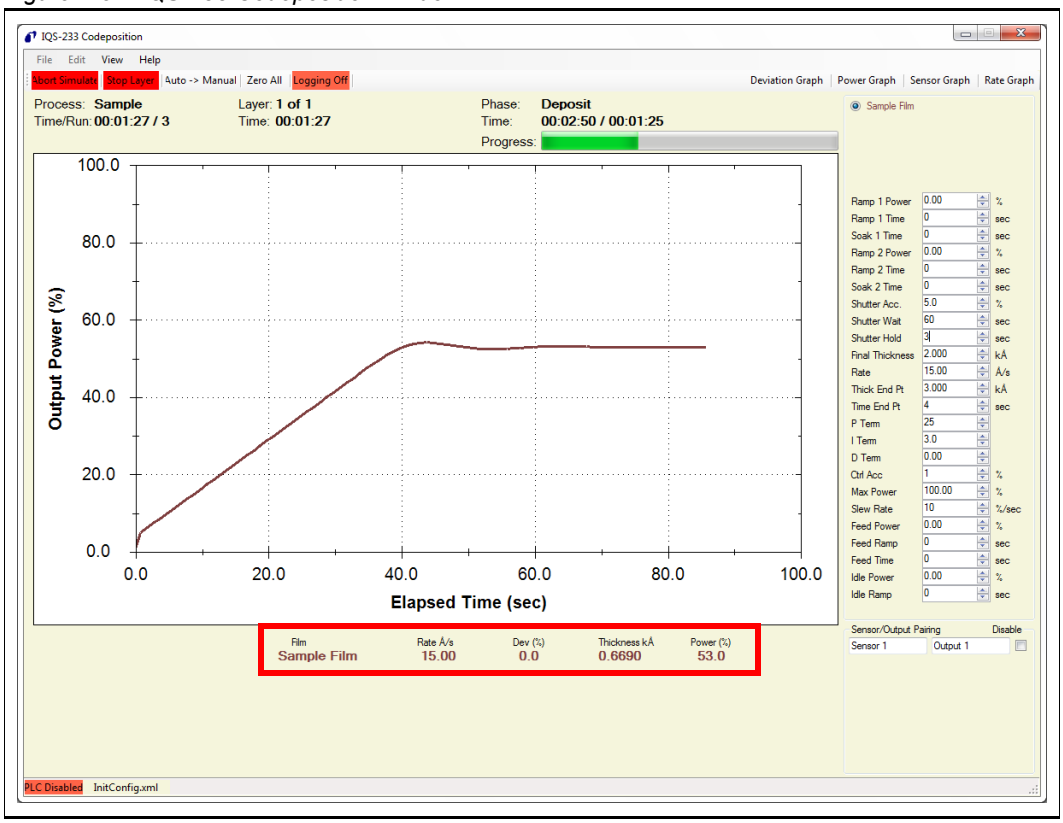
IPN 074-585-P1A

2.3.4.8 High Resolution

Selecting High Resolution will display rate on the IQS-233 Codeposition window to 0.01 Å/s and thickness to 0.1 Å. See Figure 2-54.

NOTE: The IQM-233 card resolution for PID control is unchanged.

Figure 2-54 IQS-233 Codeposition window



2.3.5 Help

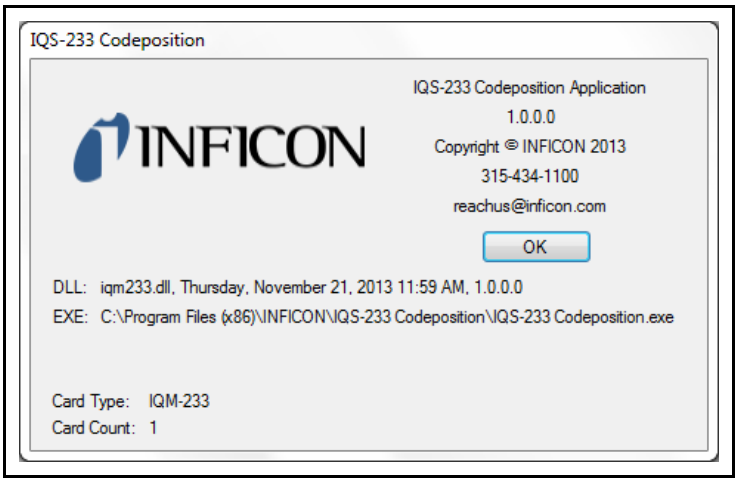
2.3.5.1 Help

Click **Help >> Help** on the menu bar to display the IQS-233 Codeposition Software Operating Manual.

2.3.5.2 About

Click **Help >> About** on the menu bar to display the **About** window, where the IQS-233 Codeposition software version, software installation path, DLL version, installed card type, and installed card count are displayed. See Figure 2-55.

Figure 2-55 About window



Card Type: . . . . . None if no cards are installed.
IQM-233 if at least one IQM-233 card is installed.
SQM-242 if only SQM-242 cards are installed.

NOTE: If IQM-233 and SQM-242 cards are installed, the SQM-242 cards will not be reported.

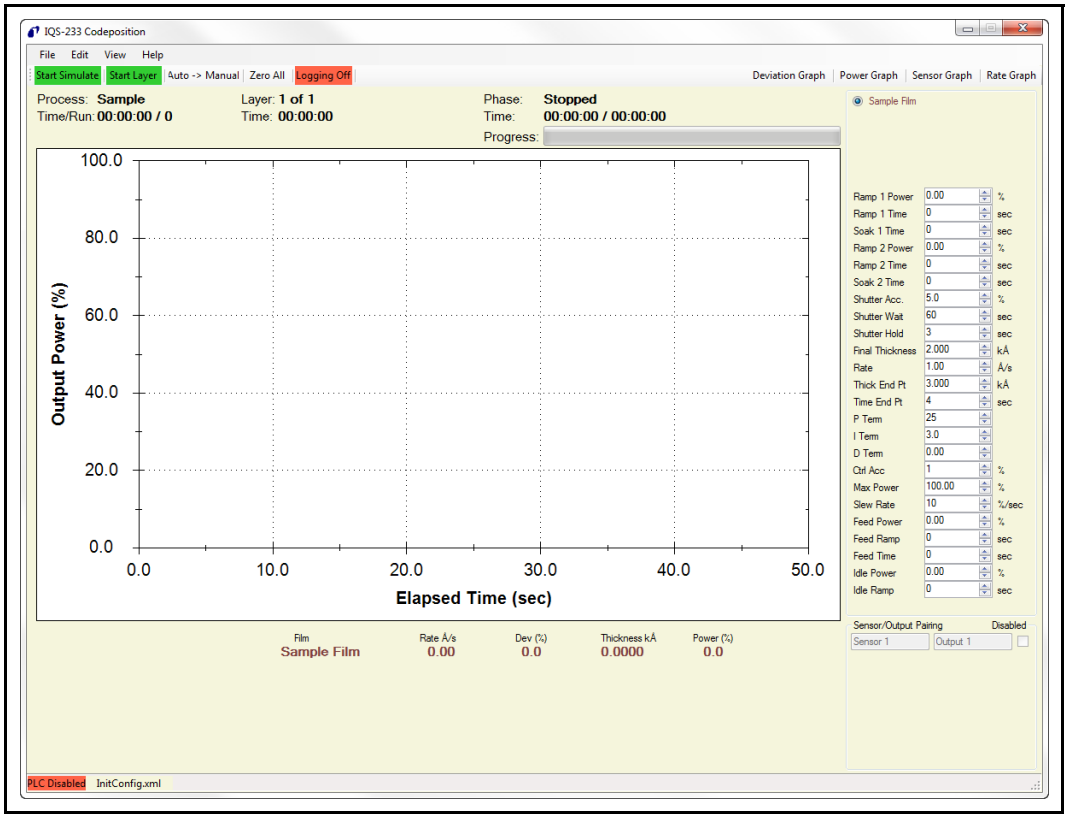
Card Count . . . . . 0 to 6. The displayed number refers to the quantity of installed IQM-233 or SQM-242 cards.

NOTE: If IQM-233 and SQM-242 cards are installed, only the quantity of IQM-233 cards will be reported.

IPN 074-585-P1A

2.3.6 Command Buttons

Figure 2-56 IQS-233 Codeposition window - command buttons



Start Simulate

Abort Simulate . . . . . Displayed if the Simulate check box is selected in the Card tab of the System Setup window. Click Start Simulate, which changes to Abort Simulate, to start a simulated Process. Click Abort Simulate, which changes to Start Simulate, to stop the simulated Process.

Start Process

Abort Process . . . . . Click Start Process, which changes to Abort Process, to start a Process. Click Abort Process, which changes to Start Process, to stop the Process.

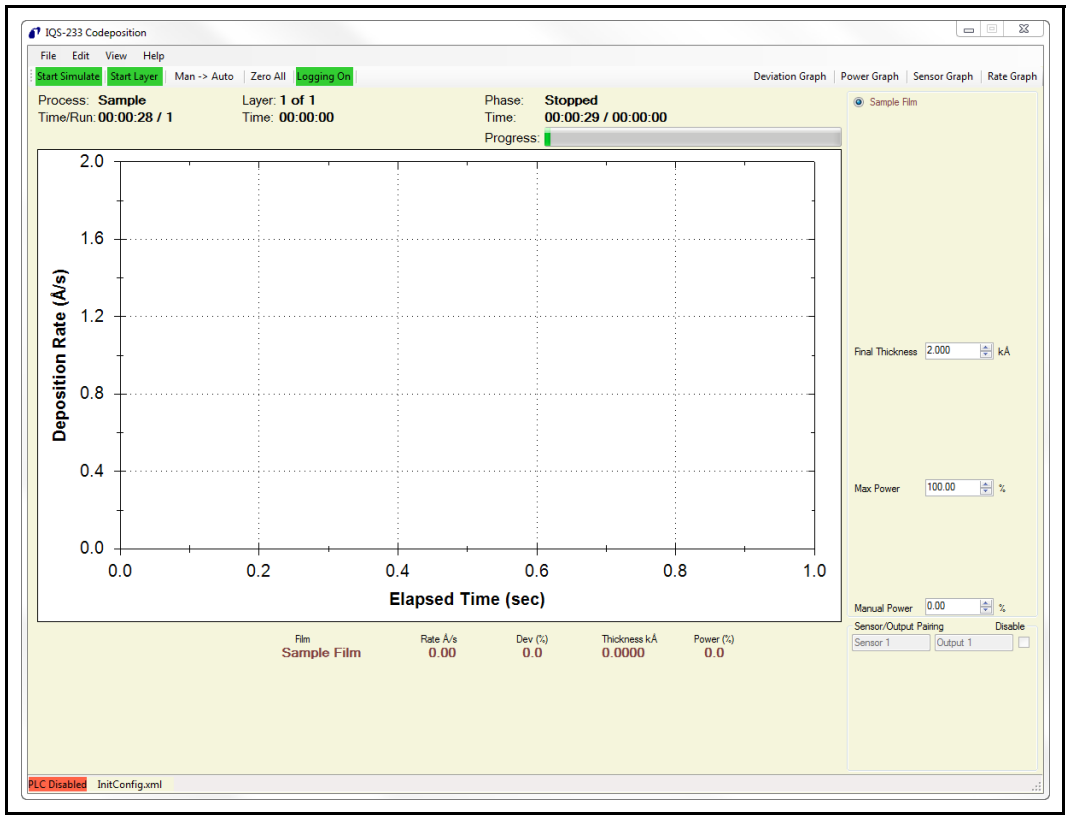
Start Layer, Stop Layer . . . Click Start Layer, which changes to Stop Layer, to start a Layer. Click Stop Layer, which changes to Start Layer, to stop the Layer.

Next Layer . . . . . Abort Simulate changes to Next Layer after reaching Final Thickness of a layer, when clicking Stop Layer, or when an error causes the process to stop. Clicking Next Layer increments the Layer number to the next Layer of a Process.

IPN 074-585-P1A

Auto→Man , Man→Auto . . . . Click Auto→Man , which changes to Man→Auto , to activate Manual mode and display parameters used for manually controlling a deposition without PID loop control.

Figure 2-57 Manual control parameters



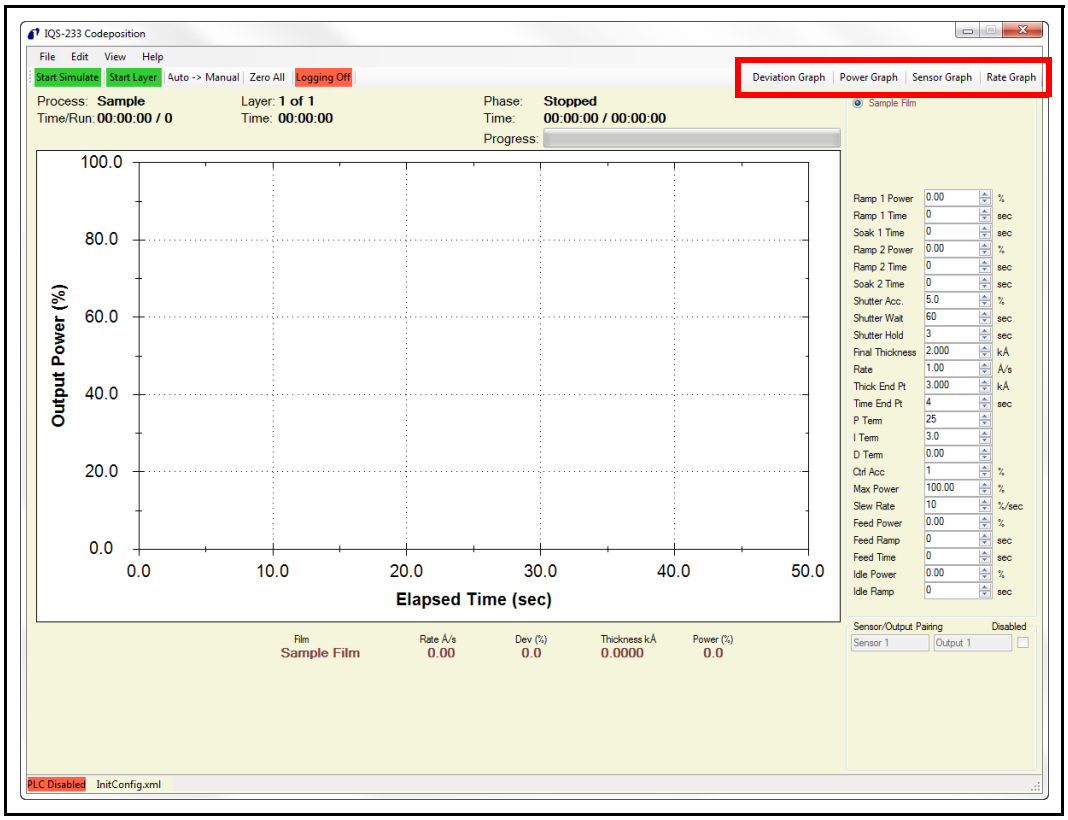
Zero All . . . . . Zeroes the Thickness readouts of all sensors.

Logging Off
Logging On . . . . . Click Logging Off, which changes to Logging On, to activate data logging. Click Logging On, which changes to Logging Off, to make data logging unavailable. Data logging may be activated with Start or Stop displayed; however, data is not collected when Start is displayed.

2.3.7 Graph Buttons

Click **Deviation Graph**, **Power Graph**, **Sensor Graph** or **Rate Graph** to display the selected graph in a new window. Any combination of graphs may be displayed, each opening in a new window. See Figure 2-58.

Figure 2-58 IQS-233 Codeposition window - graph buttons



NOTE: To zoom in the graph, click in the graph window and drag to draw a box over the data needing to be enlarged. To further zoom in, or to zoom out, rotate the wheel button up or down, respectively, with the pointer in the graph window.

- **Deviation Graph**, see section 2.3.7.1
- **Power Graph**, see section 2.3.7.2 on page 2-78
- **Sensor Graph**, see section 2.3.7.3 on page 2-79
- **Rate Graph**, see section 2.3.7.4 on page 2-80

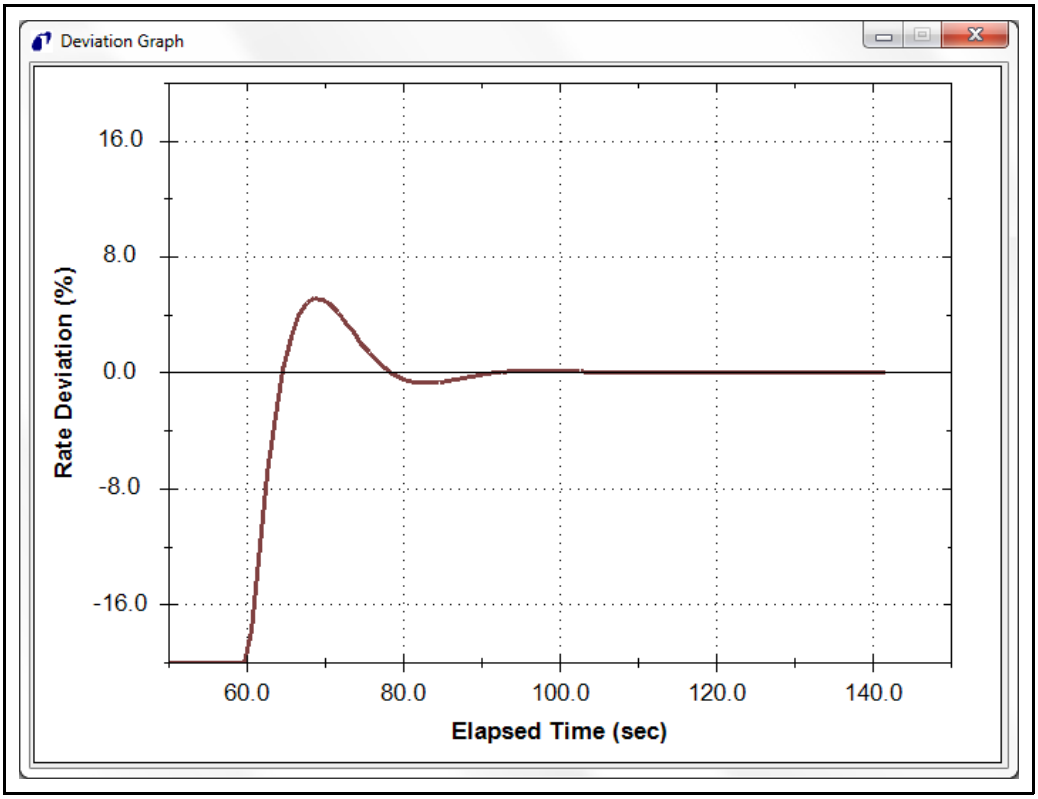
IPN 074-585-P1A

2.3.7.1 Deviation Graph

Click **Deviation Graph** to display the **Deviation Graph** window. See Figure 2-59. The Deviation Graph displays the percent deviation from the desired rate versus time.

NOTE: For a Codeposition Layer, the Rate Deviation of each Film will be displayed on the graph.

Figure 2-59 Deviation Graph window

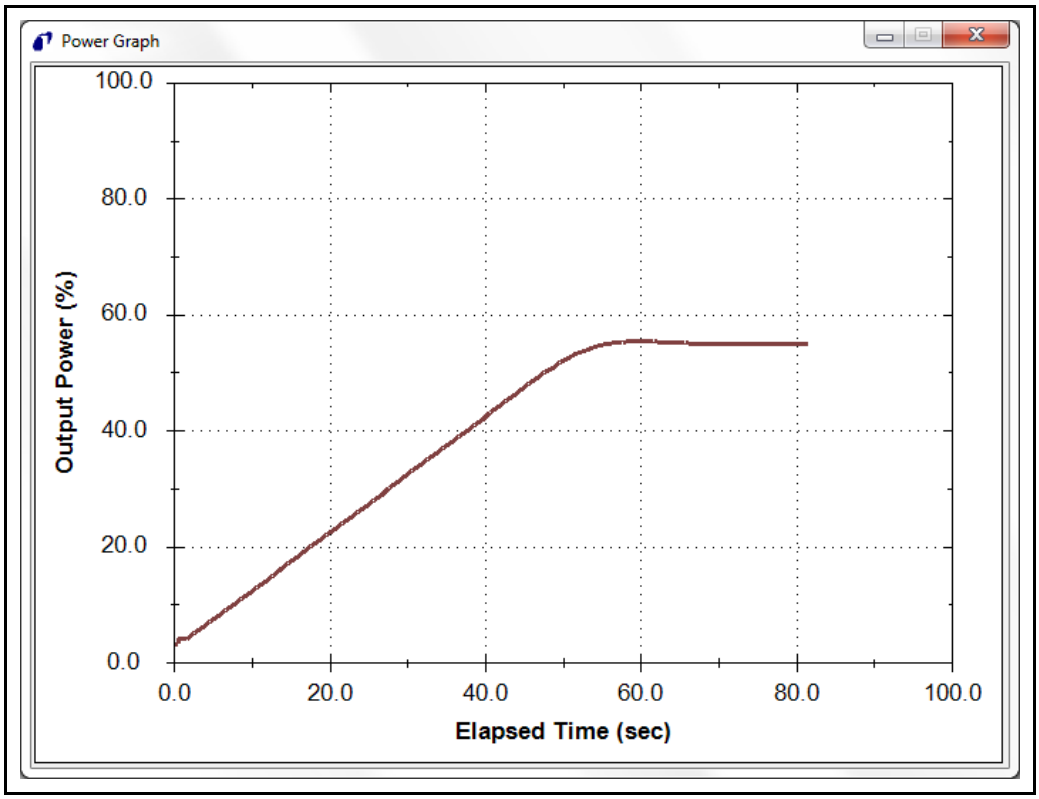


2.3.7.2 Power Graph

Click **Power Graph** to display the **Power Graph** window. See Figure 2-60. The Power Graph displays Output Power for the current Layer versus time.

NOTE: For a Codeposition Layer, the Output Power of each Film will be displayed on the graph.

Figure 2-60 Power Graph window



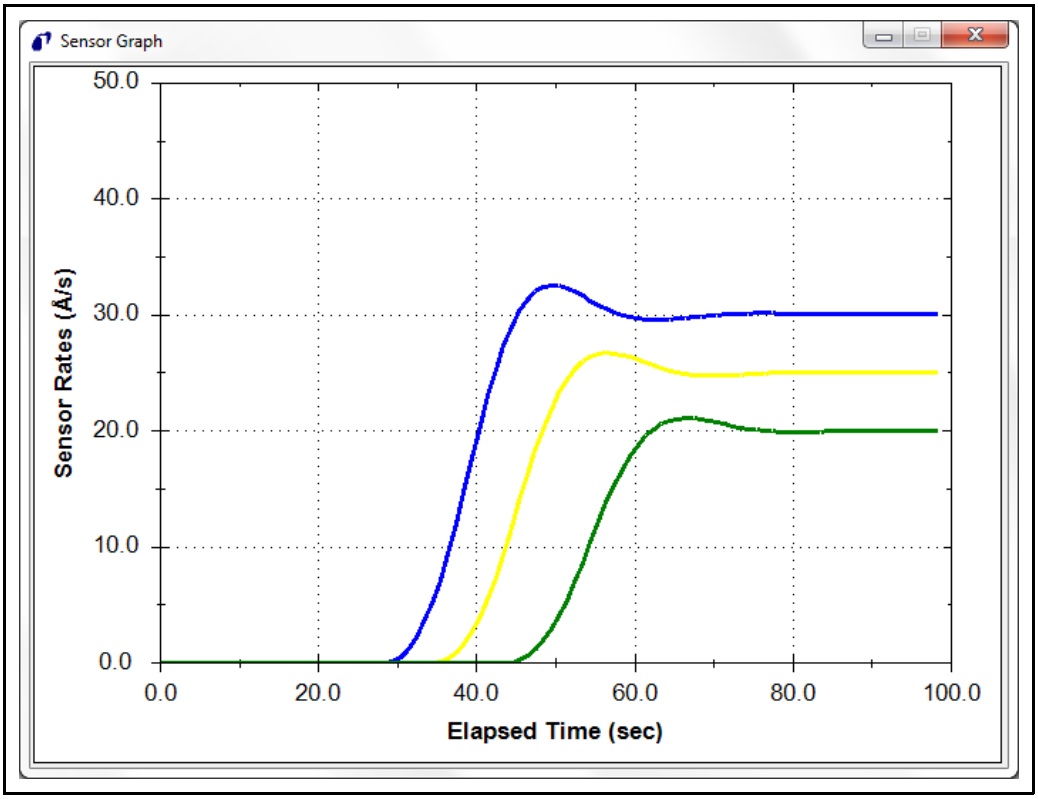
IPN 074-585-P1A

2.3.7.3 Sensor Graph

Click **Sensor Graph** to display the **Sensor Graph** window. See Figure 2-61. The Sensor Graph displays the deposition rate of individual sensors mapped to the Output used for the current Layer versus time.

NOTE: For a Codeposition Layer, the individual sensor rates of each assigned sensor will be displayed on the graph.

Figure 2-61 Sensor Graph window



IPN 074-585-P1A

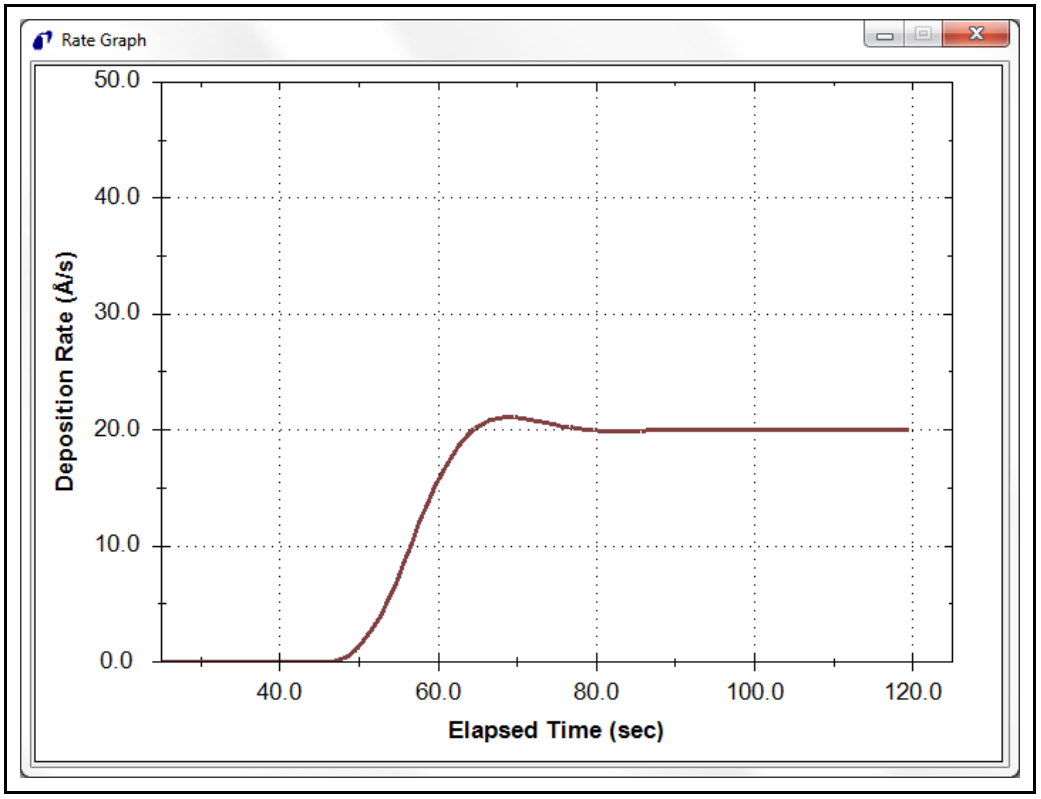
2.3.7.4 Rate Graph

Click **Rate Graph** to display the Rate Graph window. See Figure 2-62.

The Rate Graph window displays deposition rate versus time. If more than one sensor is mapped to the output used by the current Layer, the displayed Rate is an average of the rates for the individual sensors.

NOTE: For a Codeposition Layer, the Deposition Rate of each Film will be displayed on the graph.

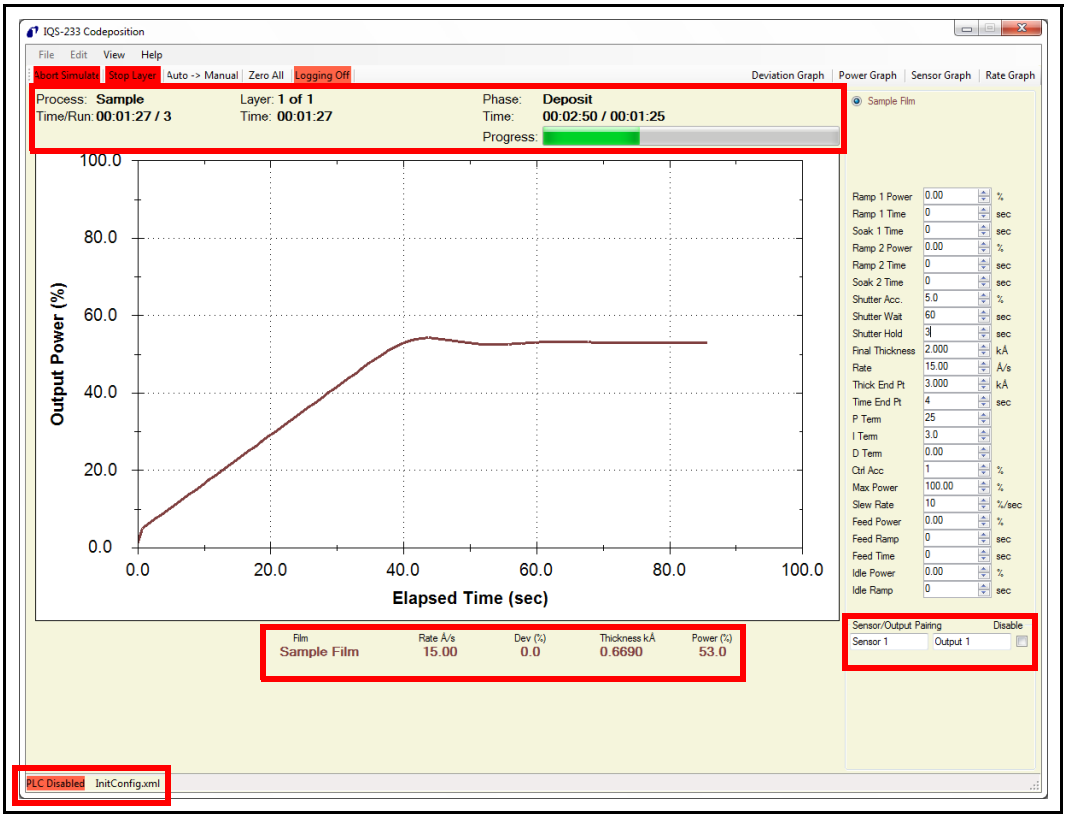
Figure 2-62 Rate Graph window



IPN 074-585-P1A

2.3.8 Process Readouts

Figure 2-63 IQS-233 Codeposition window



Process . . . . . The name of the current Process.

Layer . . . . . The current Layer of the Process.

Time/Run . . . . . Time displays the elapsed time from the start of the current Layer until the Layer is completed or stopped. Run displays the number of times the current Process has been started.

Time (Process) . . . . . The elapsed time from the start of the current Process until the Process is completed or stopped.

Phase . . . . . The current phase of the Process.

- Preconditioning (Indexing, Ramp 1, 2..., Soak 1, 2..., Shutter Delay)
- Deposit
- Feed
- Idle
- Stopped

Time (Phase) . . . . . The left-side displays the time remaining until the current phase ends. The right-side displays the elapsed time for:

- entire preconditioning phase
- Deposition phase
- entire Feed phase
- entire Idle phase

Progress . . . . . Bar graph displaying an indication of the progress of the current phase.

Film . . . . . The name of the Film used for the current Layer.

Rate Å/s . . . . . The calculated rate of deposition at the substrate. If more than one sensor is mapped to the Output used by the current Layer, the displayed rate is an average of the rates for those individual sensors.

NOTE: To display the Readings window where Rates for individual sensors are displayed, click View >> Sensor Readings on the menu bar.

Rate stability is affected by the PID loop values in the Deposit tab on the Film Edit window. Refer to section 2.3.3.5.8 on page 2-31.

Rate accuracy is affected by:

- Density and Z-Ratio values in the Materials window. Refer to section 2.3.3.5.12 on page 2-42.
- Tooling value(s) in the Source/Sensor tab on the Film Edit window. Refer to section 2.3.3.5.10 on page 2-36.
- Period value in the Card tab on the System Setup window. Refer to section 2.3.3.6.5 on page 2-56.

Dev (%) . . . . . Percentage deviation of the Rate (Å/Sec) display from the desired rate setting in the Source Setup window.

IPN 074-585-P1A

Thickness kÅ . . . . . Calculated thickness of material deposited on the substrate. If more than one sensor is mapped to the Output used by the current Layer, the displayed thickness is an average of the thicknesses for those individual sensors.

Thickness is affected by:

- Density and Z-Ratio values in the Materials window (refer to section 2.3.3.5.12 on page 2-42)
- Tooling value(s) in the Source/Sensor tab of the Film Edit window (refer to section 2.3.3.5.10 on page 2-36).

Power (%) . . . . . Percentage of source output voltage relative to the Full Scale (V) voltage setting for the corresponding output channel.

Sensor/Output Pairing . . . . Displays the active sensor(s) monitoring the current Layer and the corresponding output(s) selected in the Layer tab of the Process window (refer to Figure 2-22 on page 2-23).

- **Disable**: Selecting Disable will stop the selected sensor from taking readings and will display the Thickness measured before Disable was selected. Rate and Power will be displayed as zero.

NOTE: If Disable is selected, it cannot be cleared while a Process is running to enable that sensor.

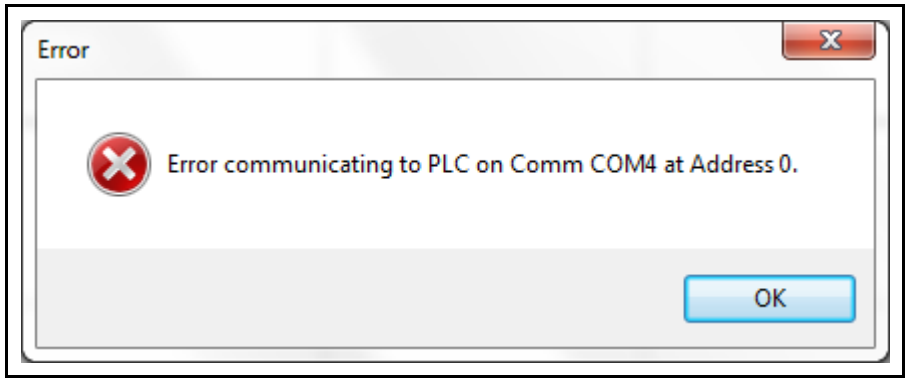
Graph . . . . . The graph displayed in the IQS-233 Codeposition window is selected by clicking **View** on the menu bar and selecting a graph from the list.

- **Rate Graph**: Refer to section 2.3.4.3 on page 2-71.
- **Deviation Graph**: Refer to section 2.3.4.4 on page 2-71.
- **Power Graph**: Refer to section 2.3.4.5 on page 2-71.
- **Sensors Graph**: Refer to section 2.3.4.6 on page 2-71.
- **Automatic**: Refer to section 2.3.4.7 on page 2-71.

IPN 074-585-P1A

Message Area . . . . . PLC Disabled is displayed when Disabled is selected from the list of Port (9600, E, 7, 2) items on the PLC Comm pane of the I/O tab. This can be accessed by clicking Edit >> System and selecting the I/O tab. Refer to section 2.3.3.6.4 on page 2-52. PLC Disabled is also displayed if the Port (9600, E, 7, 2) or Address (CJ1) are invalid and cause a communication error. See Figure 2-64.

Figure 2-64 Error window



- PLC Enabled is displayed when PLC communication is detected and a valid comm serial bus has been selected from the list of Port (9600, E, 7, 2) items on the PLC Comm pane of the I/O tab, accessed by clicking Edit >> System and selecting the I/O tab (refer to section 2.3.3.6.4 on page 2-52), and Address (CJ1) has been assigned a working value (usually 0).
- Init.Config.xml is displayed when the IQS-233 Codeposition software is started.
- The name of a selected configuration file is displayed.

IPN 074-585-P1A

2.4 Configuring a Process

This section provides a general overview on how to use the IQS-233 Codeposition software to configure a process with user selected parameters. For help installing or opening software, refer to:

- section 2.2, Installing IQS-233 Codeposition Software, on page 2-1
- section 2.3.2, Logging On to the Software, on page 2-7

2.4.1 Process Example

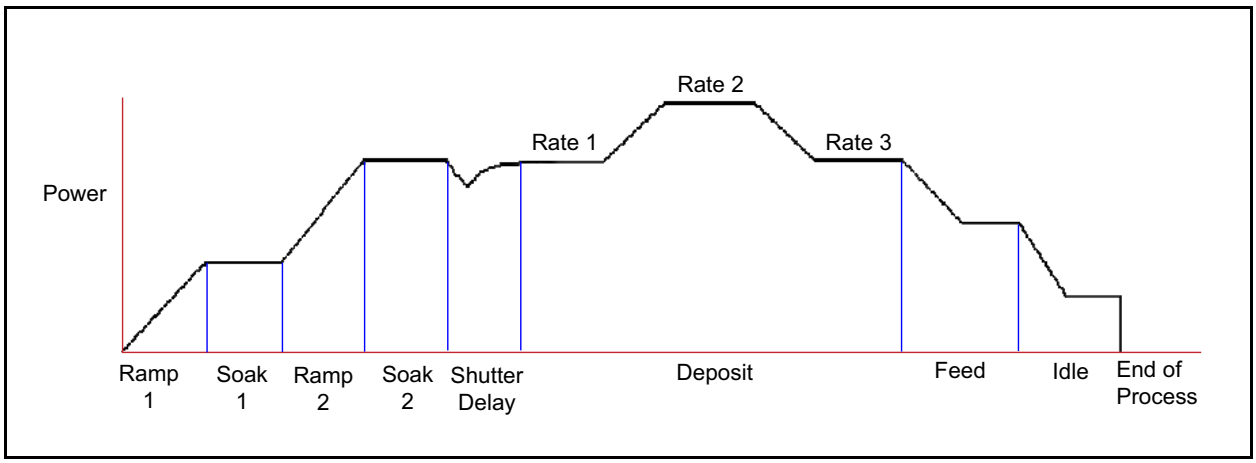
A typical thin film deposition cycle, shown in Figure 2-65, is comprised of three distinct phases:

(1) Preconditioning (ramp/soak)

(2) Deposition

(3) Postconditioning (feed/idle)

Figure 2-65 Typical Deposition Process



During preconditioning, power is applied to prepare the source material for deposition. The first ramp/soak preconditioning phase is used to bring the material to a uniform molten state. The second ramp/soak preconditioning phase is typically set to a power that is near the power required to achieve the desired deposition rate.

When preconditioning ends, PID rate control of deposition begins. Initially, the substrate material may remain shuttered until the desired deposition rate is achieved (shutter delay). Once the control loop achieves the desired rate, the shutter opens and deposition begins. Multiple deposition rates (rate ramps) can be programmed. (Refer to section 2.3.3.5.5 on page 2-26).

IPN 074-585-P1A

When the desired thickness is reached, the evaporation source is set to feed or idle power. At this point the process may be complete, or deposition of another film layer may begin. Up to six separate films can be codeposited within a single layer. There is no practical limit to the total number of processes, layers, or materials that can be stored in the process database.

2.4.2 Selecting a Material

Click **Edit >> Materials** (refer to Figure 2-33 on page 2-42). Select the material to be deposited from the **Material** list. If the material is not listed, click **New** and create a list item with a user supplied name, density, and Z-Ratio. Click **OK** to save changes.

2.4.3 Configuring a Film

1. Click **Edit >> Film** (refer to Figure 2-24 on page 2-28).
2. Click **New** to create and name a new film (refer to section 2.3.3.5.6 on page 2-28).
3. On the **Deposit** tab (refer to section 2.3.3.5.8 on page 2-31), enter **Loop**, **Shutter Delay**, and **Rate Sampling** parameters.
4. On the **Condition** tab (refer to section 2.3.3.5.9 on page 2-34), enter precondition and postcondition parameters.
5. On the **Source/Sensor** tab (refer to section 2.3.3.5.10 on page 2-36), select the material to be used for the film from the **Material** list. Then, enter maximum power, slew rate, and sensor tooling for each sensor in the system.
6. On the **Errors** tab (refer to section 2.3.3.5.11 on page 2-37), click **Ignore**, **Stop Layer**, or **Timer Power** in the **On Error** pane, and then click **Enabled**. Enter parameters for **Control Error**, **Crystal Quality**, **Crystal Fail**, and/or **Crystal Stability** if required by the process.
7. Configure all of the films for the process by repeating steps 1 through 5 for each source.
8. Click **OK** to save changes.

IPN 074-585-P1A

2.4.4 Creating a Process

1. Click **Edit >> Process** (refer to Figure 2-16 on page 2-18).
2. Click **New** to create and name a new process (refer to section 2.3.3.5.1 on page 2-18).
3. On the the **Layer** tab (refer to section 2.3.3.5.4 on page 2-23), select a Film from the **Film** list, an Output from the **Output** list, an Input from the **Input** list, and a Start Mode from the **Start Mode** list, and then enter process parameters for **Setpoint**, **Final Thickness**, **Thickness End Point**, and **Time End Point**. If using indexers, select a pocket number that corresponds to the layer from each list on the **Indexers** pane.

   NOTE: Click on the **Layer Information** pane (refer to Figure 2-21 on page 2-21) to update changes for the layer.
4. If the process requires rate ramps, click the **Rate Ramps** tab (refer to section 2.3.3.5.5 on page 2-26) and enter parameters for **Start Thickness**, **Ramp Time**, and **Setpoint**. Click **Insert Ramp**. Click **OK** to save the changes.

   NOTE: Click on the **Layer Information** pane (refer to Figure 2-21 on page 2-21) to update changes for the layer.
5. With Layer 1 selected, click **Copy Layer >> Paste Layer** to add an additional layer into the process. Edit the parameters for the additional layer.
6. To create a codeposition layer, select Layer 2, click **Cut Layer >> Paste CoDep**.

2.4.5 Configuring the System

1. Click **Edit >> System** and select the **Outputs** tab (refer to Figure 2-37 on page 2-45).
2. Enter the **Full Scale Output Voltages** for each physical output connection on the IQM-233 or SQM-242 card. Test each output prior to connecting a physical output.

   NOTE: Refer to the IQM-233 or SQM-242 operating manual for information about the physical source output connection.
3. Click **OK** to save changes.
4. Click **Edit >> System** and select the **Sensors** tab (refer to Figure 2-38 on page 2-47).
5. Select the physical sensor number for each named sensor and select a monitor output.
6. Select **Dual** for each sensor in a dual sensor configuration connected to the IQM-233 or SQM-242 card.

IPN 074-585-P1A

7 Select **Rate** and/or **Thickness** control for each sensor. If neither **Rate** nor **Thickness** are selected, the crystal will only monitor the process, and the displayed rate and thickness for that sensor will not be used for PID control.

NOTE: Refer to the IQM-233 or SQM-242 operating manual for information about the sensor connection.

8 Click **OK** to save changes.

9 If using an indexer:

9a Click **Edit >> System** and select **Indexers** tab (refer to Figure 2-39 on page 2-50).

9b Enter the **Timeout** for each source or layer indexer connected to the IQM-233 or SQM-242 card.

9c Test each indexer prior to starting the process. Refer to section 2.3.3.6.3 on page 2-50.

NOTE: Refer to the IQM-233 or SQM-242 operating manual for information about indexer connections.

9d Click **OK** to save changes.

10 If using a PLC:

10a Click **Edit >> System** and select **I/O** tab (refer to Figure 2-40 on page 2-52).

10b Select Relay and Input Events to be controlled by the PLC.

10c Select the PLC Comm Port and Address.

10d Test each event prior to starting the process. Refer to section 2.3.3.6.4 on page 2-52.

10e Click **OK** to save changes.

11 Click **Edit >> System** and select **Card** tab (refer to Figure 2-41 on page 2-56).

12 Select a measurement period from the **Period (sec)** list.

NOTE: Longer measurement periods will increase the resolution of the IQM-233 card PID control loop.

13 Enter maximum, initial, and minimum frequency for the crystal that will be used in the process.

14 Click **OK** to save changes.

15 If using remote communication:

15a Click **Edit >> System** and select **Comm** tab (refer to Figure 2-42 on page 2-58).

IPN 074-585-P1A

15b Click **Enabled** or **Ethernet Enabled** to enable RS-232 or Ethernet remote communication, respectively. Refer to section 2.3.3.6.6 on page 2-58.

15c Click **OK** to save changes.

16 Click **Edit >> System** and select the **Display** tab (refer to Figure 2-36 on page 2-44).

17 Select **Display** and **Graph** settings to be viewed in the IQS-233 Codeposition window, refer to section 2.3.3.6.7 on page 2-60.

18 Click **OK** to save changes.

19 Click **File >> Save** to save the current Process and System parameter values to the configuration filename displayed in the message area of the IQS-233 Codeposition window. If the default configuration file, InitConfig.xml, is displayed, the default parameters loaded when IQS-233 Codeposition software is started will be overwritten by any changes made to the **Process** and **System** parameters.

19a Click **File >> Save As** to save the current Process and System configuration under a different name. Configuration files are saved in .xml format. The default folder to save a configuration file to is **C: >> INFICON >> IQS-233 Codeposition**; however, the configuration file may be saved to another folder location if desired (refer to Figure 2-11 on page 2-13).

20 Click **Edit >> System** and select **Card** tab (refer to Figure 2-41 on page 2-56).

21 Select **Enabled** in the Simulate pane.

22 Click **OK** to save changes.

23 Click **Start Simulate** on the IQS-233 Codeposition window (refer to Figure 2-56 on page 2-74) to simulate the process prior to making an actual deposition.

NOTE: Disconnect outputs from the IQM-233 or SQM-242 card(s) to prevent the supply of power to source outputs.

2.4.6 Starting a Process

1 If in Simulate Mode:

1a Click **Edit >> System** and select **Card** tab (refer to Figure 2-41 on page 2-56).

1b Deselect **Enabled** in the Simulate pane.

1c Click **OK** to save changes.

2 Connect the appropriate inputs and outputs to IQM-233 or SQM-242 card(s).

NOTE: Refer to the IQM-233 or SQM-242 operating manual for information about the physical input and output connections.

IPN 074-585-P1A

3 Click **File** and select **Process** to display a list of saved Process configurations (refer Figure 2-9 on page 2-10). The Process list displays a check next to the current Process name indicating that the Process configuration has been loaded for the Process name.

4 Select Auto source control (using a PID control loop) or Manual source control using the command buttons on the IQS-233 Codeposition window (refer to Figure 2-56 on page 2-74).

NOTE: When **Auto→Man** is displayed, PID control loop is activated and parameters used for automatic control are displayed.

5 Click **Auto→Man** , which changes to **Man→Auto** , to activate Manual mode and display parameters used for manually controlling a deposition without PID loop control.

6 If the process requires data logging:

6a Click **Logging Off,** which changes to **Logging On**, to activate data logging. (Click **Logging On**, which changes to **Logging Off**, to make data logging unavailable.)

6b Click **File >> Log Data** to select the parameters to be logged (refer to section 2.3.3.1.5 on page 2-14).

7 Click **Edit >> System** and select **Card** tab (refer to Figure 2-41 on page 2-56).

8 Deselect **Enabled** in the **Simulate** pane.

9 Click **OK** to save changes.

10 Click **View** and click the graph to be displayed on the graph pane of the IQS-233 Codeposition Software window (refer to Figure 2-50 on page 2-66). Also, click Film Settings, Sensor Readings, and/or High Resolution to customize the display of the IQS-233 Codeposition Software window. Refer to section 2.3.4 on page 2-66, for a detailed listing and explanation of each item.

11 Click **Start Process**, which changes to **Abort Process**, to start the Process.

12 Click **Start Layer**, which changes to **Stop Layer**, to start the Layer.

13 Click **Stop Layer**, which changes to **Start Layer**, to stop the Layer.

14 Click **Next Layer** to increment the Layer number to the next Layer of the Process.

15 Click **Abort Process**, which changes to **Start Process**, to stop the Process.

16 Click **File >> Exit** to exit IQS-233 Codeposition software (refer to section 2.3.3.4 on page 2-17).

IPN 074-585-P1A

Chapter 3
Digital I/O

3.1 Introduction

IQS-233 and SQM-242 cards used with IQS-233 Codeposition software do not have digital inputs and outputs. However, digital I/O can be provided by interfacing an external Programmable Logic Controller (PLC) to the computer having IQS-233 or SQM-242 card(s) and IQS-233 Codeposition software installed. This section will cover interfacing a PLC to the computer.

There are several benefits to using an external PLC for I/O. The associated I/O wiring can be placed in a convenient location in a wiring cabinet. A single, serial communications cable connects the PLC to the computer. The PLC provides electrical isolation, fail-safe operation, and extensive I/O processing capabilities through its ladder logic programming.

3.2 PLC Installation

CAUTION

Refer to the PLC operating manual for detailed PLC mounting and connection information.

1. Mount the PLC controller near the devices it is controlling and sensing.
2. Connect the PLC to a properly grounded power source.
3. Connect the RS-232 cable (refer to the PLC operating manual for the cable requirements) from the PLC serial port to the computer serial port.
4. Properly wire the input and output relays according to the PLC operating manual.

3.2.1 Crucible Indexer I/O

Indexers from different manufacturers use a variety of pocket decoding schemes. The PLC monitor program adapts information from IQS-233 Codeposition software to a specific indexer. The two most common indexer decoding schemes are illustrated below.

Binary Pocket Select . . . . . Each pocket requires a dedicated relay. For example, 8 pockets require 8 relays.

IPN 074-585-P1A

Binary Coded Pocket Select . . . . . Pockets are selected by a value that is the binary representation of the pocket, requiring fewer relays. For example, 16 pockets can be selected with four relays.

NOTE: Please refer to the indexer operating manual for information regarding pocket selection.

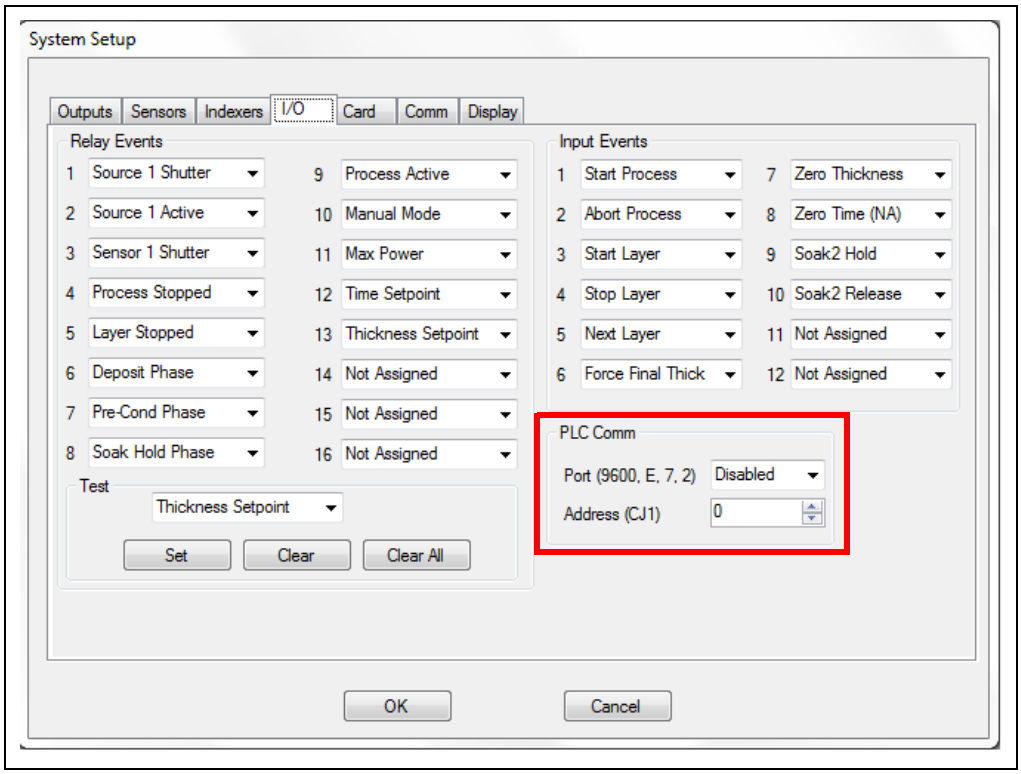
3.2.2 Other Digital I/O

Depending on the PLC, additional relay and input pins are available for other commands.

3.3 PLC Setup and Test

1. In IQS-233 Codeposition software click **Edit >> System >> I/O**.
2. Set the Port (9600, E, 7, 2) to match the serial port connected to the PLC.
3. Set the PLC Comm Address (CJ1) to match the assigned PLC Address (usually 0). See Figure 3-1.

Figure 3-1 System Setup window - I/O tab



IPN 074-585-P1A

4 The COMM LED on the PLC will flash several times a second when the Address and Comm Port are set properly.

5 The **Test** pane of the **I/O** tab provides a means of testing PLC communications and digital I/O wiring.

To test a PLC relay:

5a Note which event is assigned to the relay in **Relay Events**.

5b Select the same event name from the **Test** list.

5c Click **Set** to close the relay.

5d Click **Clear** to open the relay. Refer to Figure 3-1.

6 The **Indexers** tab of the **System Setup** window allows the moving of a source or substrate indexer. Select the index (i.e., pocket) to activate, then click the **Move** button. (Refer to Figure 2-39 on page 2-50).

3.4 PLC Programming

The PLC runs a small ladder logic program that communicates with IQS-233 Codeposition software. This program transfers external relay and input states from the PLC connecting block to internal PLC registers. IQS-233 software reads/writes to those registers.

The IQS-233 software preset commands are adequate for most applications. Additional logic commands can be programmed using the PLC software. Refer to the PLC operating manual for more information on additional ladder logic programming.

The following commands of the internal PLC registers are used by IQS-233 Codeposition software.

PLC Register	IQS-233 Software Command
200	Layer/Phase Register Bits 0-9 are BCD layer number running Bits 10-15 are BCD Phase# as shown below 00 Application Startup 01 Program Initializing 02 Not Used 03 Not Used 04 Process Stopped 05 Ramp1 Phase 06 Soak1 Phase 07 Ramp2 Phase 08 Soak2 Phase 09 Shutter Delay Phase 10 Deposit Phase 11 Layer Stopped 12 Layer Starting 13 Not Used 14 Feed Ramp Phase 15 Feed Hold Phase 16 Idle Ramp Phase 17 Idle Phase 18 Continuous Phase

IPN 074-585-P1A

201	Sensors/Outputs 1-4 Register (updated each layer) Bits 0-7 are sensors used (1=used, 0=unused) Bits 12-15 are outputs used, 12 is Out1, 13 is Out2, etc.
202	Analog/Outputs 5-6 Register (updated each layer) Bits 0-3 are analog inputs used (1=used, 0=unused) Bits 4-5 outputs used, 4 is Out5, 5 is Out6 Bits 8-11 are BCD of Output source index Bits 12-15 are BCD of Output 6 source index
220	Source Index Register (updated each layer) Bits 0-3 are BCD of Output 1 source index Bits 4-7 are BCD of Output 2 source index Bits 8-11 are BCD of Output 3 source index Bits 12-15 are BCD of Output 4 source index
221	Source Indexer Done Flag Bit 0 is Source Indexer 1 (1= Indexer Done, 0=Not Done) Bit 1 is Source Indexer 2 Bit 2 is Source Indexer 3 Bit 3 is Source Indexer 4 Bit 4 is Source Indexer 5 Bit 6 is Source Indexer 6
222	Relays 1-16 Bit 0 is Relay 1, etc.
224	Inputs 1-12 Bit 0 is Input 1, etc.
225	Layer Index Register Bits 0-3 are BCD of Layer Indexer 1 Bits 4-7 are BCD of Layer Indexer 2 Bits 8-15 are BCD of Layer Indexer 3
226	Layer Indexer Done Flag Bit 0 is Layer Indexer 1 (1= Indexer Done, 0=Not Done) Bit 1 is Layer Indexer 2 Bit 2 is Layer Indexer 3

IPN 074-585-P1A

Chapter 4
Calibration Procedures

4.1 Importance of Density, Tooling and Z-Ratio

The quartz crystal microbalance precisely measures the mass added to the face of the oscillating quartz crystal sensor. IQM-233 has knowledge of the density of this added material allowing conversion of the mass information into thickness. In some instances, where highest accuracy is required, it is necessary to make a density calibration as outlined in section 4.2.

Because the flow of material from a deposition is not uniform, it is necessary to account for the different amount of material flow onto the sensor compared to the substrates. This is accounted for by the Tooling parameter. Tooling can be experimentally established by following the guidelines in section 4.3.

The Z-Ratio compensates for the elasticity of the deposited material to the quartz crystal. If the Z-Ratio is not known, it can be estimated from the procedures outlined in section 4.4, Determining Z-Ratio, on page 4-3.

4.2 Determining Density

NOTE: The bulk density values retrieved from Appendix A, Material Table are sufficiently accurate for most applications.

Follow the steps below to determine density value.

1. Place a substrate (with proper masking for film thickness measurement) adjacent to the sensor, so that the same thickness will be accumulated on the crystal and substrate.
2. Set Density to the bulk value of the film material or to an approximate value in the Material window (click **Edit >> Materials**).
3. Set Z-Ratio to 1.000 in the Material window (click **Edit >> Materials**) and Sensor Tooling to 100.00% in the Source/Sensor tab of the Film Edit window (click **Edit >> Films**).
4. Place a new crystal in the sensor. Make a short deposition (1000-5000 Å), and record the Thickness reading displayed in IQS-233 Codeposition software window when finished depositing.
5. After deposition, remove the test substrate and measure the film thickness with a multiple beam interferometer or a stylus-type profilometer.

IPN 074-585-P1A

6 Determine the new density value with equation [1]:

$$\text{Density}(g/cm^3) = D_i\left(\frac{T_x}{T_m}\right) \quad [1]$$

where:

D_i = Initial density setting

T_x = Thickness reading in the IQS-233 Codeposition software window.

T_m = Measured thickness

7 Round off density to the nearest 0.01 g/cm^3.

8 A quick check of the calculated density may be made by programming IQS-233 Codeposition software with the new density value and observing that the displayed thickness is equal to the measured thickness, provided that the Thickness readout has not been zeroed between the test deposition and entering the calculated density.

NOTE: Due to variations in source distribution and other system factors, it is recommended that a minimum of three separate evaporations be made to obtain an average value for density.

NOTE: Slight adjustment of density may be necessary in order to achieve $T_x = T_m$.

4.3 Determining Tooling

1 Place a test substrate in the system's substrate holder.

2 Make a short deposition and record the Thickness reading displayed in the IQS-233 Codeposition software window when finished depositing.

3 Remove the test substrate and measure the film thickness with a multiple beam interferometer or a stylus-type profilometer.

4 Calculate Tooling from the relationship shown in equation [2]:

$$\text{Tooling}\ (\%) = TF_i\left(\frac{T_m}{T_x}\right) \quad [2]$$

where:

T_m = Actual thickness at substrate holder

T_x = Thickness reading in the IQS-233 Codeposition software window

TF_i = Initial Tooling factor

IPN 074-585-P1A

5 Enter this new value for Sensor Tooling, rounded to the nearest 0.1%, in the Source/Sensor tab of the Film Edit window (click **Edit >> Films**); T_m will equal T_x if calculations are done properly.

NOTE: Due to variations in source distribution and other system factors, it is recommended that a minimum of three separate evaporations be made to obtain an average value for Tooling.

4.4 Determining Z-Ratio

A list of Z-Ratio values for materials commonly used are available in Appendix A, Material Table. For other materials, Z-Ratio can be calculated from the following formula:

$$Z = \left(\frac{d_q \mu_q}{d_f \mu_f}\right)^{\frac{1}{2}} \quad [3]$$

$$Z = 9.378 \times 10^5 (d_f \mu_f)^{-\frac{1}{2}} \quad [4]$$

where:

d_f = Density (g/cm^3) of deposited film

μ_f = Shear modulus (dynes/cm^2) of deposited film

d_q = Density of quartz (crystal) (2.649 g/cm^3)

μ_q = Shear modulus of quartz (crystal) (3.32 x 10^{11} dynes/cm^2)

The densities and shear moduli of many materials can be found in a number of handbooks.

Laboratory results indicate that Z-Ratio values of materials in thin-film form are very close to the bulk values. However, for high stress producing materials, Z-Ratio values of thin films are slightly smaller than those of the bulk materials. For applications that require more precise calibration, the following direct method is suggested:

1 Establish the correct density value as described in section 4.2 on page 4-1.

2 Install a new crystal and record its starting frequency, F_{co}. The starting frequency is displayed in the Frequency (MHz) readout of the Readings window (click View >> Sensor Readings).

IPN 074-585-P1A

3 Make a deposition on a test substrate such that the percent crystal Life readout in the Readings window displays approximately 50%, or near the end of crystal life for the particular material, whichever is smaller (the accuracy of the Z-Ratio determination will improve with increased material thickness).

4 Stop the deposition and record the ending crystal frequency F_c from the Frequency (MHz) readout of the Readings window.

5 Remove the test substrate and measure the film thickness with either a multiple beam interferometer or a stylus-type profilometer.

6 Using the density value from step 1 and the recorded values for F_{co} and F_c, adjust the Z-Ratio value in thickness equation [5] to bring the calculated thickness value into agreement with the actual thickness. If the calculated value of thickness is greater than the actual thickness, increase the Z-Ratio value. If the calculated value of thickness is less than the actual thickness, decrease the Z-Ratio value.

$$T_f = \frac{Z_q \times 10^4}{2\pi z p}\left\{\left(\frac{1}{F_{co}}\right)\mathrm{ATan}\left(z\mathrm{Tan}\left(\frac{\pi F_{co}}{F_q}\right)\right) - \left(\frac{1}{F_c}\right)\mathrm{ATan}\left(z\mathrm{Tan}\left(\frac{\pi F_c}{F_q}\right)\right)\right\} \qquad [5]$$

where:

T_f = Thickness of deposited film (kÅ)

F_{co} = Starting frequency of the sensor crystal (Hz)

F_c = Final frequency of the sensor crystal (Hz)

F_q = Nominal blank frequency = 6045000 (Hz)

z = Z-Ratio of deposited film material

Z_q = Specific acoustic impedance of quartz = 8765000 (kg/(m^2 x s))

p = Density of deposited film (g/cm^3)

For multiple layer deposition (for example, two layers), the Z-Ratio used for the second layer is determined by the relative thickness of the two layers. For most applications the following three rules will provide reasonable accuracies:

- If the thickness of layer 1 is large compared to layer 2, use the Z-Ratio of material 1 for both layers.
- If the thickness of layer 1 is thin compared to layer 2, use the Z-Ratio of material 2 for both layers.
- If the thickness of both layers is similar, use a value for Z-Ratio which is the weighted average of the two Z-Ratios for deposition of layer 2 and subsequent layers.

IPN 074-585-P1A

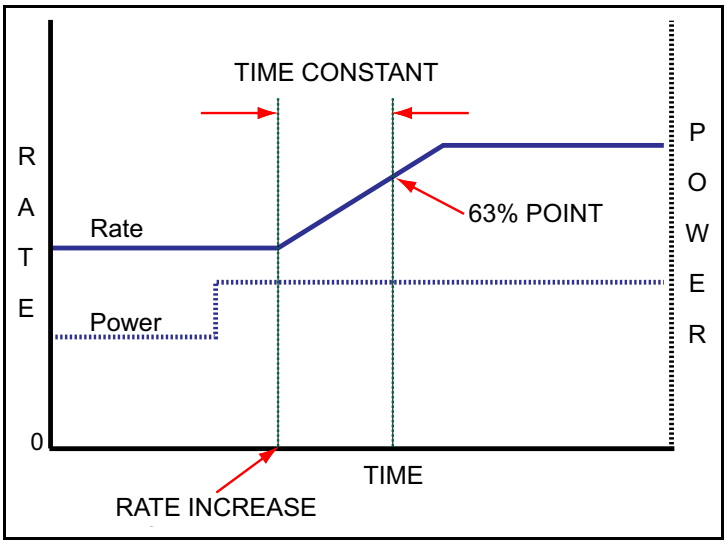
4.5 Tuning the Control Loop

The command of the control loop parameters is to match the instrument's reaction to an error (between the measured deposition rate and the desired rate) to the time related characteristics of the deposition source and its power supply. There are three adjustable parameters; **P** (proportional), **I** (integral) and **D** (derivative) used to accomplish this. It is convenient to think of sources as falling into two categories: "fast" or "slow." The tuning parameters are affected by source level, rate, sweep range or beam density, Tooling and source condition.

The P parameter is the proportional term that sets the gain of the control loop. Enter a higher value for a more responsive (but potentially unstable) control loop and a lower value for the less responsive control loop.

The I parameter is defined as the integral term that inversely sets the setpoint correction gain (a small number causes more error correction). It can be estimated as twice the time for the rate to go from 1/3 to 2/3 of the desired rate (see Figure 4-1). It instructs the controller on how much attention to pay to the schedule of the rate profile.

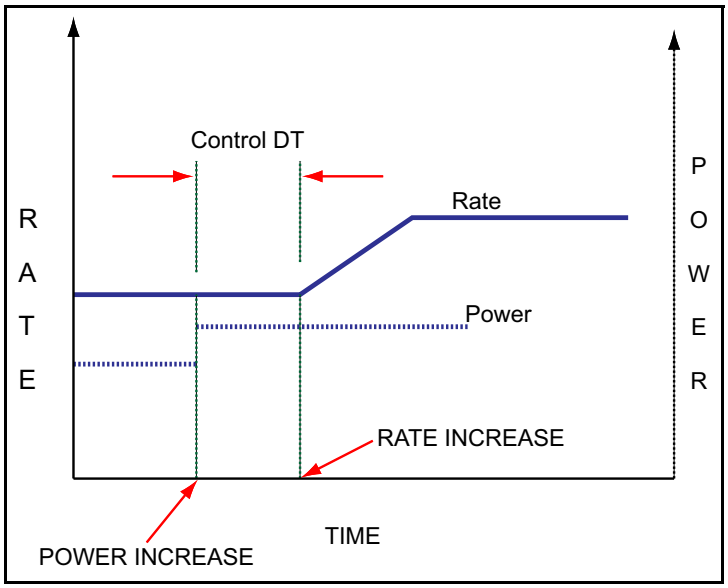
Figure 4-1 Determining the I value



The D parameter is equivalent to the system Dead Time and is used to compensate for slow responding sources such as boats and induction heated sources. This value can be estimated from the time difference between a change in % power and the start of an actual change in rate (see Figure 4-2.) The D parameter instructs the controller on how much attention to pay to the Rate Deviation error. A value of zero tells the controller to ignore the Rate Deviation error. A large value tells the controller that the source is slow and it is going to be harder to get it going and harder to stop it. Therefore, if the rate starts to fall off, power increases, or if the target rate is quickly approaching, power decreases. Measurement rate noise may cause power output instability with larger D values.

IPN 074-585-P1A

Figure 4-2 Determining the D value



4.5.1 Identifying a Fast or Slow Source

Classifying a source as being fast or slow is based on the time it takes for the rate to change from a change in power (delay). It is straight forward to measure the delay. Using manual power, establish a rate and allow it to become steady. Increase the source power a few percent (~5% if possible). Allow the source to again stabilize. If the delay time is greater than 1 second, the source is characterized as slow. All other sources are considered fast. In general, electron beam (e-beam) sources (unless a hearth liner is used), some very small filament sources, and sputtering sources are considered fast sources. Thermal evaporation sources are typically considered slow.

IPN 074-585-P1A

4.5.2 Loop Tuning Procedure

NOTE: Control loop tuning is a trial and error process and there is no "best" procedure to accomplish this task. It may take several adjustments to achieve the desired tune.

1 **Set System Parameters**

1a In the **System Setup** window (**Edit >> System**), click the Card tab and clear the **Enable Simulate** check box (if selected).

1b In the **System Setup** window, click the **Display** tab. Set **Period** to **0.25** to see the noise of the system.

2 **Create a One-Layer Test Process**

2a In the **Materials** window (**Edit >> Materials**), enter the **Z-Ratio** and **Density** of the material being deposited.

2b In the **Layer** tab of the **Process window** (**Edit >> Process**), set the desired **Setpoint** (rate) and a non-zero **Final Thickness** (Final Thickness setting must be large enough so it will not be reached during this procedure).

3 **Activate Data Logging**

3a In the **DataLog** window (**File >> Log Data**) select the Data Log path and attributes.

3b Click **Logging Off** (changes to **Logging On**) to activate data logging.

NOTE: Data Logging does not collect data until Start is clicked.

4 **Test the System Setup**

4a In the **Process** window, select **Manual Start** for **Start Mode** and click **OK**.

4b In the **IQS-233 Codeposition** window, click **Auto -> Man** (changes to **Man -> Auto**) and click **Start**.

4c In the **Manual Power** box, slowly increase power to **10%** and verify that the power supply output is 10% of Full Scale. If the readings do not agree, verify that the **Full Scale Out** voltage in the **Outputs** tab of the **System Setup** window (**Edit >> System**) agrees with the power supply input specifications.

4d Continue to increase power until the desired rate is achieved.

4e Log the data for a few minutes.

4f Slowly decrease power to **0%**, and then click **Stop**.

IPN 074-585-P1A

4g Plot the data in a spreadsheet program. If the system has significant short term noise at a fixed power, the control loop will be difficult to adjust, especially at low rates. The source of the noise should be eliminated before attempting to set the PID values (refer to the Troubleshooting section in the IQM-233 or SQM-242 operating manual).

5 **Determine Max Power**

5a In the **Process** window, verify **Manual Start** is selected for **Start Mode**.

5b Click **Start**.

5c In the **Manual Power** box, slowly increase power until the desired rate is achieved.

5d Record the **Power (%)** reading at the desired rate as PWR_{DR}.

5e In the **Max Power** box, select a value 20% higher than PWR_{DR}.

5f If finished, slowly decrease power to 0%, and then press **Stop**. Otherwise, continue to step 7.

6 **Determine Open Loop Response Time** (refer to Figure 4-1 on page 4-5)

6a Calculate 1/3 of the desired rate ($RATE_{1/3}$), and 2/3 of the desired rate ($RATE_{2/3}$).

6b Slowly adjust the power until the rate matches $RATE_{1/3}$ and is steady.

6c Quickly adjust Power (%) to PWR_{DR} and measure the time for the rate to equal $RATE_{2/3}$.

6d Twice the measured time is the step response time, $TIME_{SR}$.

6e If finished, slowly decrease power to 0%, and then press **Stop**. Otherwise, continue to step 8.

NOTE: $TIME_{SR}$ is typically 0.2 to 1 second for e-beam evaporation and at least 5 seconds for thermal evaporation.

NOTE: It is recommended to repeat this step several times to get an average response time.

IPN 074-585-P1A

7 **Determine the Dead Time** (refer to Figure 4-2 on page 4-6)

7a Slowly increase power until the desired rate is achieved.

7b Quickly adjust power by 1 to 2% and measure the time between when the power is changed and when a change in rate is observed.

7c The time between the change in power and when the rate starts to change is the Dead Time.

7d If finished, slowly decrease power to 0%, and then press **Stop**. Otherwise, continue to step 9.

NOTE: It is common for the Dead Time of a fast source, such as an e-beam, to be very small and possibly immeasurable. In this case, the Dead Time can be considered zero.

8 **Set Initial PID Values**

8a Set the power to zero.

8b **For a fast source** (refer to section 4.5.1 on page 4-6)

- In the **Deposit** tab on the **Film Edit** window (**Edit >> Films**):
  - Set **P** to **25**.
  - Set **I** to the TIMESR value (calculated in step 7) or zero.
  - Set **D** to zero.

8c **For a slow source** (refer to section 4.5.1 on page 4-6)

- In the **Deposit** tab on the **Film Edit** window (**Edit >> Films**):
  - Set **P** to **25**.
  - Set **I** to the TIMESR value (calculated in step 7).
  - Set **D** to the Dead Time value (calculated in step 8).

IPN 074-585-P1A

9 Adjust PID Values according to control response.

9a Click **Man -> Auto** (changes to **Auto -> Man**) to activate PID control and observe the power.

- The power should rise from 0% and stabilize near PWR$_{DR}$.
- If there is more than 10% overshoot in power or if the curve appears under damped, lower the **P** value. If the time to reach PWR$_{DR}$ is very slow (over damped), increase the **P** value. See Figure 4-3.
- A lower **I** value will increase response for over damped sources. A higher value may reduce ringing and rate deviations seen with under damped sources. See Figure 4-3.
- The **D** value should not need much adjustment, but if under damped behavior is observed, increase the **D** value. If it appears over damped, decrease the **D** value. See Figure 4-4.

9b Continue to adjust **P** and **I** values, alternating between 0% power in **Manual** mode and **Auto** mode until the steady-state response is smooth and the step response is controlled.

9c If finished, slowly decrease power to 0%, and then press **Stop**.

NOTE: Preconditioning will minimize step changes.

NOTE: E-beam systems may require additional steps to limit the control loop response during arcing. First, be sure the **Max Power** parameter in the **Source/Sensor** tab of the **Film Edit** window (**Edit >> Films**) is set to limit the output power to a reasonable value for the material and rate. The **Slew Rate** setting can further limit aggressive power changes. At rates below 10 Å/s, a Slew Rate of 1 - 2% is common.

IPN 074-585-P1A

Figure 4-3 Examples of Control Loop Damping

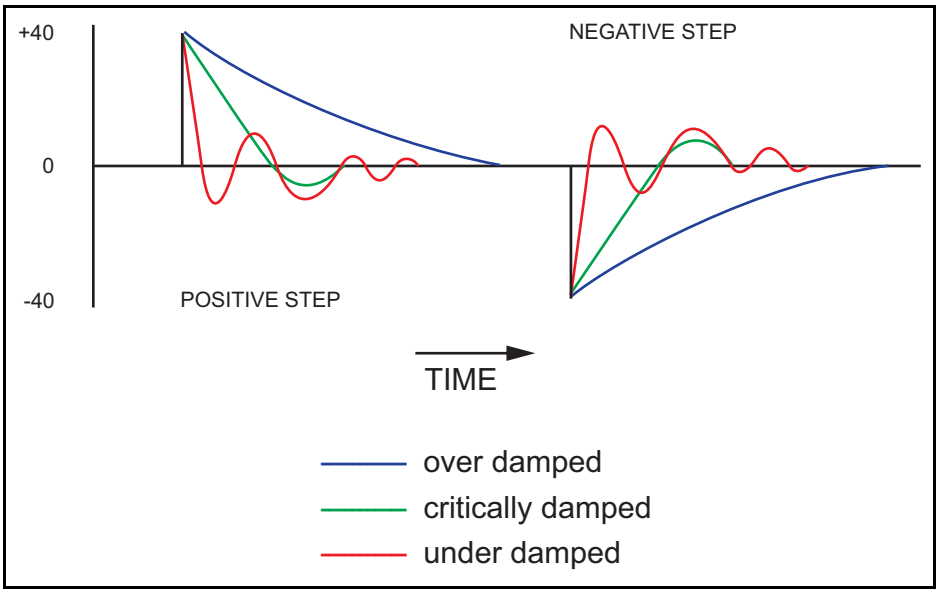
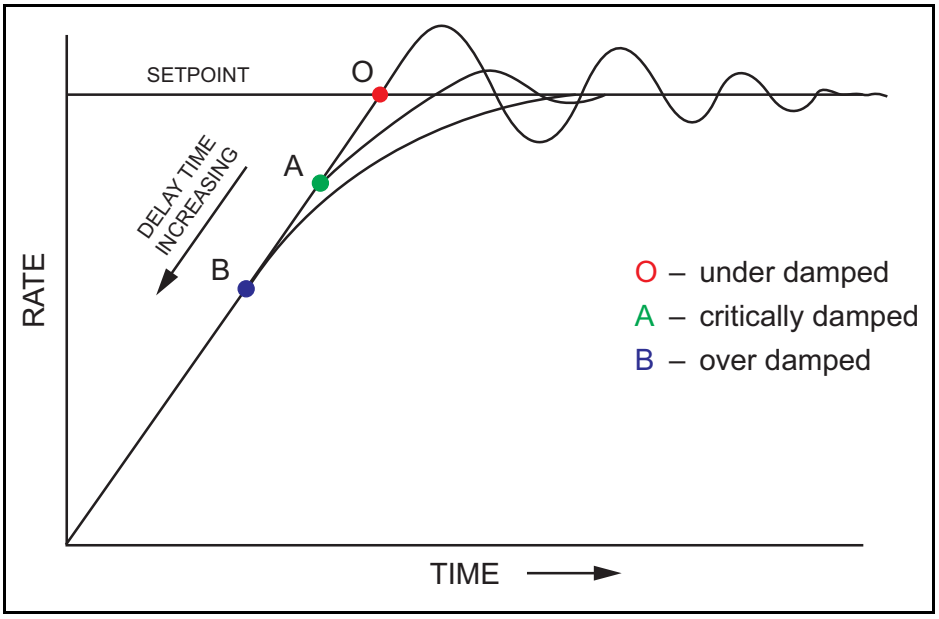


Figure 4-4 Examples of Dead Time Settings



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IPN 074-585-P1A

Appendix A
Material Table

A.1 Introduction

Table A-1 represents the density and Z-Ratio for various materials. The list is alphabetical by chemical formula.

An * is used to indicate that a Z-Ratio has not been established for a certain material. A value of 1.000 is defaulted in these situations. To determine the Z-Ratio where the Z-Ratio for a material has not been established, refer to section 4.4, Determining Z-Ratio, on page 4-3.

WARNING

Some of these materials are toxic. Consult their material safety data sheet and safety instructions before use.

Table A-1 Material table

Formula	Density	Z-Ratio	Material Name
Ag	10.500	0.529	silver
AgBr	6.470	1.180	silver bromide
AgCl	5.560	1.320	silver chloride
Al	2.700	1.080	aluminum
Al_2O_3	3.970	0.336	aluminum oxide
Al_4C_3	2.360	*1.000	aluminum carbide
AlF_3	3.070	*1.000	aluminum fluoride
AlN	3.260	*1.000	aluminum nitride
AlSb	4.360	0.743	aluminum antimonide
As	5.730	0.966	arsenic
As_2Se_3	4.750	*1.000	arsenic selenide
Au	19.300	0.381	gold
B	2.370	0.389	boron
B_20_3	1.820	*1.000	boron oxide
B_4C	2.370	*1.000	boron carbide
BN	1.860	*1.000	boron nitride

IPN 074-585-P1A

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
Ba	3.500	2.100	barium
BaF_2	4.886	0.793	barium fluoride
BaN_2O_6	3.244	1.261	barium nitrate
BaO	5.720	*1.000	barium oxide
$BaTiO_3$	5.999	0.464	barium titanate (tetr)
$BaTiO_3$	6.035	0.412	barium titanate (cubic)
Be	1.850	0.543	beryllium
BeF_2	1.990	*1.000	beryllium fluoride
BeO	3.010	*1.000	beryllium oxide
Bi	9.800	0.790	bismuth
Bi_2O_3	8.900	*1.000	bismuth oxide
Bi_2S_3	7.390	*1.000	bismuth trisulphide
Bi_2Se_3	6.820	*1.000	bismuth selenide
Bi_2Te_3	7.700	*1.000	bismuth telluride
BiF_3	5.320	*1.000	bismuth fluoride
C	2.250	3.260	carbon (graphite)
C	3.520	0.220	carbon (diamond)
C_8H_8	1.100	*1.000	parlyene (union carbide)
Ca	1.550	2.620	calcium
CaF_2	3.180	0.775	calcium fluoride
CaO	3.350	*1.000	calcium oxide
$CaO\text{-}SiO_2$	2.900	*1.000	calcium silicate (3)
$CaSO_4$	2.962	0.955	calcium sulfate
$CaTiO_3$	4.100	*1.000	calcium titanate
$CaWO_4$	6.060	*1.000	calcium tungstate
Cd	8.640	0.682	cadmium
CdF_2	6.640	*1.000	cadmium fluoride
CdO	8.150	*1.000	cadmium oxide
CdS	4.830	1.020	cadmium sulfide
CdSe	5.810	*1.000	cadmium selenide
CdTe	6.200	0.980	cadmium telluride
Ce	6.780	*1.000	cerium
CeF_3	6.160	*1.000	cerium (iii) fluoride

IPN 074-585-P1A

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
CeO_2	7.130	*1.000	cerium (iv) dioxide
Co	8.900	0.343	cobalt
CoO	6.440	0.412	cobalt oxide
Cr	7.200	0.305	chromium
Cr_2O_3	5.210	*1.000	chromium (iii) oxide
Cr_3C_2	6.680	*1.000	chromium carbide
CrB	6.170	*1.000	chromium boride
Cs	1.870	*1.000	cesium
Cs_2SO_4	4.243	1.212	cesium sulfate
CsBr	4.456	1.410	cesium bromide
CsCl	3.988	1.399	cesium chloride
CsI	4.516	1.542	cesium iodide
Cu	8.930	0.437	copper
Cu_2O	6.000	*1.000	copper oxide
Cu_2S	5.600	0.690	copper (i) sulfide (alpha)
Cu_2S	5.800	0.670	copper (i) sulfide (beta)
CuS	4.600	0.820	copper (ii) sulfide
Dy	8.550	0.600	dysprosium
Dy_2O_3	7.810	*1.000	dysprosium oxide
Er	9.050	0.740	erbium
Er_2O_3	8.640	*1.000	erbium oxide
Eu	5.260	*1.000	europium
EuF_2	6.500	*1.000	europium fluoride
Fe	7.860	0.349	iron
Fe_2O_3	5.240	*1.000	iron oxide
FeO	5.700	*1.000	iron oxide
FeS	4.840	*1.000	iron sulphide
Ga	5.930	0.593	gallium
Ga_2O_3	5.880	*1.000	gallium oxide (b)
GaAs	5.310	1.590	gallium arsenide
GaN	6.100	*1.000	gallium nitride
GaP	4.100	*1.000	gallium phosphide
GaSb	5.600	*1.000	gallium antimonide

IPN 074-585-P1A

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
Gd	7.890	0.670	gadolinium
Gd_2O_3	7.410	*1.000	gadolinium oxide
Ge	5.350	0.516	germanium
Ge_3N_2	5.200	*1.000	germanium nitride
GeO_2	6.240	*1.000	germanium oxide
GeTe	6.200	*1.000	germanium telluride
Hf	13.090	0.360	hafnium
HfB_2	10.500	*1.000	hafnium boride
HfC	12.200	*1.000	hafnium carbide
HfN	13.800	*1.000	hafnium nitride
HfO_2	9.680	*1.000	hafnium oxide
$HfSi_2$	7.200	*1.000	hafnium silicide
Hg	13.460	0.740	mercury
Ho	8.800	0.580	holminum
Ho_2O_3	8.410	*1.000	holminum oxide
In	7.300	0.841	indium
In_2O_3	7.180	*1.000	indium sesquioxide
In_2Se_3	5.700	*1.000	indium selenide
In_2Te_3	5.800	*1.000	indium telluride
InAs	5.700	*1.000	indium arsenide
InP	4.800	*1.000	indium phosphide
InSb	5.760	0.769	indium antimonide
Ir	22.400	0.129	iridium
K	0.860	10.189	potassium
KBr	2.750	1.893	potassium bromide
KCl	1.980	2.050	potassium chloride
KF	2.480	*1.000	potassium fluoride
KI	3.128	2.077	potassium iodide
La	6.170	0.920	lanthanum
La_2O_3	6.510	*1.000	lanthanum oxide
LaB_6	2.610	*1.000	lanthanum boride
LaF_3	5.940	*1.000	lanthanum fluoride
Li	0.530	5.900	lithium

IPN 074-585-P1A

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
LiBr	3.470	1.230	lithium bromide
LiF	2.638	0.778	lithium fluoride
$LiNbO_3$	4.700	0.463	lithium niobate
Lu	9.840	*1.000	lutetium
Mg	1.740	1.610	magnesium
$MgAl_2O_4$	3.600	*1.000	magnesium aluminate
$MgAl_2O_6$	8.000	*1.000	spinel
MgF_2	3.180	0.637	magnesium fluoride
MgO	3.580	0.411	magnesium oxide
Mn	7.200	0.377	manganese
MnO	5.390	0.467	manganese oxide
MnS	3.990	0.940	manganese (ii) sulfide
Mo	10.200	0.257	molybdenum
Mo_2C	9.180	*1.000	molybdenum carbide
MoB_2	7.120	*1.000	molybdenum boride
MoO_3	4.700	*1.000	molybdenum trioxdide
MoS_2	4.800	*1.000	molybdenum disulfide
Na	0.970	4.800	sodium
Na_3AlF_6	2.900	*1.000	cryolite
$Na_5Al_3F_{14}$	2.900	*1.000	chiolite
NaBr	3.200	*1.000	sodium bromide
NaCl	2.170	1.570	sodium chloride
$NaClO_3$	2.164	1.565	sodium chlorate
NaF	2.558	1.645	sodium fluoride
$NaNO_3$	2.270	1.194	sodium nitrate
Nb	8.578	0.492	niobium (columbium)
Nb_2O_3	7.500	*1.000	niobium trioxide
Nb_2O_5	4.470	*1.000	niobium (v) oxide
NbB_2	6.970	*1.000	niobium boride
NbC	7.820	*1.000	niobium carbide
NbN	8.400	*1.000	niobium nitride
Nd	7.000	*1.000	neodynium
Nd_2O_3	7.240	*1.000	neodynium oxide

IPN 074-585-P1A

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
NdF_3	6.506	*1.000	neodynium fluoride
Ni	8.910	0.331	nickel
NiCr	8.500	*1.000	nichrome
NiCrFe	8.500	*1.000	inconel
NiFe	8.700	*1.000	permalloy
NiFeMo	8.900	*1.000	supermalloy
NiO	7.450	*1.000	nickel oxide
P_3N_5	2.510	*1.000	phosphorus nitride
Pb	11.300	1.130	lead
$PbCl_2$	5.850	*1.000	lead chloride
PbF_2	8.240	0.661	lead fluoride
PbO	9.530	*1.000	lead oxide
PbS	7.500	0.566	lead sulfide
PbSe	8.100	*1.000	lead selenide
$PbSnO_3$	8.100	*1.000	lead stannate
PbTe	8.160	0.651	lead telluride
Pd	12.038	0.357	palladium
PdO	8.310	*1.000	palladium oxide
Po	9.400	*1.000	polonium
Pr	6.780	*1.000	praseodymium
Pr_2O_3	6.880	*1.000	praseodymium oxide
Pt	21.400	0.245	platinum
PtO_2	10.200	*1.000	platinum oxide
Ra	5.000	*1.000	radium
Rb	1.530	2.540	rubidium
RbI	3.550	*1.000	rubidium iodide
Re	21.040	0.150	rhenium
Rh	12.410	0.210	rhodium
Ru	12.362	0.182	ruthenium
S_8	2.070	2.290	sulphur
Sb	6.620	0.768	antimony
Sb_2O_3	5.200	*1.000	antimony trioxide
Sb_2S_3	4.640	*1.000	antimony trisulfide

IPN 074-585-P1A

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
Sc	3.000	0.910	scandium
Sc_2O_3	3.860	*1.000	scandium oxide
Se	4.810	0.864	selenium
Si	2.320	0.712	silicon
Si_3N_4	3.440	*1.000	silicon nitride
SiC	3.220	*1.000	silicon carbide
SiO	2.130	0.870	silicon (ii) oxide
SiO_2	2.648	1.000	silicon dioxide
Sm	7.540	0.890	samarium
Sm_2O_3	7.430	*1.000	samarium oxide
Sn	7.300	0.724	tin
SnO_2	6.950	*1.000	tin oxide
SnS	5.080	*1.000	tin sulfide
SnSe	6.180	*1.000	tin selenide
SnTe	6.440	*1.000	tin telluride
Sr	2.600	*1.000	strontium
SrF_2	4.277	0.727	strontium fluoride
SrO	4.990	0.517	strontium oxide
Ta	16.600	0.262	tantalum
Ta_2O_5	8.200	0.300	tantalum (v) oxide
TaB_2	11.150	*1.000	tantalum boride
TaC	13.900	*1.000	tantalum carbide
TaN	16.300	*1.000	tantalum nitride
Tb	8.270	0.660	terbium
Tc	11.500	*1.000	technetium
Te	6.250	0.900	tellurium
TeO_2	5.990	0.862	tellurium oxide
Th	11.694	0.484	thorium
ThF_4	6.320	*1.000	thorium (iv) fluoride
ThO_2	9.860	0.284	thorium dioxide
$ThOF_2$	9.100	*1.000	thorium oxyfluoride
Ti	4.500	0.628	titanium
Ti_20_3	4.600	*1.000	titanium sesquioxide

IPN 074-585-P1A

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
TiB_2	4.500	*1.000	titanium boride
TiC	4.930	*1.000	titanium carbide
TiN	5.430	*1.000	titanium nitride
TiO	4.900	*1.000	titanium oxide
TiO_2	4.260	0.400	titanium (iv) oxide
Tl	11.850	1.550	thallium
TlBr	7.560	*1.000	thallium bromide
TlCl	7.000	*1.000	thallium chloride
TlI	7.090	*1.000	thallium iodide (b)
U	19.050	0.238	uranium
U_3O_8	8.300	*1.000	tri uranium octoxide
U_4O_9	10.969	0.348	uranium oxide
UO_2	10.970	0.286	uranium dioxide
V	5.960	0.530	vanadium
V_2O_5	3.360	*1.000	vanadium pentoxide
VB_2	5.100	*1.000	vanadium boride
VC	5.770	*1.000	vanadium carbide
VN	6.130	*1.000	vanadium nitride
VO_2	4.340	*1.000	vanadium dioxide
W	19.300	0.163	tungsten
WB_2	10.770	*1.000	tungsten boride
WC	15.600	0.151	tungsten carbide
WO_3	7.160	*1.000	tungsten trioxide
WS_2	7.500	*1.000	tungsten disulphide
WSi_2	9.400	*1.000	tungsten silicide
Y	4.340	0.835	yttrium
Y_20_3	5.010	*1.000	yttrium oxide
Yb	6.980	1.130	ytterbium
Yb_2O_3	9.170	*1.000	ytterbium oxide
Zn	7.040	0.514	zinc
Zn_3Sb_2	6.300	*1.000	zinc antimonide
ZnF_2	4.950	*1.000	zinc fluoride
ZnO	5.610	0.556	zinc oxide

IPN 074-585-P1A

Table A-1 Material table (continued)

Formula	Density	Z-Ratio	Material Name
ZnS	4.090	0.775	zinc sulfide
ZnSe	5.260	0.722	zinc selenide
ZnTe	6.340	0.770	zinc telluride
Zr	6.490	0.600	zirconium
ZrB_2	6.080	*1.000	zirconium boride
ZrC	6.730	0.264	zirconium carbide
ZrN	7.090	*1.000	zirconium nitride
ZrO_2	5.600	*1.000	zirconium oxide

IPN 074-585-P1A

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IPN 074-585-P1A