



XTC/C



XTC/2

XTC/C XTC/2

Thin Film Deposition Controller

IPN 074-183



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

XTC/C XTC/2

Thin Film Deposition Controller

IPN 074-183X

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**INFICON Inc.
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East Syracuse, NY 13057
USA**

meets the essential safety requirements of the European Union and is placed on the market accordingly. It has been constructed in accordance with good engineering practice in safety matters in force in the Community and does not endanger the safety of persons, domestic animals or property when properly installed and maintained and used in applications for which it was made.

Equipment Description: XTC/2 and XTC/C Deposition Controllers, including
the Oscillator Package and Crystal Sensor as properly
installed.

Applicable Directives: 73/23/EEC as amended by 93/68/EEC
89/336/EEC as amended by 93/68/EEC

Applicable Standards: EN 61010-1 : 1993, Fixed Equipment
EN 55011, Group 1, Class A : 1991
EN 50082-2 : 1995

CE Implementation Date: January 3, 1995
Revised to include EMC Directive: January 2, 1997

Authorized Representative: Gary W. Lewis
Vice President – Quality Assurance
INFICON Inc.

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Using the table below, please circle the appropriate rank for each aspect.
In the Importance column, please indicate the importance of each aspect.

Manual Title _____

Part # (see Title Page) 074-

Aspect	Very Dissatisfied	Dissatisfied	No Opinion	Satisfied	Very Satisfied	Importance (ranked from 1 to 5, where 1 is low and 5 is high)
Found everything I needed	VD	D	NO	S	VS	
Easy to read	VD	D	NO	S	VS	
Easy to use	VD	D	NO	S	VS	
Relevant to my work	VD	D	NO	S	VS	
Accurate information	VD	D	NO	S	VS	
Well-written	VD	D	NO	S	VS	
Well-organized	VD	D	NO	S	VS	
Technical Enough	VD	D	NO	S	VS	
Helped me solve problems	VD	D	NO	S	VS	

If you have additional comments, please contact INFICON®

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Appendix A

Table of Densities and Z-ratios

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Chapter 1

Introduction and Specifications

1.1 Instrument Safety

1.1.1 Notes, Cautions, Warnings

When using this manual, please pay attention to the NOTES, CAUTIONS and WARNINGS found throughout. For the purposes of this manual they are defined as follows:

NOTE: Pertinent information that is useful in achieving maximum instrument efficiency when followed.



CAUTION

Failure to heed these messages could result in damage to the instrument.



WARNING

Failure to heed could result in personal injury.



WARNING

Dangerous voltages are present. Failure to heed could result in personal injury.

1.1.2 General Safety Information

  **WARNING**

This product is not for use in a manner not specified by the manufacturer.

There are no user serviceable components within the instrument case.

Potentially lethal voltages are present when the line cord, system I/O or aux I/O are connected.

Refer all maintenance to qualified personnel.

 **CAUTION**

This instrument contains delicate circuitry which is susceptible to transient power line voltages. Disconnect the line cord whenever making any interface connections. Refer all maintenance to qualified personnel.

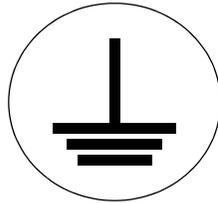
1.1.3 Earth Ground

This instrument is connected to earth via a sealed three-core (three-conductor) power cable, which must be plugged into a socket outlet with a protective earth terminal. Extension cables must always have three conductors, including a protective earth conductor.

 **WARNING**

Never interrupt the protective earth circuit.

Any interruption of the protective earth connection inside or outside the instrument, or disconnection of the protective earth terminal is likely to make the instrument dangerous.



This symbol indicates where the protective earth ground is connected inside the instrument. Never unscrew or loosen this connection.

1.1.4 Main Power Connection



WARNING

This instrument has line voltage present on the primary circuits whenever it is plugged into a main power source.

Never remove the covers from the instrument during normal operation.

There are no operator serviceable items within this instrument.

Removal of the top or bottom covers must be done only by a technically qualified person.

If this instrument is installed into a rack system which contains a mains switch, this switch must break both sides of the line when it is open and it must not disconnect the safety ground. This configuration is required in order to comply with accepted European safety standards.

1.2 Introduction to the Instrument

The XTC/2 and XTC/C are quartz crystal transducer type deposition process controllers with three layer capability. They are readily connected to interact with and control the other instruments associated with a vacuum coating plant of moderate complexity. These instruments incorporate the patented (US #5,117,192—May 27, 1992) ModeLock measurement system. This innovative system provides process security, measurement speed and precision at a level that no active oscillator based instrument can provide.

The bright Liquid Crystal Display of the XTC/2 is easily read and keeps the operator continuously informed with pertinent deposition data including rate, thickness, phase, rate deviation and elapsed time. Special messages such as Stop, Crystal Fail or Time-Power are clearly presented to reduce operator uncertainty and eliminate the possibility of costly mistakes.

The XTC/C is a variant of the XTC/2 that has a limited front panel. Instead of an LCD display, it has 8 LED type status indicators that indicate process status and instrument functional status. It is primarily designed for use in vacuum coating plants that have a computer based central controller. The original equipment manufacturer (OEM) will design a custom user input-output system through his system controller. Once programmed and started, the XTC/C will essentially run as independent of the central controller as is desired. The deposition layer can complete without further intervention, freeing the central controller for other tasks. Status and data may be queried as frequently as is desired, however.

Interaction with the coating system for both units is multifaceted. All units come with RS232 and support data rates to 9600 baud. The SECSII protocol is supported. The optional computer interface is IEEE-488. The instrument is configured to sequentially control two separate deposition sources with 15 bit resolution using either PID or integrating type controller algorithms. Twelve relays are used to manipulate various external devices such as source and sensor shutters, heaters or valves. Lower power outputs are used to control the position of multi-hearth crucibles. There are eight input lines to provide the ability to sense and react to discrete external signals.

There are numerous special control functions for accommodating the needs of the deposition process. Full predeposit processing is provided, including shutter delay which allows the establishment of the desired rate prior to opening the substrate shutter. A Rate Ramp allows the deposition rate to be changed during the deposit phase. The RateWatcher feature allows the deposition stream to be periodically sampled, extending the life of the crystal.

These instruments are fully compatible with the complete family of INFICON transducers, including Dual and CrystalSix®.

1.3 Specifications

At the time of this manual's writing, the specifications for performance are as published below. INFICON continuously improves its products, affecting the instrument's performance.

1.3.1 Specifications XTC/2 and XTC/C

1.3.1.1 General

- Usage Indoor use only.
- Altitude Range Up to 2000 m (6,561 ft)
- Pollution Degree 1—No pollution occurs
- Overvoltage Category 2—Local level, appliances, etc.
- Cleaning The unit enclosure can be safely cleaned with a mild detergent or spray cleaner designed for that purpose. Care should be taken to prevent any cleaner from entering the unit.

1.3.1.2 Measurement

- Crystal Range & Precision 6.0 to 5.0 MHz +/- .05 Hz
(per 250 msec sample)
- Thickness & Rate Resolution 0.0617Å (per 250 msec sample)
Material density = 1.0; Z-Ratio = 1.0;
crystal frequency = 6 MHz.
Å/S/M = Angstroms/second/measurement.
- Thickness accuracy 0.5%
- Measurement frequency 4 Hz

1.3.1.3 Source Controls

- Source-Control Voltage 0 to +/- 10 v
- Number of Sources 2
- Resolution 15 bits over full range (10 v)
- Update Rate 4 Hz max.
- Maximum Load 400 Ohm (100 Ohm internal impedance)

1.3.1.4 Input/Output

Inputs	9 TTL inputs
Outputs	
a) relay	12 SPST 2.5-amp relays rated @ 30 V(dc) / 30 V(ac) / 42 V(peak) max.
b) crucible select	8 open collector (5 volt DC max sink, 5 TTL loads)
Scan/Change Rate	4 Hz

1.3.1.5 Recorder Output

Voltage	0 to +10 v
Resolution	13 bits over full range (one reserved for sign)
Update Rate	4 Hz
Function	Rate / Thickness / Mass
Maximum Load	2.0 KOhm (100 Ohm internal impedance)

1.3.1.6 Display

Applies to XTC/2 only; the XTC/C provides LED annunciators.

Type	4x multiplexed custom LCD with backlight. If desired, backlight automatically dims during prolonged period of inactivity, automatically brightening when activity begins.
Thickness Resolution	1 Å
Rate Resolution1 Å for 1 to 99.9 Å/sec 1 Å for 100 to 999 Å/sec
Update Rate	1 Hz

1.3.1.7 Process Recipe Storage

Film Programs	9, 30 variables per program
Process layers	3

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1.3.1.8 Hardware interface

Sensors	
Single	2
Dual	1
CrystalSix	2
Sources	2 BNC female
Crucible Locations	8, 1 of 8 and BCD encoded
I/O	
Standard (inputs/outputs)	8/12
Optional	None
Communications	
Standard	RS232C
Optional	IEEE
Chart Recorder	1 BNC female

1.3.1.9 Operation

Power Requirements	
"115 V" input range	90 to 132 V(ac), 49 to 61 Hz, 45 VA max. fused at 3/8 Amp Type T fuse
"230 V" input range	180 to 264 V(ac), 49 to 61 Hz, 45 VA max. fused at 3/16 Amp Type T fuse
Operating Temperature	0 to 50 °C (32 to 122 °F)
Size	3.5" H x 8" W x 12" D (89 mm x 203 mm x 305 mm)
Weight	6 lb. (2.7 kg)

1.3.2 Transducer Specifications (optional)

	Max. Bakeout Temperature*	Size (Max. Envelope)	Water Tube & Coax Length	Body & Holder	IPN
CrystalSix Sensor	130 °C	3.5" dia. x 2.0" high (89 mm dia. x 51 mm high)	30" (762 mm)	304 SS (plate, holders, & material shield)**	750-446-G1
Standard Sensor	130 °C	1.063" x 1.33" x .69" high (27 mm dia. x 34 mm x 17.5 mm high)	30" (762 mm)	304 SS	750-211-G1
Standard Sensor with Shutter	130 °C	1.06" x 2.24" x .69" high (27 mm dia. x 57 mm x 17.5 mm high)	30" (762 mm)	304 SS	750-211-G2
Sputtering Sensor	105 °C	1.36" dia. x .47" high (34.5 mm dia. x 11.8 mm high)	30" (762 mm)	Au-plated BeCu	007-031
Compact Sensor	130 °C	1.11" x 1.06" x 1.06" high (28 mm x 27 mm x 27 mm high)	30" (762 mm)	304 SS	750-213-G1
Compact Sensor with Shutter	130 °C	2.08" x 1.62" x 1.83" high (53 mm x 41 mm x 46 mm high)	30" (762 mm)	304 SS	750-213-G2
UHV Bakeable Sensor	450 °C	1.35" x 1.38" x .94" high (34 mm x 35 mm x 24 mm high)	12" (305 mm) 20" (508 mm) 30" (762 mm)	304 SS	007-219 007-220 007-221
UHV Bakeable Sensor with Shutter	400 °C	1.46" x 1.37" x 1.21" high (37 mm x 35 mm x 31 mm high)	12" (305 cm) 20" (508 cm) 30" (762 cm)	304 SS	750-012-G1 750-012-G2 750-012-G3
Dual Sensor	130 °C	1.45" x 3.45" x 1.70" high (37 mm x 88 mm x 43 mm high)	30" (762 mm)	304 SS	750-212-G2
Shutter Assembly	400 °C	two models available	N/A	300-series SS	750-210-G1 750-005-G1 (Sputtering)

*For Bake only; waterflow is required for actual deposition monitoring. These temperatures are conservative maximum device temperatures, limited by the properties of Teflon (PTFE) at higher temperatures. In usage, the water cooling allows operation in environments that are significantly elevated, without deleterious affects.

**Aluminum body for heat transfer.

1.3.3 XIU (Crystal Interface Unit) Specifications

The XTC/2 Series instruments use a new type of "passive intelligent" oscillator. It is available with cable lengths of 15' (4.572 m), 30' (9.144 m), 50' (15.24 m), and 100' (30.28 m) as IPN 757-305-G15, G30, G50, or G100, respectively. Conventional, active style oscillators do not work with these instruments. In-vacuum cable lengths to a maximum of 2 m (6.6') are supported with this new technology.

1.4 Guide to the Use of the Manual

This manual is configured to be used by both experienced and inexperienced deposition process engineers. For those with significant experience, especially on INFICON controllers, nearly all pertinent information is contained in [Chapter 2, Quick Use Guide](#). Other sections contain the details that supplement the information in the quick use section.

Every user should read the complete manual. It is strongly suggested that the user or installer follow the following plan to gain the most information in the shortest period of time.

- ◆ Register the instrument to receive updates and important information from the factory.
- ◆ Read [section 1.1.1, Notes, Cautions, Warnings, on page 1-1](#) to understand the safety related issues.
- ◆ Read [Chapter 2, Quick Use Guide](#), to become familiar with the instrument's needs and capabilities. Use the other sections of the manual to supplement areas where you do not feel you have an adequate understanding of the material. Throughout [Chapter 2](#) there will be frequent references to the manual sections that provide more detailed information. The final sections of the [Chapter 2](#) build the understanding of the full use of the instrument in a logical progression, as suggested in [section 2.3 on page 2-8](#).

1.5 XTC/C Users and Installers Note

The XTC/C can do anything that an XTC/2 can do, but it must be controlled through the computer interface. In order to install and use this instrument effectively, all aspects of XTC/2 operation must be understood. Because of this additional burden, it is probably not cost effective for an end-user of a single unit to purchase and install the XTC/C version.



There are no user serviceable components within the instrument case.

Potentially lethal voltages are present when the line cord, System I/O or Aux I/O are connected.

Refer all maintenance to qualified personnel.

1.6 Related Manuals

Transducers are covered under separate manuals.

IPN	Transducer Type
074-154	Bakeable
074-155	CrystalSix
074-156	Single/Dual/Compact
074-157	Sputtering

1.7 How To Contact Customer Support

If you cannot find the answer to your question in this manual, please contact one of the following Customer Support groups after deciding whether:

- ◆ your difficulty is with how you are using the instrument—in this case, contact Application Support.

or

- ◆ your instrument needs repair—in this case, contact Field Service and Repair Support.

When you contact Customer Support, please have this manual at hand, along with the following information:

- ◆ The serial number for your instrument.
- ◆ A description of your problem.
- ◆ An explanation of the corrective action that you may have already attempted.
- ◆ The exact wording of any error messages that you have received from the instrument.

Within the USA, you may reach Customer Support at the following phone numbers. Please contact the location that is closest to you. If you are located outside of the USA, please contact your sales office. A complete listing of INFICON Worldwide Service Centers is available at www.inficon.com.

1.7.1 Application Support

Austin, TXph. 512-448-0488 fax 512-448-0398
 San Jose, CAph. 408-361-1200 ext. 125 . . fax 408-362-1556
 Syracuse, NYph. 315-434-1128 fax 315-437-3803

If you are located outside the USA, please contact your sales office. A complete listing of INFICON Worldwide Service Centers is available at www.inficon.com.

1.7.2 Field Service and Repair Support

Austin, TX ph. 512-448-0488 fax 512-448-0398

San Jose, CA. . . . ph. 408-361-1200 ext. 120 . . . fax 408-362-1556

Syracuse, NY. . . . ph. 315-434-1167 fax 315-434-2551

If you are located outside the USA, please contact your sales office. A complete listing of INFICON Worldwide Service Centers is available at www.inficon.com.

1.7.3 Returning Your Instrument

Do not send your instrument without first speaking with a Customer Support Representative.

You must obtain an RMA (Return Material Authorization) number from the Customer Support Representative. If the delivery of a package without an RMA number is attempted, INFICON will refuse the delivery and the package will be returned to you.

If your instrument has been exposed to process materials, you will be required to complete a Declaration Of Contamination form.

Chapter 2

Quick Use Guide

2.1 Unpacking, Initial Inspection and Inventory

2.1.1 Unpacking and Inspection Procedures

- 1 If you haven't removed the instrument from its shipping containers, do so now.
- 2 Carefully examine the unit for damage that may have occurred during shipping. This is especially important if you notice signs of obvious rough handling on the outside of the cartons. *Report any damage to the carrier and to INFICON, immediately.*
- 3 DO NOT discard any packing materials until you have taken inventory and have verified proper instrument operation to your satisfaction. See [section 2.2 on page 2-4](#) for voltage selection and [section 3.6 on page 3-11](#) for test mode operation.

2.1.2 Inventory

Make sure you have received all of the necessary equipment by checking the contents of the shipping containers with the parts list below. INFICON ships these products on a feature-option basis. Check your order for the part number before comparing to the lists below.

2.1.2.1 XTC/2 System Configuration

BASIC CONFIGURATION	IPN #	CODE#	XTC/2 ---
115V 50/60 Hz	757-500-G1	1	
230V 50/60 Hz	757-500-G2	2	
Computer Communications Module			
None	757-211-G1	1	
IEEE-488 Parallel	760-142-G1	2	
Remote Module			
None		0	
Hand Controller	755-262-G1	1	
Rack Mounting			
None		0	
1 Unit Mounting Kit	757-212-G1	1	
2 Unit Mounting Kit	757-212-G2	2	

2.1.2.2 XTC/C System Configuration

BASIC CONFIGURATION	IPN #	CODE#	XTC/C ---
115V 50/60 Hz	759-500-G1	1	
230V 50/60 Hz	759-500-G2	2	
Computer Communications Module			
None	757-211-G1	1	
IEEE-488 Parallel	760-142-G1	2	
Remote Module			
None		0	
Hand Controller	755-262-G1	1	
Rack Mounting			
None		0	
1 Unit Mounting Kit	757-212-G1	1	
2 Unit Mounting Kit	757-212-G2	2	

IPN 074-183X

2.1.2.3 Ship Kit - XTC/2 XTC/C

Both instruments are shipped with the following accessories. To find which accessories were shipped with your unit look for the "X" which represents the voltage of your particular instrument and follow that column.

Table 2-1 Accessories

Item	Qty		IPN Number	Part # and/or Description
	G2 (230V)	G1 (115V)		
01	-	X	757-203-G1	Ship Kit - XTC/2 & XTC/C 115V
02	X	-	757-203-G2	Ship Kit - XTC/2 & XTC/C 230V
03	-	1	068-0385	North American Power Cord, shielded
04	1	-	068-0390	European Power Cord, shielded
05	1	1	051-485	Conn 9 Pin Male D/Sub Sod. Cup
06	1	1	051-620	Cable Clamp 11.3015
07	2	2	051-483	Conn 25 Pin Female D/Sub Sod. Cup
08	2	2	051-619	Cable Clamp
09	-	1	062-011	3/8 Amp Fuse Type T
10	1	-	062-053	3/16 Amp Fuse Type T
11	4	4	070-811	8014 Bumpon Feet

In addition, you have already found a copy of this manual, IPN 074-183.

2.2 Voltage Selection

Voltage selection is required only between low (nominal 100-120 V) and high (nominal 200-240 V) ranges. There is no distinction between 50 and 60 Hz supplies. Refer to [section 1.3.1 on page 1-6](#) for specific power requirements.



CAUTION

Verify that the correct fuse is in place by visually inspecting the fuse for the proper rating. Use of an improperly sized fuse may create a safety hazard.

**For 100-120 V(ac) operation use a 3/8 Amp Type T fuse.
For 200-240 V(ac) operation use a 3/16 Amp Type T fuse.**

NOTE: These instruments are designed to operate between 90 V(ac) and 132 V(ac) on Low Range and between 180 V(ac) and 264 V(ac) on High Range.



WARNING

This instrument has line voltage present on the primary circuits whenever it is plugged into a main power source.

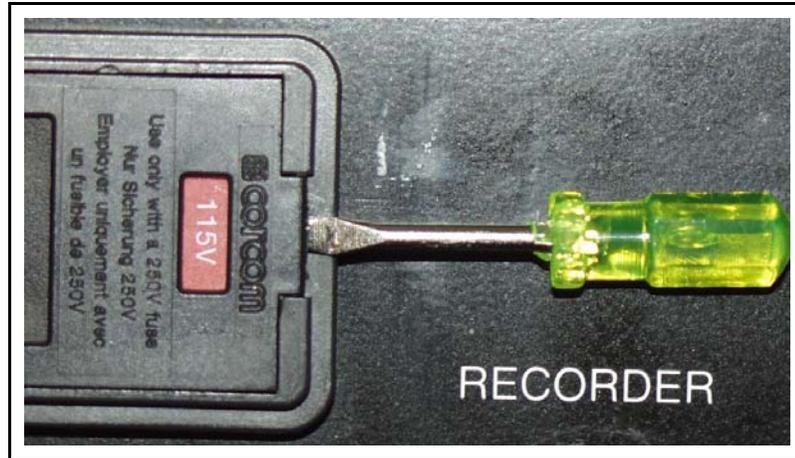
Potentially lethal voltages are present when the line cord, system I/O or aux I/O are connected.

This instrument must be disconnected from the main power source before inspecting or replacing the fuse.

To inspect the fuse, proceed as follows.

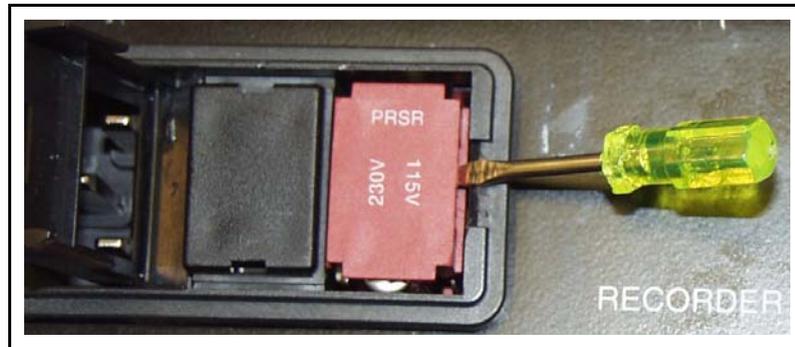
- 1 Pry open the power entry module cover. See [Figure 2-1](#).

Figure 2-1 Opening the Power Entry Module Cover



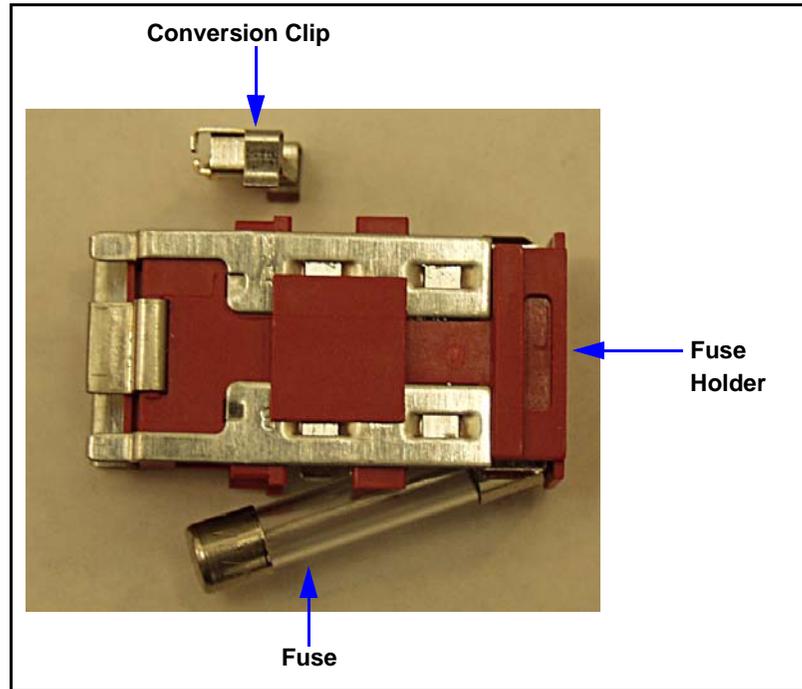
- 2 Pry the fuse holder out of the housing. See [Figure 2-2](#).

Figure 2-2 Removing the Fuse Holder



3 Inspect the fuse. See [Figure 2-3](#).

Figure 2-3 Clip, Fuse Holder, Fuse



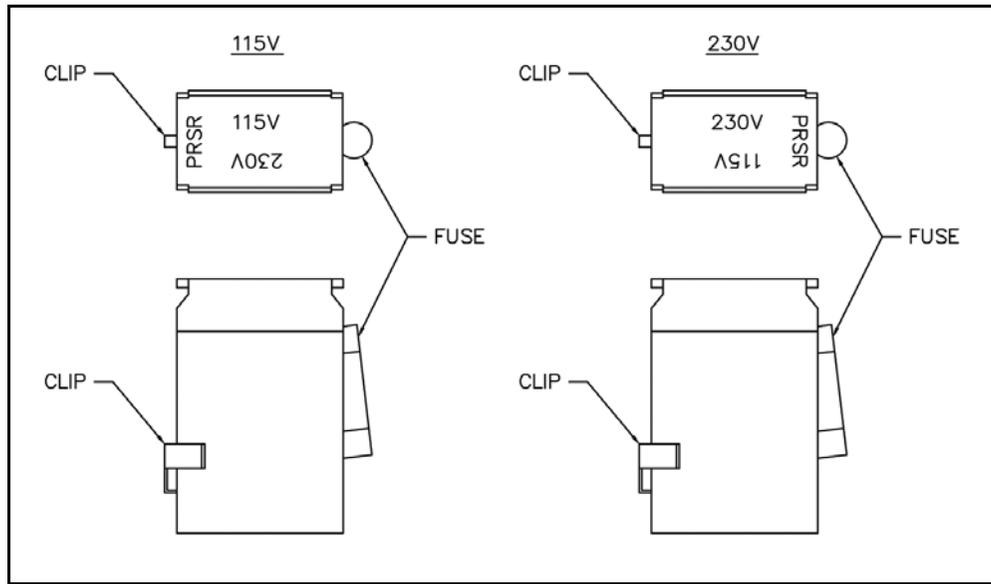
The Corcom fuse holder has chambers for two 1/4" x 1 1/4" (5 mm x 20 mm) fuses. Since only one fuse is used, that fuse must be on the live (hot) side and a conversion clip is inserted to bridge the unused fuse chamber in the neutral side.

An additional function of the conversion clip is to act as a polarization key to assure that only the neutral line can be bridged leaving the live (hot) line always fused. A special feature has been built into the live side of the fuse holder compartment of the housing. It will interfere with the conversion clip and therefore stop the fuse holder from being inserted fully into the housing if the clip is on the live side.

When the power entry module is flipped around for voltage changing, the conversion clip must be re-installed to the other side. Otherwise, the fuse holder will not seat completely into the housing and the power entry module will not function.

The proper location of the conversion clip is at the left hand side of the voltage number selected, that is, the upright voltage number. See [Figure 2-4](#).

Figure 2-4 Proper Clip and Fuse Location



Once the fuse and clip have been configured, the fuse holder is inserted into the power entry module housing with the fuse towards the bottom of the instrument (and the clip towards the top) with the desired voltage showing through the hole into the cover.

2.3 Installation Guide and Schematic

Many experienced deposition monitor users will be able to fully install and use the instrument by studying the installation schematic, [Figure 2-5](#) on the next page, and the State Sequence Diagrams, [Figure 4-2](#) on page 4-2, [Figure 4-3](#) on page 4-3, [Figure 4-4](#) on page 4-4, and [Figure 4-5](#) on page 4-5.

A more systematic approach would be to start by reviewing the two figures and then following the procedure below.



WARNING

Completely review [section 1.1](#) on page 1-1 on safety. All warnings in this section, as well as ones found in other sections listed below, must be followed to ensure the safety of the personnel operating this instrument.

- 1 Check for correct line voltage, [section 2.2](#) on page 2-4.
- 2 Verify basic unit operation by exercising it in the Test Mode, [section 3.6](#) on page 3-11.
- 3 Review the system interface capability as outlined in [section 2.6](#) on page 2-18. Be especially attentive of the special features available on the configuration switches, [section 2.6.2](#) on page 2-19
- 4 Wire the necessary connectors following the installation procedures in [section 3.1](#) on page 3-1, [section 3.2](#) on page 3-1, and [section 3.3](#) on page 3-4.
- 5 Review the front panel controls and display description per [section 2.4](#) on page 2-10 for the XTC/2 or [section 2.5](#) on page 2-16 for the XTC/C.
- 6 Program the desired film parameter values per [section 4.1](#) on page 4-1 and [section 4.2](#) on page 4-6.
- 7 Verify the operation of the just programmed film utilizing the Test Mode.
- 8 Attach the XIU (757-305-G15, G30, or G100) to an existing transducer or install a new transducer following the guidelines of [section 3.5](#) on page 3-7 and [Figure 3-3](#) on page 3-8.
- 9 Exit the Test Mode and deposit when ready.

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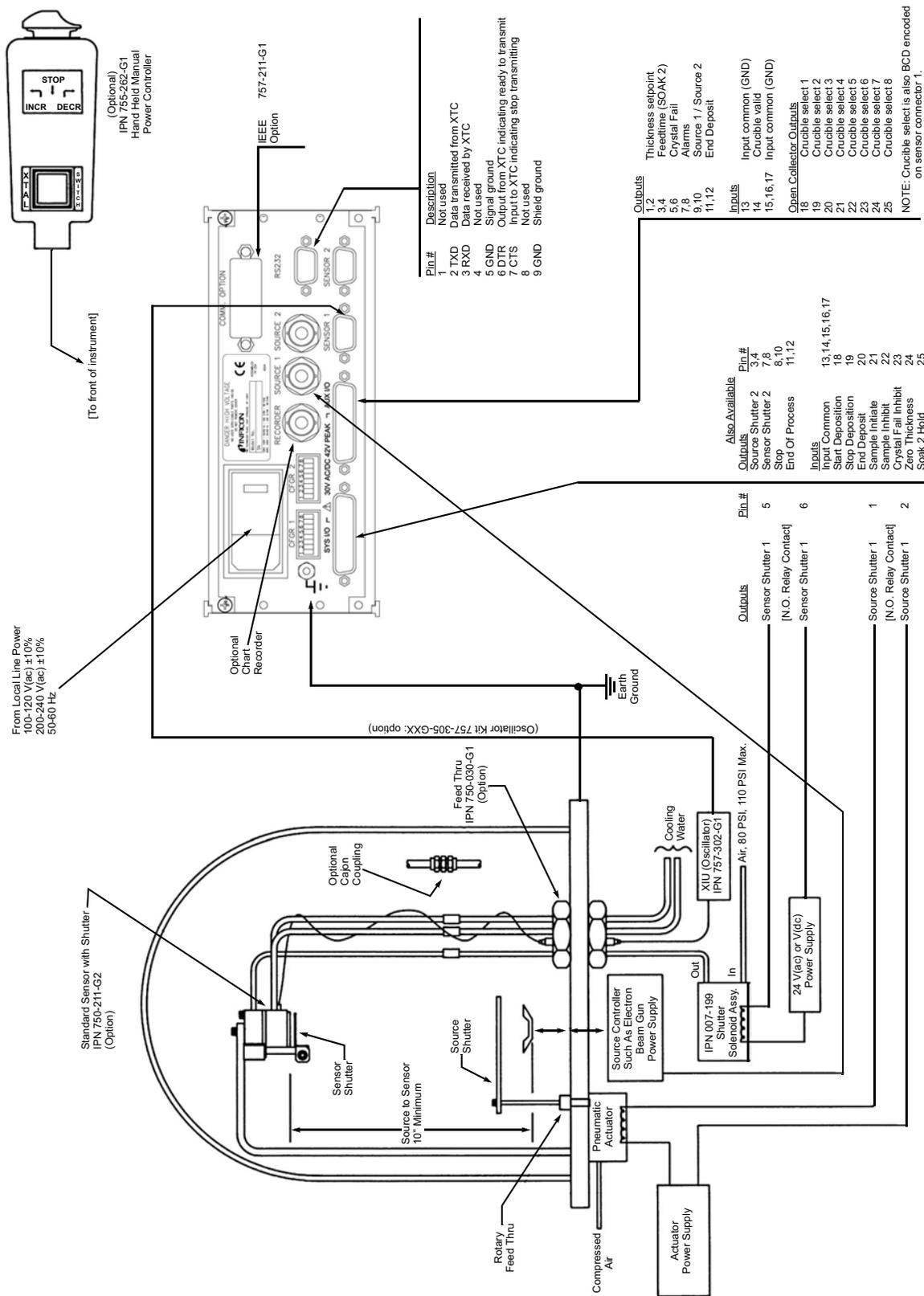
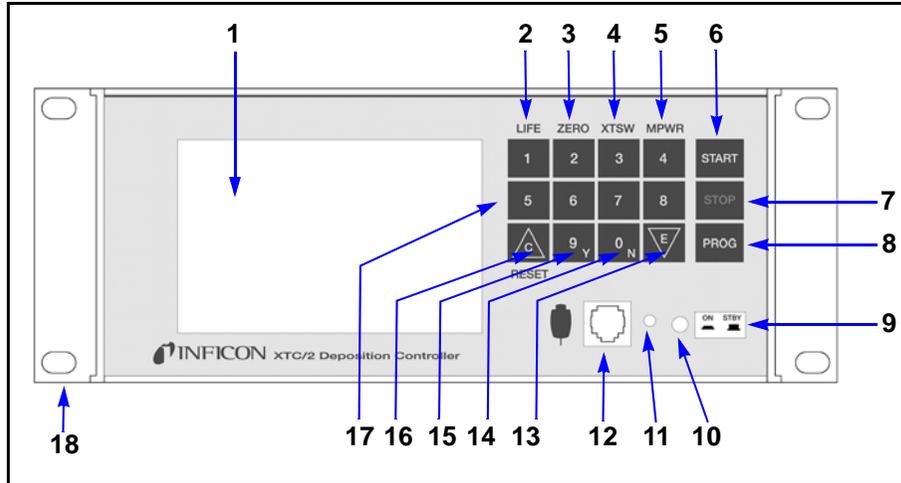


Figure 2-5 Installation Guide Schematic

2.4 XTC/2 Front Panel Description

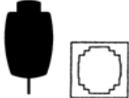
The description of the XTC/2 front panel is divided into two sections, the display area and the front control panel.

Figure 2-6 Front Panel XTC/2



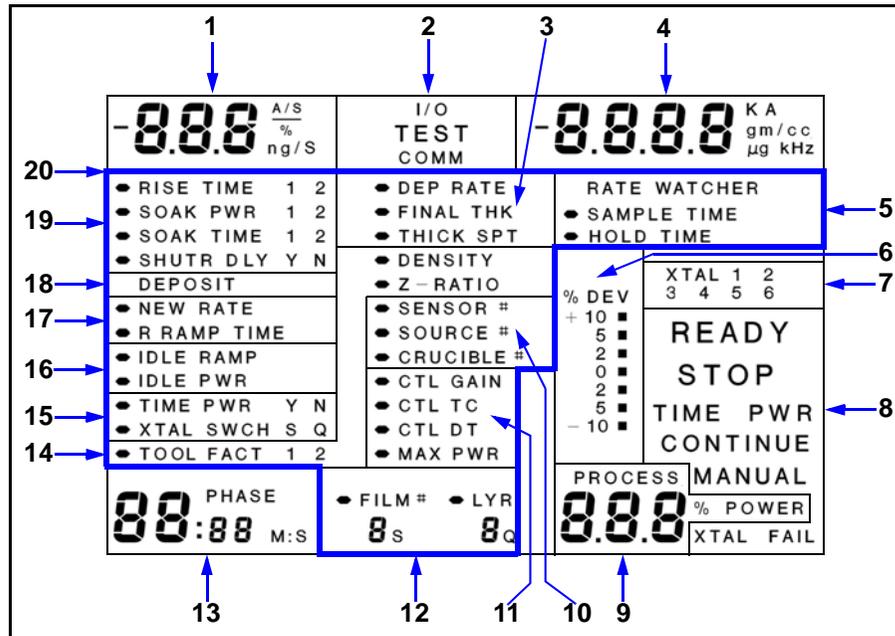
2.4.1 XTC/2 Front Control Panel Description

- 1— LCD DISPLAY
Highly visible display of current information. See [section 2.4.2 on page 2-12](#) for details.
- 2— LIFE
Pressing the 1 key momentarily switches the display to percent of crystal life used, software version, crystal frequency, and S and Q values, when the display is in the operate mode.
- 3— ZERO
Pressing the 2 key zeros the displayed thickness when the display is in the operate mode.
- 4— XTSW
Crystal Switch. Pressing the 3 key advances the CrystalSix to the next available crystal or changes the active crystal of the dual head when the display is in the operate mode. (See [section 4.15.1 on page 4-25](#).)
- 5— MPWR
Manual. Pressing the 4 key places the unit in manual power control or rate control mode when the display is in the operate mode.
- 6— START
Initiates action. (Starts State Sequencing, see [Figure 4-2 on page 4-2](#) and [Figure 4-3 on page 4-3](#).)
- 7— STOP
Halts State Sequencing, see [Figure 4-2 on page 4-2](#) and [Figure 4-3 on page 4-3](#).
- 8— PROG
Program. Toggles the display between the program and operate modes.

- 9— ON/STBY
Switches secondary power of the instrument between **ON** and **STANDBY**.
 - 10— 
Green LED indicates that the unit is connected to an active line power source and the **ON/STBY** switch is set to ON.
 - 11— 
Access to adjust LCD contrast, see [section 6.1 on page 6-1](#).
 - 12— 
Connection for optional manual power and crystal switch hand controller (IPN 755-262-G1).
-  **WARNING**
-
- This connector is not for telecommunications equipment. Do not connect a phone to this connector.**
-
- 13— 
Enter and cursor down. Two function switch used when the display is in the program mode. All numeric and "Y" "N" parameter entries need to be followed by a . Also used to manually decrease source power when in **MPWR** and the display is in the operate mode.
 - 14— 0/N
Zero or no. Two function switch used when the display is in the program mode. Also, places unit in communications set up mode if held down during power up, see [section 3.8.1 on page 3-20](#).
 - 15— 9/Y
Nine or yes. Two function switch used when display is in program mode.
 - 16— /RESET
Clear and cursor up. Two function switch that is also used to "reset" the instrument to the beginning of a process from a STOP state. Also used to increase source power when in **MPWR** and the display is in the operate mode.
 - 17— DIGITS (0-9)
Decimal based key pad for data entry. If the nine key is held down during power-up, all of the LCD segments will remain lit until the key is released, see [Figure 2-7 on page 2-12](#).
 - 18—
Optional mounting kit, (IPN 757-212-G1) for mounting one unit in full rack or (757-212-G2) for mounting two units side by side in full rack.

2.4.2 XTC/2 Display Description

Figure 2-7 XTC/2 Display



- 1— RATE DISPLAY GROUP
Indicates the deposition or etching rate in Å/sec or the version level of the installed firmware when the **LIFE** key is pressed and display is in the Operate mode. When the display is in the Program mode, it is used to display and enter the values of parameters requiring three significant digits.
- 2— COMMUNICATIONS & TEST GROUP
A message area that:
 - a. Indicates that the I/O has been put into external communication control through the **R-15** through **R-18** commands.
 - b. The instrument is in **TEST** mode, see [section 3.6 on page 3-11](#).
 - c. The instrument is sending or receiving an external computer **COMM**unication command.
- 3— DEPOSITION (ETCH) RATE and THICKNESS SUBGROUP
Indicators and annunciators for parameter entry of starting **DE**Position **R**ATE, film's **F**INAL **T**HicKness and an intermediate **T**HicKness **S**et**P**oin**T**.
- 4— THICKNESS and FREQUENCY GROUP
Indicates the deposited (etched) thickness or the active crystal's frequency in KHz when the **LIFE** key is pressed when the display is in the operate mode. When the display is in the Program mode it is used to display and enter the values of parameters that require four significant digits.
- 5— RATEWATCHER SUBGROUP
Indicator annunciator and cursor array for the definition of the RateWatcher parameters when the display is in the Program mode. Used as an indicator of the **S**AMPLE and **H**OLD deposition substrates when the display is in the Operate mode.

6— RATE DEVIATION GROUP

A graphic annunciator that displays the current deviation of the deposition rate from the value of the active film's **DEP RATE** parameter. This annunciator structure is updated each 250ms measurement when the display is in the Operate mode. A 0% deviation is indicated when the computed value is less than +/-2%. The plus or minus 10% values are indicated when the computed value is more than +/-10%, respectively.

7— ACTIVE CRYSTAL INDICATION GROUP

A graphic annunciator that provides information concerning the presently active crystal or the availability of backup crystals. Its meaning is somewhat altered by the instrument's configuration regarding the crystal switch type, see [section 2.6.2 on page 2-19](#).

- a. If the instrument is configured for "Single Heads", the annunciator will indicate which sensor is active.
- b. If the instrument is configured for "Dual Sensor Head", the annunciator will display the number representing the active crystal's "sensor number." Whenever the instrument is operating with the secondary (backup) crystal the number of the backup crystal will be flashing as an indication of the lack of a subsequent backup crystal.
- c. If the instrument is configured for one or two CrystalSix, the annunciator will display the numbers of all crystals of the active sensor's output that are "good." The "active" crystal's number will flash. The absence of all numbers may also indicate that the switcher is not operating.

8— STATUS MESSAGE GROUP

A group of annunciators that provide information concerning the state of the instrument.

- a. **READY** — when illuminated the instrument will accept a start command to begin state processing of the active layer.
- b. **STOP** — when illuminated indicates that the instrument is in the STOP state, see [section 4.3 on page 4-9](#) and [section 4.4 on page 4-10](#).
- c. **TIME PWR** — when illuminated indicates that the instrument is in the Time-Power state. See [section 4.12 on page 4-22](#).
- d. **CONTINUE** — when illuminated the instrument will again execute state processing of the active layer, allowing for any previously accumulated material, when the START key is pressed. Pressing the RESET key prior to the START key resets the process to layer 1; see [section 4.4 on page 4-10](#).
- e. **MANUAL** —when illuminated the instrument is in the manual power control mode and the source's power level is modified by either the optional hand controller or the front panel keys (XTC/2 only).
- f. **XTAL FAIL** — this indicator illuminates when the active crystal has failed. In the case of instruments configured for dual or CrystalSix operation it indicates that no further crystals are available.

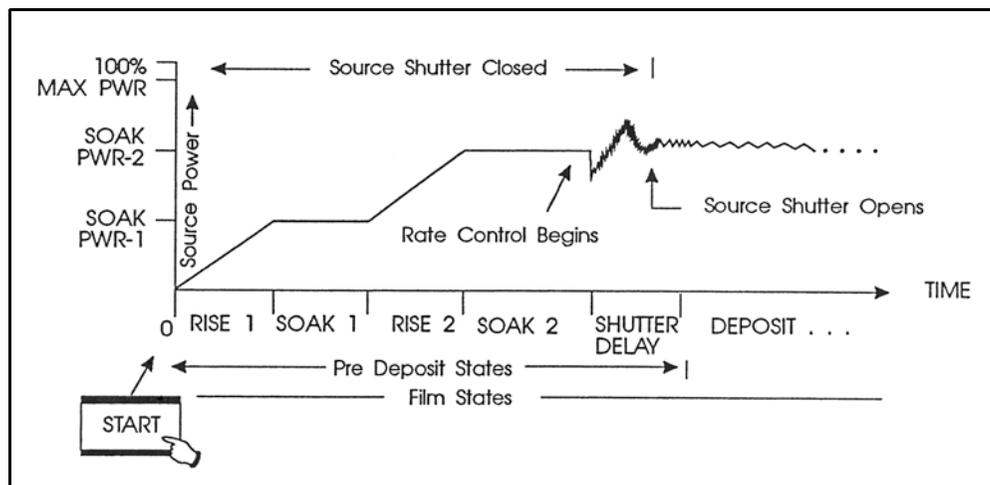
- 9— POWER and PROCESS GROUP
Indicates the relative source power when the display is in the Operate mode and displays the % xtal life when the LIFE key is pressed. When the display is in the Program mode, these three digits are used for the entry of some 3 digit film parameter values. It is also used to define the instrument's sequencing of multi-layers, see [section 2.9 on page 2-36](#).
- 10— SENSOR and SOURCE SUBGROUP
The annunciators and cursors for the definition of a film's:
- SENSOR # — designates the active or primary (for dual head) sensor as 1 or 2.
 - SOURCE # — designates the film's active source control output as 1 or 2.
 - CRUCIBLE # — designates the active film's crucible pocket as 1-8, corresponding to crucible select outputs 1-8. A value of 0 disables this parameter and associated outputs; see [section 2.6.5 on page 2-24](#).
- 11— CONTROL PARAMETER SUBGROUP
The annunciators and cursors for entering the values used in a film's Rate Control algorithm; see [section 4.5 on page 4-11](#).
- 12— CRYSTAL and PROCESS SUBGROUP
When the display is in the Program mode:
- the **XTAL SWCH** parameter's values are entered for **S & Q** as labeled.
 - the "FILM #" parameter value defines the particular film's (1-9) values being programmed/displayed.
 - The "LYR #" defines the process layer to be assigned a film. This parameter works with the power and process display group.
- When the display is in the Operate mode:
- "FILM #" parameter value defines the film being executed and the "LAYER #" parameter value defines the layer being executed.
- 13— TIMER GROUP
When the display is in the Operate mode, serves as the elapsed time indicator and unit annunciator. Also displays **S & Q** values when the **LIFE** key is pressed. The values in the **S** accumulator replace the time display while the **LIFE** key is pressed. When the key is released the value of the **Q** accumulator is shown for about 1 second. Used for entering and displaying the value of time-based parameters when the display is in the Program mode.
- 14— CALIBRATION SUBGROUP
Annunciators and cursors used when the display is in the Program mode. Allows conversion of the crystal's frequency shift to material thickness; see [section 5.1 on page 5-1](#) through [section 5.4 on page 5-3](#).

- 15— CRYSTAL FAIL SUBGROUP
Annunciators and cursors used when the display is in the program mode to determine tolerated levels of crystal performance and subsequent instrument actions.
 - a. TIME PWR Y-N — defines the action taken when a crystal fails; see [section 4.11 on page 4-22](#).
 - b. XTAL SWCH S-Q — a two parameter data field used with the digits in the crystal and process subgroup. These are used to set the level of soft crystal failures tolerated; see [section 4.6 on page 4-14](#).
- 16— POST DEPOSIT SUBGROUP
Annunciators and cursors used to define the source's post deposition power levels; see [section 4.9.3 on page 4-21](#).
- 17— RATE RAMP SUBGROUP
Annunciators and cursors used to define a change in deposition rate during the deposit state; see [section 4.7 on page 4-19](#).
- 18— DEPOSIT STATE INDICATOR
Annunciator used to indicate that the instrument is executing the deposit state of the active film; see [section 4.1 on page 4-1](#).
- 19— PRE DEPOSIT SUBGROUP
Annunciators and cursors used to define the predeposition source conditioning when the display is in the Program mode.
 - a. RISE TIME 1-2 — defines the length of the rise 1 (2) state.
 - b. SOAK PWR 1-2 — defines the power level(s) of the soak 1 (2) state.
 - c. SOAK TIME 1-2 — defines the length of the soak 1 (2) state.

These parameters, together, define a two step source power profile with linear changes in power between levels as shown graphically in [Figure 2-8](#).

 - d. SHUTR DLY Y-N — executes (Y) or skips (N) the shutter delay phase; see [section 4.14 on page 4-23](#).

Figure 2-8 Source Power Level Profile



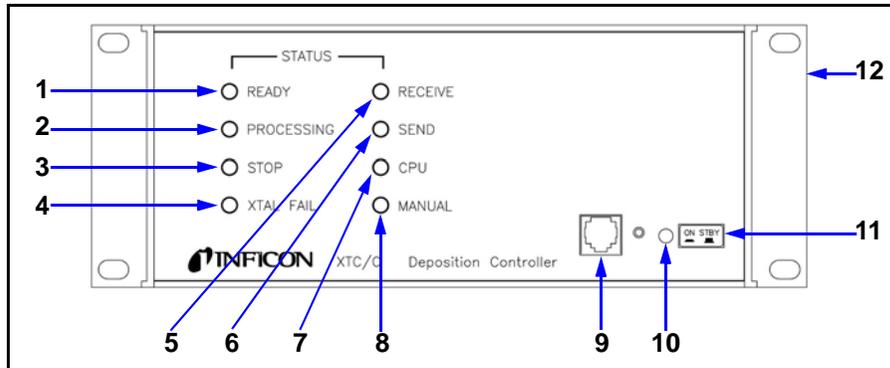
IPN 074-183X

- 20— PROGRAMMING and PHASE INDICATOR GROUP
Annunciators and cursors for navigating, displaying and changing a film's individual parameter values when the display is in the Program mode.

The annunciators are also used to indicate the current state of the film being executed when the display is in the Operate mode.

2.5 XTC/C Front Panel Description

Figure 2-9 Front Panel XTC/C



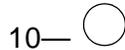
- 1— READY
When the associated LED is illuminated the instrument is in the READY TO START state.
- 2— PROCESSING
When the associated LED is illuminated the instrument is state executing a layer. See [Figure 4-2 on page 4-2](#).
- 3— STOP
When the associated LED is illuminated the instrument is in the STOP state.
- 4— XTAL FAIL
When the associated LED is illuminated the measurement crystal has failed. In the case of units configured for dual or CrystalSix operation it indicates that there are no further crystals available.
- 5— RECEIVE
When the associated LED is illuminated the instrument is receiving information from the connected computer controller.
- 6— SEND
When the associated LED is illuminated the instrument is sending information to the connected computer controller.
- 7— CPU
When the associated LED is illuminated the instrument's computer is not operating normally.

8— MANUAL

When the associated LED is illuminated the instrument is capable of responding to power changes as directed by the optional manual power controller.



Connection for optional manual power and crystal switch hand controller (IPN 755-262-G1).



Green LED indicates that the unit is connected to an active line power source and the ON/STBY switch is set to ON.

11— ON/STBY

Switches secondary power of the instrument between **ON** and **STANDBY**.

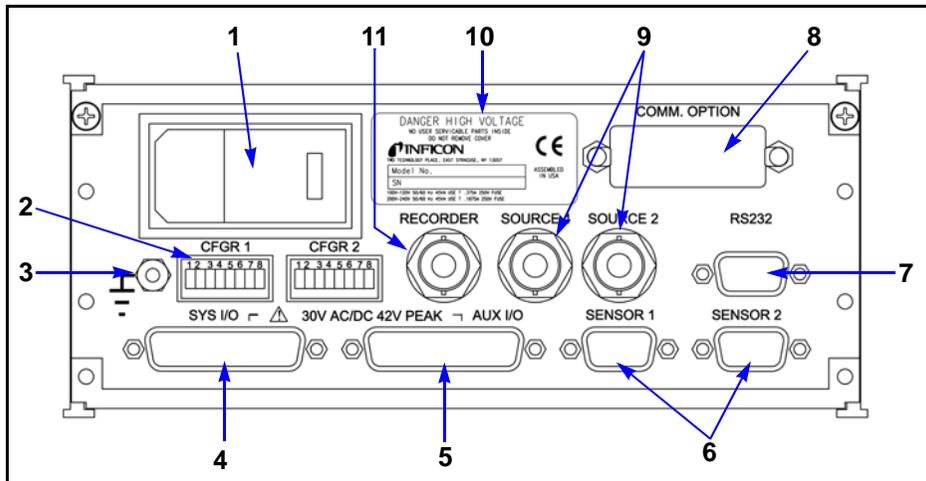
12—

Optional mounting kit for mounting one instrument in full rack (IPN 757-212-G1) or for mounting two units side by side in full rack (IPN 757-212-G2).

2.6 Rear Panel Description

The rear panel provides the interface for all external connections to the instrument.

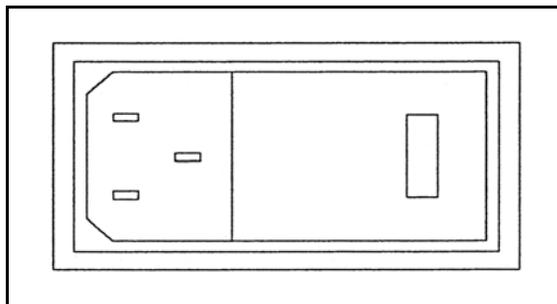
Figure 2-10 Rear Panel



2.6.1 Power Module

Allows selection of optional voltages, contains the instrument fuse and provides modular connection to line power. Refer to [section 2.2 on page 2-4](#).

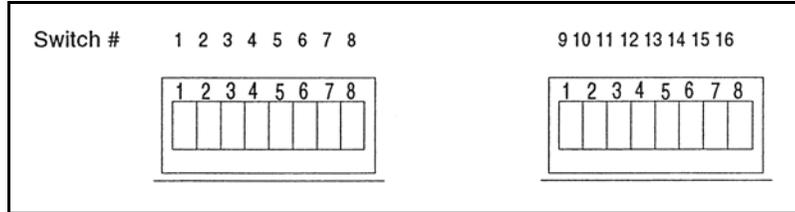
Figure 2-11 Power Module



2.6.2 Configuration Switches 1 & 2

Two eight position DIP switches used to customize the instrument as follows.

Figure 2-12 Configuration Switch



CAUTION

The configuration switches are only read on instrument power up. If an option is changed, the instrument must be switched to standby and then powered up.

Table 2-2 Configuration Switch Settings

	XTC/2	XTC/C
Switch 1	Test Mode (0 = off, 1 = on)	Communications (2 ⁴) Address
Switch 2	Parameter Lock (0 = off, 1 = on)	Communications (2 ³) Address
Switch 3	Control Mode (0 = deposit, 1 = etch)	Communications (2 ²) Address
Switch 4	Stop On Alarms (0 = no, 1 = yes)	Communications (2 ¹) Address
Switch 5	Stop on Max Power (0 = no, 1 = yes)	Communications (2 ⁰) Address
<p>XTC/C Switches 1-5 are only used for the optional IEEE488 (IPN 760-142-G1 or 757-122-G1). [Addresses 0 to 30 are allowed.]</p>		
Switch 6	Recorder Type MSB	Communications Protocol 0 = INFICON, 1 = SECS
Switch 7	Recorder Type	Baud Rate MSB
Switch 8	Recorder Type LSB	Baud Rate LSB
<p>NOTE: for the XTC/2 000 designates Rate, 100 Å/s full scale (unfiltered) 001 designates Rate, 1000 Å/s full scale (unfiltered) 010 designates Thickness, 100 Å full scale 011 designates, 1000 Å full scale 100 designates Power % 101 designates Rate Deviation (±50 Å/s) 110 designates Rate 100 Å/s full scale - smoothed 111 designates Rate 1000 Å/s full scale - smoothed</p> <p>NOTE: for the XTC/C 00 is 9600 baud 01 is 4800 baud 10 is 2400 baud 11 is 1200 baud</p>		
Switch 9	Beep On/Off (0=on, 1=off)	Checksum (0 = no, 1 = yes)
Switch 10	Backlight Dim (0 = no, 1 = yes)	Unused
Switch 11	Start Layer without backup crystal (0 = no, 1 = yes)	Start Layer without backup crystal (0 = no, 1 = yes)
<p>NOTE: See section 4.16 on page 4-26 for description</p>		

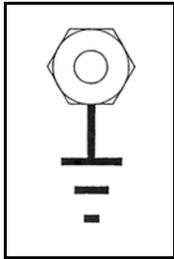
Table 2-2 Configuration Switch Settings

	XTC/2	XTC/C
Switch 12	Input Option 0 = standard 1 = film select	Unused
Switch 13	Relay Option 1 = on Relay 7 = End of Film Relay 10 = In Process 0 = off Relay 7 = Thickness Setpoint Relay 10 = Alarms	1 = on Relay 7 = End of Film Relay 10 = In Process 0 = off Relay 7 = Thickness Setpoint Relay 10 = Alarms
Switch 14 Switch 15	Crystal Switch Type MSB Crystal Switch Type LSB NOTE: 00 designates single head(s) 01 designates one dual head 10 designates one CrystalSix, on SENSOR 1 11 designates two CrystalSixs	Crystal Switch Type MSB Crystal Switch Type LSB
Switch 16	Source Control Voltage polarity 0 = neg, 1 = pos	Source Control Voltage polarity 0 = neg, 1 = pos

2.6.3 Grounding Stud

Recommended point for connecting the system ground strap. For specific recommendations see [3.2, Electrical Grounding and Shielding Requirements](#).

Figure 2-13 Grounding Stud



2.6.4 System I/O

A 25-pin male "D" type connector for interface connection. (See [Figure 2-14 on page 2-24](#) and [section 3.7 on page 3-15](#) for details.)

Relay#	Pin # Outputs	Function
1	1,2	Source Shutter 1
2	3,4	Source Shutter 2
3	5,6	Sensor Shutter 1*
4	7,8	Sensor Shutter 2*
5	9,10	STOP
6	11,12	End of Process

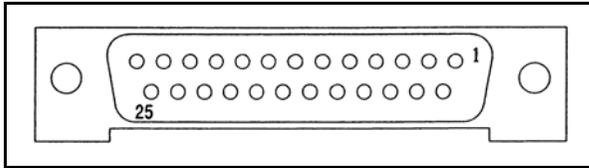
*Also used for crystal switch, see [section 4.15.1 on page 4-25](#)

Input #	Inputs	Function
	13,14,15,16,17	INPUT Common (GND)
1	18	START deposition
2	19	STOP deposition
3	20	END deposit
4	21	Sample initiate
5	22	Sample inhibit
6	23	Crystal fail inhibit
7	24	ZERO thickness
8	25	Soak 2 HOLD

2.6.5 AUX I/O

A 25-pin male "D" type connector for interface connection, see [Figure 2-14 on page 2-24](#) and [section 3.7 on page 3-15](#).

Figure 2-14 25-Pin Type "D" Male Connector



	Pin #	Function
Relay #	Outputs (Relays)	
7	1,2	Thickness setpoint/End of Film*
8	3,4	Feedtime (SOAK 2)
9	5,6	Crystal fail
10	7,8	Alarms/In Process*
11	9,10	Source 1/Source 2 toggle (closed when source 2 is active)
12	11,12	End Deposit
Input#	Inputs	
	13	Input common (GND)
9	14	Crucible valid
	15,16,17	Input common (GND)
TTL Output #	Outputs (Open Collector 1 of 8 encoding)**	
1	18	Crucible select 1
2	19	Crucible select 2
3	20	Crucible select 3
4	21	Crucible select 4
5	22	Crucible select 5
6	23	Crucible select 6
7	24	Crucible select 7
8	25	Crucible select 8

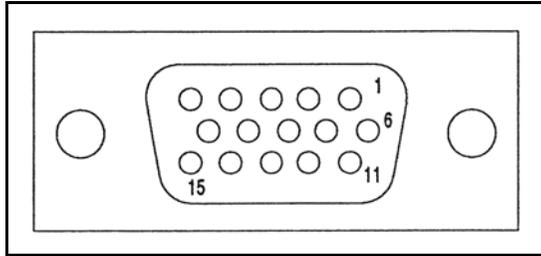
***NOTE:** See description of configuration switch 13, [section 2.6.2 on page 2-19](#).

****NOTE:** The crucible select outputs are available BCD encoded on the Sensor 1 connector, see [section 2.6.6 on page 2-25](#).

2.6.6 Sensor 1, Sensor 2

High density 15-pin female "D" type. Input connectors for intelligent oscillators 1, 2 (IPN 757-302 G1). These oscillators are normally supplied with 15 foot (4.5 meter) cables as IPN 757-305-G15. These are specifiable as 30 foot and 100 foot by changing the group (G-xx) designation to 30 or 100, respectively. The crucible select outputs are open collector BCD encoded only on Sensor 1.

Figure 2-15 15-Pin Type "D" Female Connector



Pin #	Description
11	Crucible Select (LSB)
12	Crucible Select
13	Crucible Select (MSB)
14	Ground
15	Ground

} BCD encoding

CAUTION

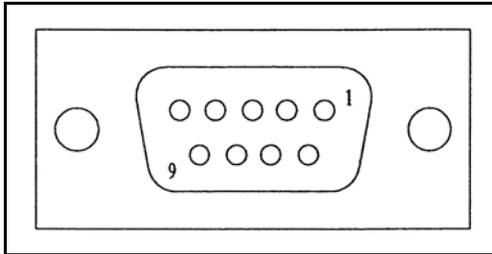
Only connect to pins 11-15, inclusive. Ignoring this warning will effect crystal and instrument performance.

Be sure to follow the best wiring and grounding practice possible see [section 3.2.3 on page 3-3](#).

2.6.7 RS232

A 9-pin female "D" type connector which enables the instrument to be controlled by a host computer.

Figure 2-16 9-Pin Type "D" Female Connector

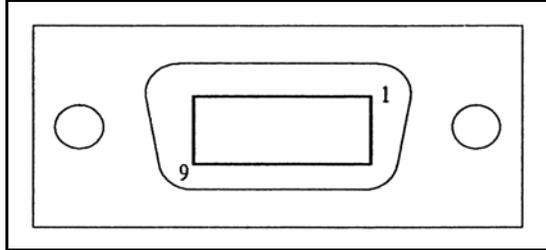


Pin #	Description	DB9*	DB25**
1	Not used	1	-
2	TXD Data transmitted from XTC2	2	3
3	RXD Data received by XTC3	3	2
4	Not used	4	-
5	GND Signal ground	5	7
6	DTR Output from XTC indicating ready to transmit	6	6
7	CTS Input to XTC indicating stop transmitting	7	4
8	Not used	8	-
9	GND Shield ground	9	-
*Host	**IBM compatible computer connector		

2.6.8 Communication Option

Location of optional computer interface.

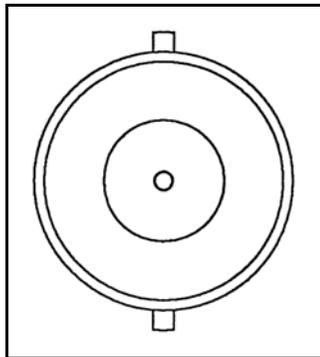
Figure 2-17 IEEE488 Option



2.6.9 Source 1,2

BNC type female connectors that supply control voltage to the designated evaporation source power supplies. The output voltage is selected as either plus or minus with respect to the shield by a *Configuration Switch*. Refer to [section 2.6.2 on page 2-19](#).

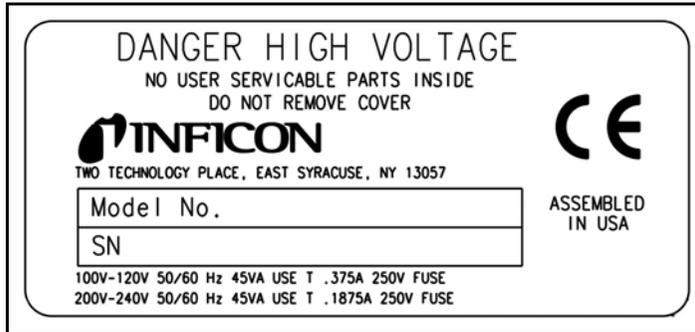
Figure 2-18 BNC Connector



2.6.10 Manufacturer's Identification and Serial Number Plate

This plate is installed at final assembly to identify the instrument's model and serial numbers.

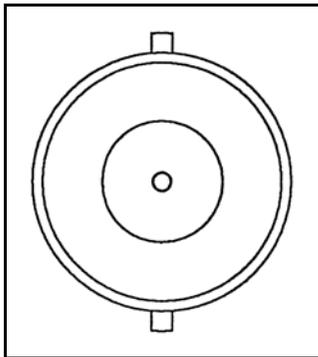
Figure 2-19 Serial Number Plate



2.6.11 Recorder

A BNC type female connector that supplies analog voltage proportional to rate, thickness, power or rate deviation. The function is determined by *configuration switches*. Refer to [section 2.6.2 on page 2-19](#). See the Remote Command description in [section 3.8.5.6 on page 3-32](#) for how to choose this function via the remote communications when using an XTC/C.

Figure 2-20 BNC Connector



2.7 Operation as a Deposition Monitor

Although this instrument is designed as a multi-layer process controller, it is also easily used as a rate and thickness deposition monitor. In addition, it is easily used for many other types of mass measurement applications.

The following discussion is divided into four segments. The first is for applications that do not require a source shutter. The second relates to those that use a source shutter. The third section is a simple application of the instrument for manual rate sampling. The fourth segment is directed towards those applications that are nontraditional; including biological, electroplating, etching and the measurement of liquid samples.

2.7.1 Monitoring - Systems Without a Source Shutter

To operate the instrument as a film rate/thickness monitor only the following three parameters need to be programmed. Press the **PROG** key to place the display in the program mode and enter the appropriate values for:

- DENSITY** Depends on the material to be measured, see [Appendix A, Table of Densities and Z-ratios](#).
- Z-RATIO** Depends on the material to be measured, see [Appendix A, Table of Densities and Z-ratios](#).
- TOOLING 1,2** Corrects for the geometrical differences between the sensor and the substrate, see [section 5.3 on page 5-2](#). **TOOLING 2** is used for the backup sensor when a dual head is used.

Properly mount and attach the appropriate transducer (see [section 3.5 on page 3-7](#)).

Set the rear panel configuration switches for the appropriate transducer type; refer to [section 2.6.2 on page 2-19](#).

Press the **PROG** key to change the display between the program and operate modes.

A **STOP** is cleared by pressing the **START** or **RESET** switch. **RESET** starts the process over (i.e., at the beginning of Layer 1).

Pressing the **ZERO** key at any time sets the displayed thickness to 000.0 KÅ.

The Rate display group will indicate the evaporation rate and the Thickness display group will increment accordingly. The front panel controls work normally.

IPN 074-183X

2.7.2 Monitoring - Systems with a Source Shutter

In addition to measuring rate and thickness, these instruments can be used to terminate the deposition at the proper thickness. Implementation requires that the deposition system have a source (or substrate) shutter capable of automatic operation. The source shutter controller must be wired through the **SYSTEM I/O** connector on the rear panel of the instrument. The following parameters (in addition to those required in the section above) must also be programmed.

DEP RATE Program to 0.1 Å/sec.

NOTE: Programming the **DEP RATE** to 0.0 Å/sec skips the Deposit state.

FINAL THK Program to the desired film thickness.

In addition set all of the pre and post deposition parameters to zero (see [Chapter 4, Programming System Operation Details](#)).

The operator manually increases the source power (using the source power supply's control) to the nominal operating level. Once the user is satisfied, the deposition begins when the **START** switch is pressed. This action zeros the accumulated thickness display and opens the source shutter. The operator must then adjust the source power manually to achieve the desired rate. The shutter will close automatically when the final thickness set point is achieved.

2.7.3 Rate Sampling

It is possible to use these instruments to periodically sample the rate in a deposition system. A shuttered transducer must be used, see [section 3.4 on page 3-6](#).

NOTE: It will be useful to refer to the separate INFICON Crystal Sensor Manual (see list below) for transducer and actuator control valve installation.

IPN	Type
074-154	Bakeable
074-155	CrystalSix
074-156	Standard, Compact and Dual
074-157	Sputtering

- 1 Electrically connect the pneumatic shutter actuator control valve (IPN 007-199) to the sensor shutter pins of the **SYSTEM I/O** connector.



CAUTION

Verify proper electrical connection, do not confuse the source shutter relay with the sensor shutter relay.

- 2 Program the **DEP RATE** parameter to 0.1 Å/sec.

NOTE: Programming the **DEP RATE** to 0.0 Å/sec skips the Deposit state.

- 3 Program the **FINAL THK** parameter to a value which allows approximately 20 seconds of material accumulation onto the sensor head. For example, if the nominal rate is 20 Å/sec, set the final thickness to 20 sec x 20 Å/sec = 400Å. If the sample time is too short there could be errors induced by temperature transients across the monitor crystal.

A sample is initiated by pressing **START** (from the **READY** mode). This zeros the displayed thickness and opens the sensor shutter. The operator may view the deposition rate display (allowing it to stabilize) and then comparing it to the desired rate. If a time longer than the programmed sample time is required to adjust the actual deposition rate the operator can press the **MPWR** key. Once the adjustments are completed, again pressing the **MPWR** key closes the shutter.

2.7.4 Nontraditional Applications

In addition to their normal application as a deposition monitor/controller, quartz crystal microbalances have significant utility as generalized mass sensors. This particular instrument family is capable of measuring mass increases or decreases on the face of the monitor crystal to an accuracy of +/- 0.617 nanograms/cm² (density = 1.00, z = 1.00). As always, it is imperative that the mass be well adhered to the face of the crystal or improper readings will be taken. It is especially important to recognize this requirement for measurements of liquids or other non-rigid materials. INFICON's 6MHz crystal holders have an open area of ~0.535 cm². For the highest accuracy possible, it is suggested that the individual crystal holder be measured with a traveling microscope to determine the exact opening area.

2.7.4.1 Etching

The instrument may be configured to display the thickness or mass removed from the face of a crystal. It is imperative that the material be removed uniformly over the active area of the crystal or improper readings will be taken. This inaccuracy occurs because of radial mass sensitivity differences across the face of the monitor crystal.

The etch mode is established by setting a configuration switch (refer to [section 2.6.2 on page 2-19](#)) on the back of the instrument.

The unit is operated normally, with the **ZERO** or **START** keys used to zero the displayed thickness. The **FINAL THK** parameter may be programmed to terminate the process.

2.7.4.2 Immersion in Liquids

Measurement of mass change in liquids is a relatively new field, consequently application information is limited. The energy loss from the vibrating crystal into the liquid environment is high, limiting the accuracy of the measurement in some cases. The ModeLock oscillator again provides superior performance, allowing operation in liquids of higher viscosity than an active oscillator system would provide. The presence of bubbles on the face of the crystal as it is immersed will drastically change the noted frequency shift and alter the sensitivity of the technique from immersion to immersion.

NOTE: It is not recommended to use standard INFICON sensors in liquids without modification.

2.7.4.3 Biological

The measurement of biological specimens is subject to many of the same problems as covered in the measurement of liquids.

2.7.4.4 Measurement of Liquids

The measurement of the mass of a liquid on the face of a crystal is a technique that is subject to very large errors. The two primary problems with liquids are that they are not infinitely rigid structures and do not necessarily form in uniform layers. Because liquids do not oscillate as a rigid solid, not all of the mass participates in the resonance. Consequently, not all of the liquid is detected. In some ways, the crystal is more appropriately called a viscosity sensor. The second problem is that liquids tend to form spheres on the face of the crystal after only very modest accumulations of a few monolayers. This aggravates the problem caused by non-infinite rigidity. Another aspect of the problem is that the liquid spheres form at random locations across the crystal. Because monitor crystals have differential radial mass sensitivity an uncontrollable measurement problem exists. Spheres formed at the center of the crystal contribute more than spheres formed near the edge of the sensor's aperture.

2.8 Operation as a One Layer Controller

This instrument is designed to provide automatic deposition rate control with thickness termination as well as pre and post deposition source conditioning. Fully automatic operation requires that the instrument be interfaced with the deposition source power supply controller and the source shutter. In addition, the instrument interfaces to many other deposition system components through the **SYSTEM I/O** and **AUX I/O** connectors.

To operate the instrument as a single layer controller it is necessary to program the film sequence parameters. A film sequence begins with a **START** command and ends when the same film reaches the "IDLE" state.

NOTE: A **START** command may be provided by pressing **START** or by activating the **START** input on the system I/O connector.

All instrumental action that occurs between these events is determined by the values programmed into the appropriate film specific parameters. Programming the instrument is easily accomplished once you have made the determination to monitor or control the process, chosen the type of material to deposit and its required rate and thickness and have become familiar with the instrument programming procedure. If you are familiar with the terminology of depositions, it is only required that the desired values of each parameter be entered for the designated **FILM #**.

A film is composed of many possible states, with a state being defined as one process event. These states sequence in order and are defined and diagramed in this manual in [Chapter 4, Programming System Operation Details](#). The values used in the various parameters tell the instrument how to specifically execute the deposition process, see [section 4.2 on page 4-6](#) for a description of which parameters affect a given process state. [Figure 2-21 on page 2-35](#) is a generalized overview of the normal processing of a film and its source control.

For example, if the first layer of the process is 1000Å of copper it would be convenient to dedicate film 1's parameters to describing this particular layer of the process.

These instruments allow up to nine individual film programs to be defined, stored and recalled. When the display is in the program mode the particular **FILM #** being modified is always visible (except when the **S** and **Q** parameters are being programmed). The **FILM #** may be changed by moving the cursor to that parameter and changing its value. When the display is in the operate mode the film executing or about to execute is displayed as **FILM #**.

A **START** command will begin processing that film if it is not already processing another film or in the **STOP** state. **START** commands are ignored if a film is already processing.

2.8.1 Skipping a State Overview

It is not necessary to use all possible film states when a film is programmed. Unwanted states will be executed in 250 ms if the film parameters which are used to define the state are set to zero. The **IDLE** state of a film, however, will always be executed. When the desired **DEP RATE** is programmed to zero, the entire **DEPOSIT** state will be skipped (including any rate ramps). If no parameters have been programmed, the film will immediately sequence to the **IDLE** state when the **START** key is pressed.

2.8.2 Idle State Processing Overview

When a film program finishes in the **IDLE** state at a programmed **IDLE PWR** level other than zero, a subsequent **START** command will initiate any film program utilizing the same source output at the **RISE TIME 2** state, skipping all previous states, even if they were programmed. If **RISE TIME 2** is not present in the film, the instrument will sequence to the next viable state — **SHUTR DLY**, **DEPOSIT**, **IDLE RAMP** or **IDLE** (in the stated order).

2.8.3 Manual Power Overview

The **MANUAL** state may be entered whenever the instrument is not in the **STOP** or **IDLE** state by pressing the **MPWR** switch. The shutter will always open and the **FINAL THK** event will be ignored. When the **MANUAL** control state is ended, the unit will sequence to the **DEPOSIT** state, provided that the **FINAL THK** limit has not been exceeded. Any thickness accumulated while the unit has been in the **MANUAL** state will be retained and added to when the **DEPOSIT** state is entered.

When the instrument is in the **MANUAL** state the control voltage output (% Power on the display) may be increased or decreased either through the Handheld Power Controller (optional) or the or the Δ or ∇ keys on the front panel. The rate of change of source power is linearly ramped from 0.4% per

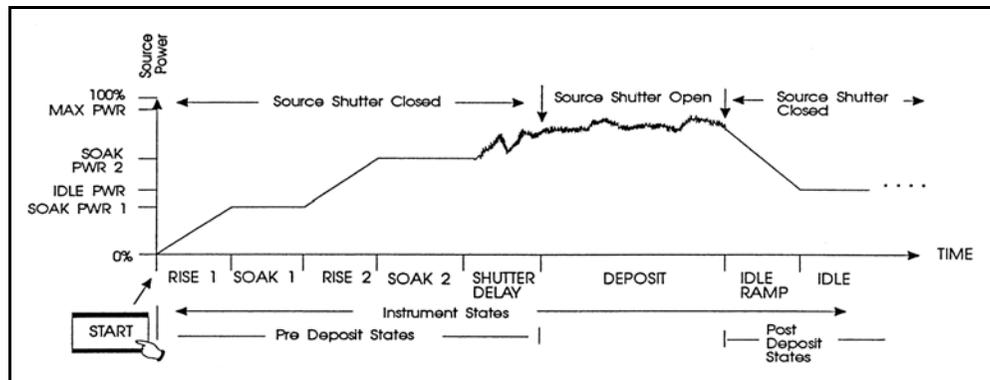
second to 4% per second over 4 seconds and then held at a constant 4% per second. This feature is designed to allow fine adjustment of the control voltage when needed, while also allowing rapid control voltage adjustment if desired.

2.8.4 Time Power State Overview

The time power state will only be entered while the instrument is in the **DEPOSIT** or **RATE RAMP** state and the film program has been set to complete on time-power in the event of a failed crystal. If a crystal fail is detected during the pre-deposit states the instrument will not sequence further, causing an instrument **STOP** even if the complete on **TIME-PWR (Y)** option is selected.

Once in the TIME-POWER state, the source power will remain at the 5 seconds average power value of the source control output computed 2.5 seconds prior to the failure. (These times are appropriately modified for PID control.) Thickness is accumulated at the programmed **DEP RATE** value. The time-power state will terminate when the **FINAL THK** value has been exceeded. Any post-deposit states will be executed exactly as if a normal deposition had occurred. The **TIME-PWR** annunciator will remain on the display. When the post-deposit states are complete, the instrument will enter the **STOP** state. A **RATE RAMP** cannot be executed in TIME-POWER and that state is consequently skipped.

Figure 2-21 State Processing for a Film



2.8.5 Controlling the Source Overview

Stable rate control during the **DEPOSIT** state requires the proper setting of the following control loop algorithm adjusting parameters: **CTL GAIN**, **CTL TC**, and **CTL DT**. By properly adjusting these parameters it is possible to control sources of nearly any physical characteristic by employing either a **PID** or integrating algorithm. The proper adjustment technique and a detailed algorithm description is covered in 4.5, [Tuning the Control Loop](#).

2.9 Operation as a Multi-Layer Controller

This instrument can be programmed to execute a series of up to three of the stored films in a repetitive sequence. This sequence of films is called a **PROCESS**. A separate **START** command is necessary to initiate each layer of a process. This command may be initiated from the front panel switch, through the rear panel I/O or through the computer interfaces.

2.9.1 Defining a Process Overview

A process is programmed by moving the cursor to the **L_{YR}** parameter when the display is in the program mode. The **L_{YR}** parameter value is visible any time the display is in the operating mode.

When the **L_{YR}** parameter is selected; the segmented digit immediately to the right begins to flash. Entering a digit between one and nine will designate the **FILM** associated with that number to be the film first executed in the **PROCESS**. Upon entry, the selected digit will become static and the second segmented digit will blink. Entering a second (or even the same) number will establish the second layer of the **PROCESS**. Now the third digit will flash, entering a third number will complete the process sequence.

A **PROCESS** sequence may be altered any time the keyboard is unlocked or through the various computer interfaces.

NOTE: If a zero is entered for the second or third layer, that layer(s) will be skipped. The first layer must be a non-zero value.

Chapter 3 Installation

3.1 Installing the Instrument - Details

A general schematic of instrument installation is given in [section 2.3 on page 2-8](#), use it for reference. *The importance of grounding the instrument cannot be over emphasized for both safety and performance needs.*

3.1.1 Control Unit Installation

Review the specific suggestions and warnings concerning safety and installation that are presented in [section 1.1 on page 1-1](#).

It is generally advisable to centrally locate the controller, minimizing the length of external cabling. The cable from the instrument to the XIU is fifteen feet. Longer cables are specifiable as 30 or 100 ft. (max.), refer to [section 2.6.6 on page 2-25](#) for ordering details.

The control unit is designed to be rack mounted. It may be also used on a table; four self-adhesive rubber feet are included in the ship kit for this purpose.

3.2 Electrical Grounding and Shielding Requirements

Careful consideration of simple electrical guidelines during installation will avoid many problems caused by electrical noise.

To maintain the required shielding and internal grounding as well as insuring safe and proper operation, the instrument must be operated with all enclosure covers and option panels in place. These must be fully secured with the screws and fasteners provided.

3.2.1 Verifying / Establishing Earth Ground

If local facilities engineering cannot provide a low impedance earth ground close to the instrument, the following procedure is recommended.

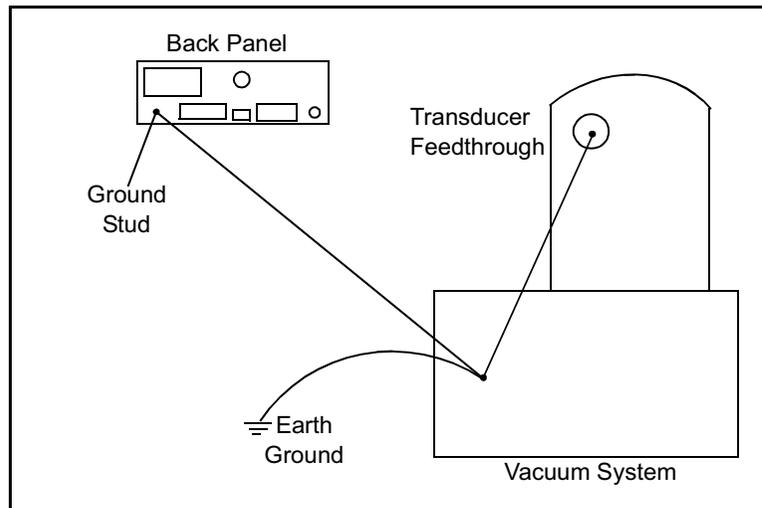
Where soil conditions allow, drive two ten foot copper clad steel rods into the ground six feet apart. Pour a copper sulfate or other salt solution around the rods to improve the soil's conduction. A near zero resistance measurement between the two rods indicates that a desirable earth ground has been established. In severe cases it may take several soakings of solution over several days to reach this condition.

NOTE: Keep connections to this grounding network as short as possible. Most noise transients contain significant power at high frequencies. A long path adds to the ground circuit's inductance and thereby increases its impedance at these frequencies.

3.2.2 Connections to Earth Ground

The ground connection on the instrument is a threaded stud with a hex nut. It is convenient to connect a ring terminal to the ground strap, thus allowing a good connection with easy removal and installation. See [Figure 3-1](#) for the suggested grounding scheme. In many cases, a braided ground strap is sufficient. However, there are cases when a solid copper strap (0.030 thick X 1" wide) is more suitable because of its lower RF impedance.

Figure 3-1 System Grounding Diagram



 **CAUTION**

An external ground connection is required to ensure proper operation, especially in electrically noisy environments.

When used with RF powered sputtering systems, the grounding scheme may have to be modified to optimize the specific situation. An informative article on the subject of "Grounding and RFI Prevention" was published by H.D. Alcaide, in "Solid State Technology", p 117 (April, 1982).

3.2.3 Minimizing Noise Pickup from External Cabling

When an instrument is fully integrated into a deposition system, there are many wire connections; each a potential path for noise to be conducted to the inside. The likelihood of these wires causing a problem can be greatly diminished by using the following guidelines:

- ◆ Use shielded coax cable or twisted pairs for all connections.
- ◆ Minimize cable lengths by centralizing the controller.
- ◆ Avoid routing cables near areas that have the potential to generate high levels of electrical interference. For example, large power supplies, such as those used for electron beam guns or sputtering sources, can be a source of large and rapidly changing electro-magnetic fields. Placing cables as little as one foot (30 cm) from these problem areas can be a very significant improvement.
- ◆ Be sure that a good ground system and straps are in place as recommended above.
- ◆ Ensure that all instrument covers and option panels are in place and tightly secured with the provided fasteners.

3.3 Connection to Rear Panel

The long term performance of this instrumentation is dependent on the quality of the installation. A first rate installation includes the proper assembly of the user/OEM installed cabling. The assembly instructions for the connectors used on this instrumentation are shown in the following sections.

3.3.1 The BNC Connectors

Because complete BNC cables are so common, there are no mating connectors supplied in the ship kit for the source and recorder outputs. It is recommended that completed BNC type cables be purchased locally, even if one end is cut off for connection to the external apparatus.

3.3.2 The "D" Shell Connectors

The "D" shell connectors use solder cup contacts that will accept solid or stranded wire with a maximum individual wire size of 20 AWG. Multiple stranded wire jumpers may equal 18 AWG, or two 22 AWG wires may be employed. The recommended wire strip length is 1/4" (6.4 mm).

The duplex tin/lead solder cup readily accepts tinned leads and will securely strain-relieve wires when properly soldered. See [Figure 3-2 on page 3-5](#).

The American National Standards Institute *Standards For Soldering Electronic Interconnections* (ANSI/IPC-S-815A) is recommended for establishing soldering quality guidelines.

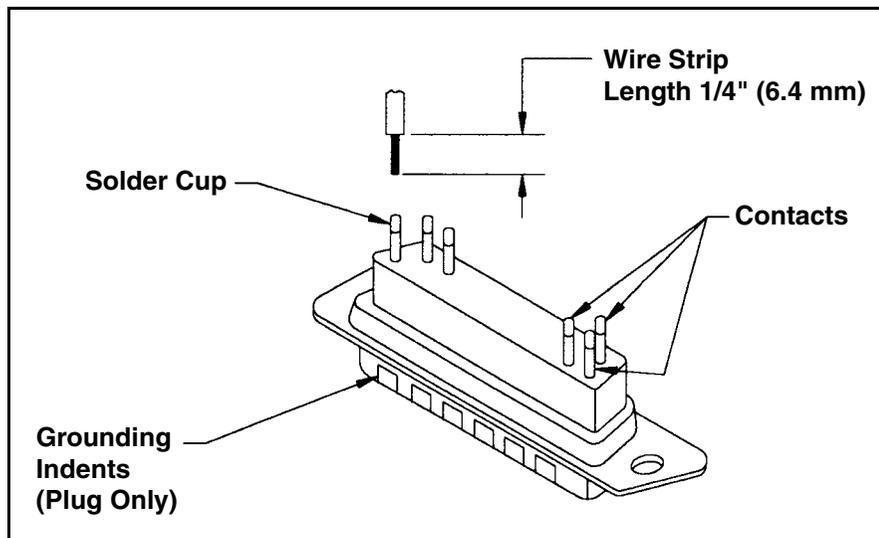
The soldering procedure is as follows:

- 1 Obtain a connector and wire(s) of the type and size required for your application.
- 2 Ensure that surfaces to be soldered are clean and free of any contaminants that may inhibit solderability.
- 3 Strip wire(s) to recommended strip length (1/4"). Tin the leads if required.
- 4 Obtain resin flux, 40/60 alloy solder, and a low-wattage soldering iron.

NOTE: It is common to use heat shrink tubing over solder joints to insulate the exposed solder connection at the cup. If using heat shrink tubing, ensure that the tubing sections are cut to proper length and placed on the wire(s) prior to soldering. After wires are terminated, slide tubing over solder connections and shrink with an appropriate heat source.

- 5** Coat the stripped portion of the wire(s) with the flux and insert into the solder cup of the contact until the conductor is bottomed in the cavity.
- 6** Heat the solder cup with the soldering iron and allow the solder to flow into the cup until the cavity is filled but not over filled.
- 7** Continue soldering wires until all terminations are complete.
- 8** Clean the soldered connections with a suitable alcohol/water rinse to remove flux and solder residue.

Figure 3-2 Solder Cup Connector



3.4 Sensor Selection Guide

The choice of sensor type must be dictated by the process, the deposition material and the physical characteristics of the process chamber. General guidelines for each sensor type produced by INFICON are outlined in the Sensor Selection table below. For specific recommendations, consult your INFICON representative.

Table 3-1 Sensor Selection Table

Name	IPN	Temp °C	Crystal Exchange	Utility Connector	Comments
Standard	750-211-G1	130°	Front	Side	
Standard w/Shutter	750-211-G2	130°	Front	Side	
Compact	750-213-G1	130°	Front	Rear	For tight spaces
Compact W/Shutter	750-213-G2	130°	Front	Rear	For tight spaces
Dual	750-212-G2	130°	Front	Side	Two crystals for crystal switch. Includes Shutter
Sputtering	007-031	130°	Rear	Side	For RF and diode sputtering. (Optional shutter available.)
Bakeable					
12" (304.8 mm)	007-219	450°	Front	Side	Must remove water cooling and open the tubes prior to bakeout
20" (508 mm)	007-220				
30" (762 mm)	007-221				
Bakeable w/Shutter					
12" (304.8 mm)	750-012-G1	450°	Front	Side	Must remove water cooling and open the tubes prior to bakeout
20" (508 mm)	750-012-G2				
30" (762 mm)	750-012-G3				
CrystalSix	750-446-G1	130°	Front	Side	6 crystals for process security.

*These temperatures are conservative maximum device temperatures, limited by the properties of Teflon at higher temperatures. In usage, the water cooling allows operation in environments that are significantly elevated, without deleterious effects.

NOTE: Do not allow water tubes to freeze. This may happen if the tubes pass through a cryogenic shroud and the water flow is interrupted.

NOTE: For best operation, limit the maximum input water temperature to less than 30 °C.

NOTE: In high temperature environments more heat may transfer to the water through the water tubes than through the actual transducer. In extreme cases it may be advantageous to use a radiation shield over the water tubes.

3.5 Guidelines for Transducer Installation

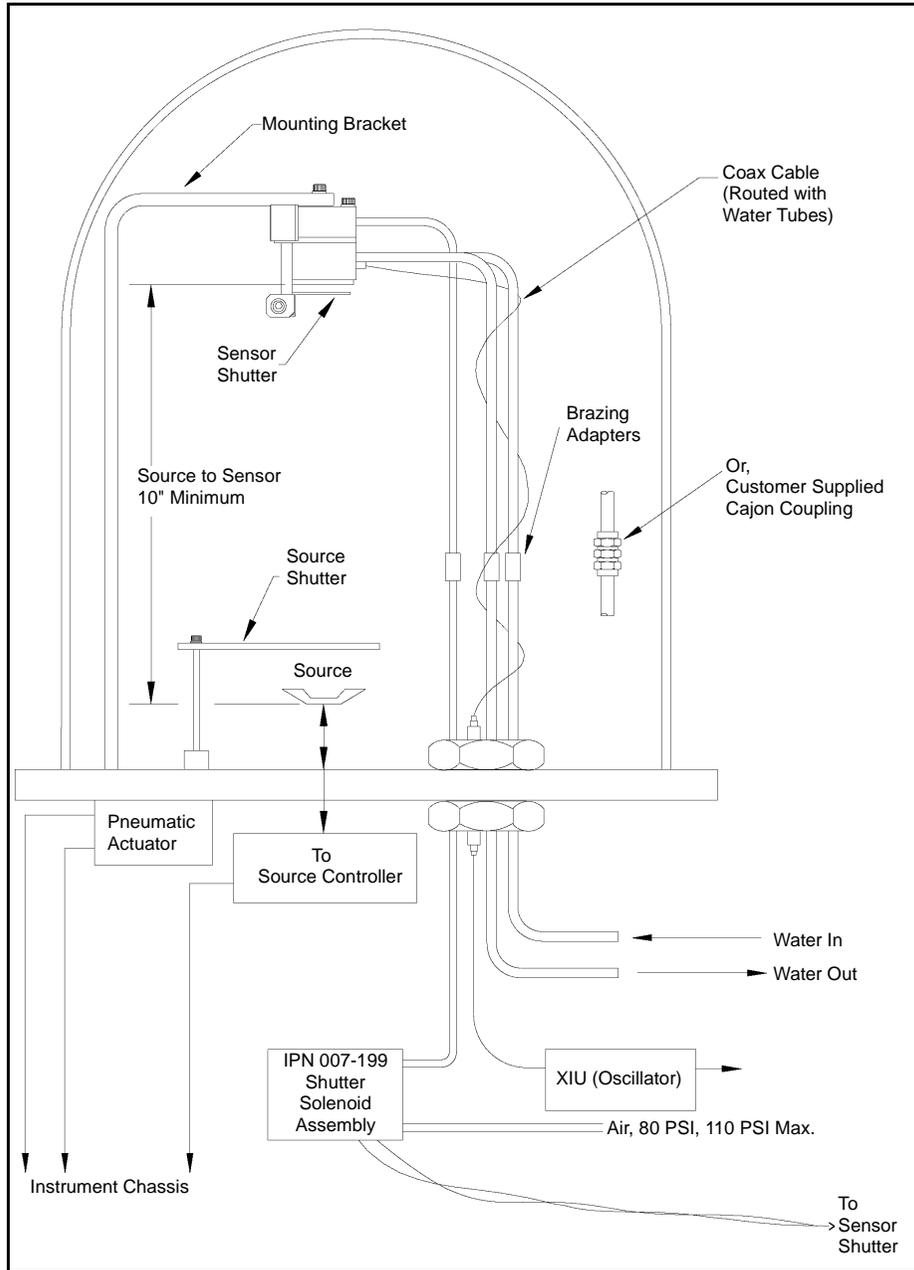


The performance of this instrument depends on the careful installation of the chosen transducer. Improper installation will cause problems with deposition repeatability, crystal life and rate stability.

3.5.1 Sensor Installation

Figure 3-3 shows a typical installation of an INFICON water cooled crystal sensor in the vacuum process chamber. Use the illustration and the following guidelines to install your sensors for optimum performance and convenience.

Figure 3-3 Typical Installation

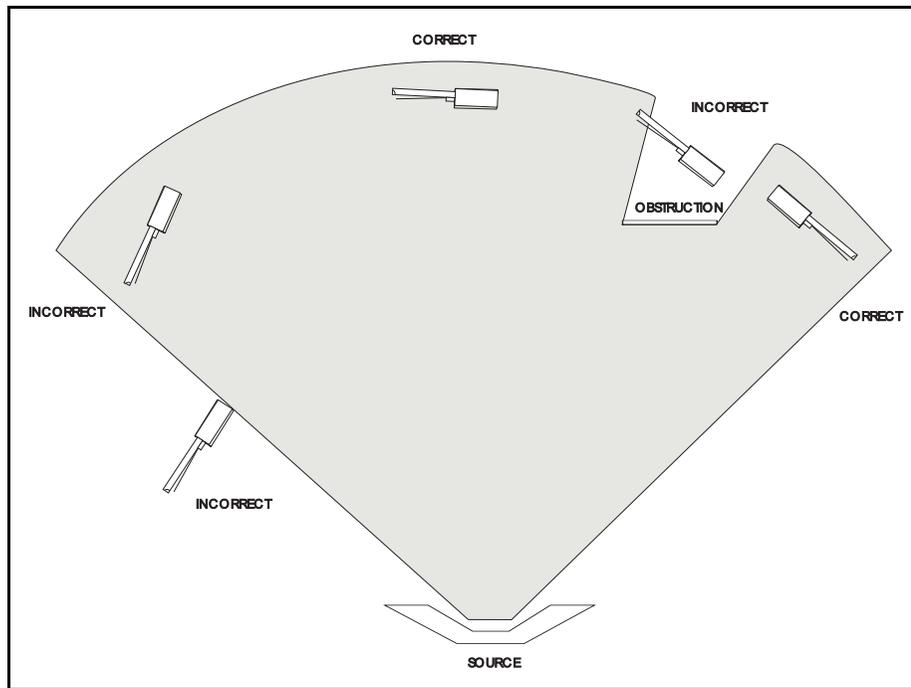


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Generally, install the sensor as far as possible from the evaporation source (a minimum of 10" or 25.4 mm) while still being in a position to accumulate thickness at a rate proportional to accumulation on the substrate. Figure 3-4 shows proper and improper methods of installing sensors.

To guard against spattering, use a source shutter or crystal shutter to shield the sensor during the initial soak periods. If the crystal is hit with even a minute particle of molten material, it may be damaged and stop oscillating. Even in cases when it does not completely stop oscillating, it may become unstable.

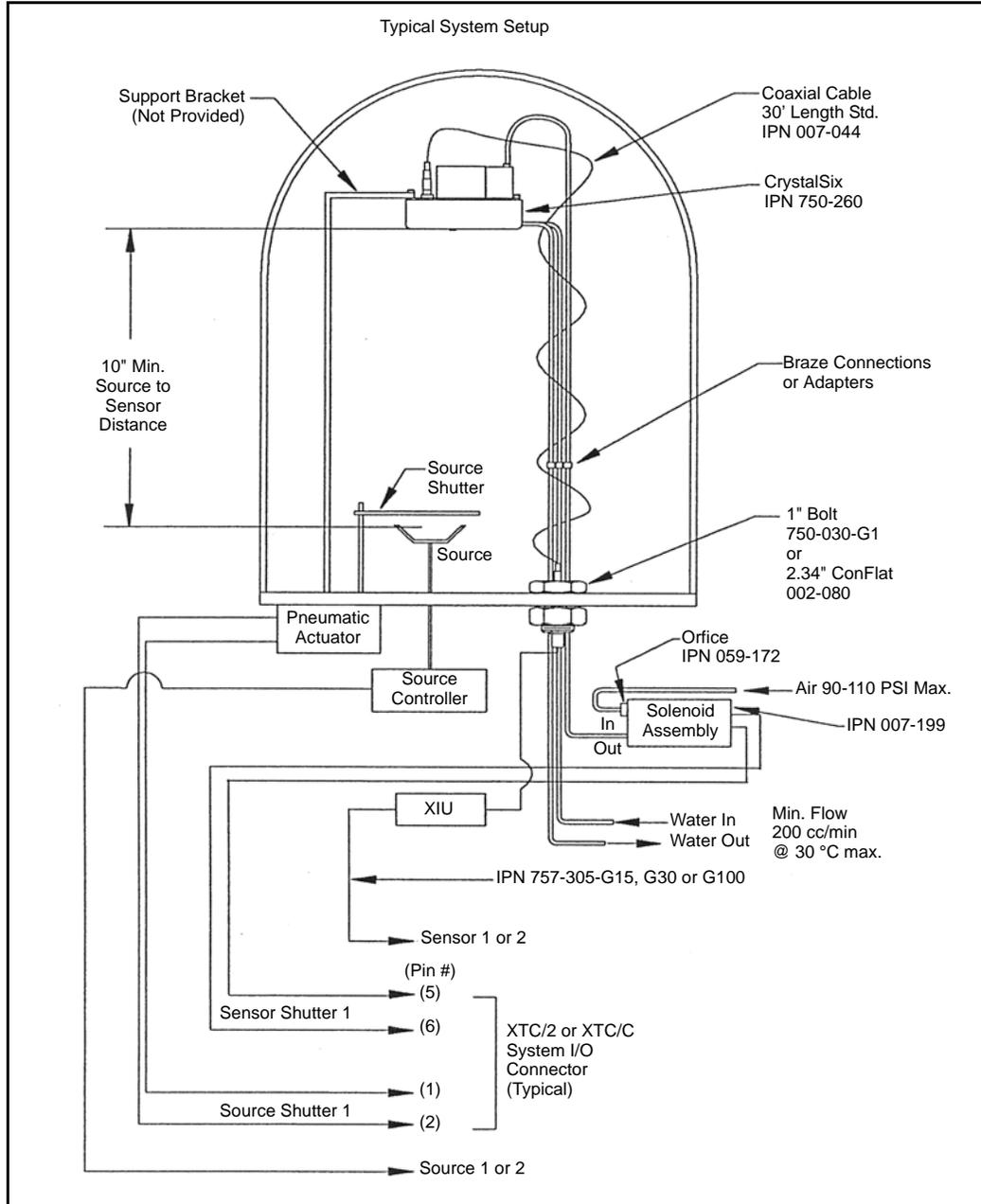
Figure 3-4 Sensor Installation Guidelines



3.5.2 CrystalSix

Installing the CrystalSix transducer requires that the CrystalSwitch configuration switches be set appropriately; refer to [section 2.6.2 on page 2-19](#). Follow the guidelines in the CrystalSix Manual (IPN 074-155) and [Figure 3-5](#). If the unit is configured for one CrystalSix, it must be connected to Sensor 1.

Figure 3-5 CrystalSix Installation for XTC/2 and XTC/C



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3.5.3 Check List for Transducer Installation

- ◆ Mount the sensor to something rigid and fixed in the chamber. Do not rely on the water tubes to provide support.
- ◆ Plan the installation to insure that there are no obstructions blocking the path between the Sensor and the Source. Be certain to consider rotating or moving fixtures.
- ◆ Install sensors so their central axis (an imaginary line drawn normal to the center of the crystal's face) is aimed directly at the virtual source being monitored.
- ◆ Be sure there is easy access for the exchange of crystals.
- ◆ For systems employing simultaneous source evaporation (co-dep), try to locate the sensors so the evaporant from each source is only flowing to one sensor. This is not generally possible to do without special shielding or optional "material directors" for the transducers.
- ◆ The use of water cooling is always recommended, even at very low heat loads and low rates.
- ◆ If penetrating a cryogenic shroud, be sure that the cooling water is kept flowing or drained between uses. Failure to do so could cause the water to freeze and the water tubing to rupture.
- ◆ Avoid running cold water tubes where condensation can drip into the feedthroughs. This condensate can effectively short the crystal drive voltage, causing premature crystal failure.

3.6 Use of the Test Mode (XTC/2 Only)

This instrument contains a software controlled test mode which simulates actual operation. The purpose of the Test Mode is to verify basic operation and for demonstrating typical operation to the technician.

The Rate displayed during Test Mode operation is determined as follows:

$$\text{Displayed Rate} = \frac{40}{\text{DENSITY (gm/cc)}} \times \frac{\text{TOOLING (\%)}}{100\%} \text{ \AA/se} \quad [1]$$

All relays and inputs operate normally during Test Mode operation.

3.6.1 Operational Test

The power switch should be in the **STBY** position before the instrument is connected to line power.

Perform the self test as follows:

- 1 Verify that no system cables other than the power cord are connected to the unit. Relays may be verified with an ohm meter or custom test box.
- 2 Set configuration switch 1 to the "ON" position.
- 3 Press the **ON/STBY** switch, the green power LED should light. If **Err** is displayed on the LCD, see [section 6.2 on page 6-1](#).
- 4 The following LCD displays will appear:
TEST
READY
XX:XX PHASE MIN:SEC
XX% POWER
XTAL FAIL
- 5 Press the **PROG** key. The program display will appear and the cursor will be located beside **RISE TIME**.

- 6** Refer to the list of parameters in [Table 3-2](#) and enter the data as they are given.

Table 3-2 Operational Test Parameters

RISE TIME 1	00:20	min:sec
SOAK PWR 1	20	%
SOAK TIME 1	00:10	min:sec
RISE TIME 2	00:15	min:sec
SOAK PWR 2	35	%
SOAK TIME 2	00:10	min:sec
SHUTR DLY	N	Y:N
NEW RATE	00.0	Å/sec
R RAMP TIME	00:0	min:sec
IDLE RAMP	00:00	min:sec
IDLE PWR	02	%
TIME PWR	N	Y:N
XTAL SWCH S	0	
XTAL SWCH Q	0	
TOOL FACT 1	110.0	%
TOOL FACT 2	100.0	%
DEP RATE	16.2	Å/sec
FINAL THK	2.000	kÅ
THICK SPT	0.000	kÅ
DENSITY	02.73	gm/cc
Z-RATIO	1.000	
SENSOR #	1	
SOURCE #	1	
CRUCIBLE #	0	
CTL GAIN	10	Å/sec / %
CTL TC	5	sec
CTL DT	0.1	sec
MAX PWR	50	%
SAMPLE	5	%
HOLD TIME	00:00	min:sec

- 7** When the correct sequence of numerals appear in the flashing display, press the key to enter and store the data.
- 8** Press the **PROG** key to exit the program display.
- 9** Press **START** to begin the programmed sequence.

- 10** **RISE TIME 1** will be displayed, the min:sec counter begins to decrement from 00:20, while **POWER** increases to 20%. At time 00:00 the state message changes to **SOAK TIME 1** while the counter begins to decrement from 00:10. Upon reaching time 00:00, the state message again changes to **RISE TIME 2**.
- 11** **RISE TIME 2** begins to decrement from time 00:15 while **POWER** increases to 35%. Upon reaching time 00:00, the state message changes to **SOAK TIME 2** and the time again begins to decrement from time 00:10. At time 00:00 the state message changes to **DEPOSIT**.
- 12** Once in **DEPOSIT**, the time begins to increment and the deposition rate will be 16.1Å/s. The **THICK SPT** annunciator is displayed and power is at 36%. Upon reaching the **FINAL THK** parameter of 2.000kÅ, deposition stops with an elapsed time of 02:03. The clock immediately begins counting up from 00:00. The **FINAL THK** annunciator is displayed.
- 13** The instrument is now in **IDLE PWR** and will remain in this mode until **START** is pressed.
- 14** When **START** is pressed, the process will repeat steps 12 through 14.
NOTE: If **IDLE PWR** is reprogrammed to 0, the process will begin at **RISE TIME 1**.
- 15** After successful completion of the above steps, power down the instrument to leave the **TEST** mode by turning configuration switch 1 "OFF" and then placing the unit first in **STBY** and then "ON" to read the new configuration.

3.7 Input and Output Details

3.7.1 Relays



The relay, relay circuit, and associated pins in the I/O connector(s) have a maximum voltage rating of 30 V(dc) or 30 V(ac) RMS or 42 V(peak). The maximum current rating per connector pin or relay contact is 2.5 Amps.

Their function is as follows:

Table 3-3 System I/O Connector

Relay #	Pin #	Function**	Closed Contacts	Open Contacts
1	1,2	Source Shutter 1	During Deposit and Manual states when source 1 is designated.	Balance
2	3,4	Source Shutter 2	During Deposit and Manual states when Source 2 is designated.	Balance
3	5,6	Sensor Shutter 1	During the following states when the designated sensor is active: - RateWatcher Sample - Deposit - Manual - CrystalSwitch to dual head backup - Pulses during CrystalSix transitions - Shutter delay	Balance
4	7,8	Sensor Shutter 2		Balance

Table 3-3 System I/O Connector (continued)

Relay #	Pin #	Function**	Closed Contacts	Open Contacts
5	9,10	Stop	When a stop condition is generated, see section 4.3.2 on page 4-9 , section 4.3.1 on page 4-9 , and section 2.6.2 on page 2-19	When stop condition is cleared
6	11,12	End of Process	When last layer of the process reaches the IDLE state.	The the start of next process.

** Function may be overwritten by Remote Communications Commands R15 - R18, see [section 3.8.5 on page 3-26](#).

Table 3-4 Aux I/O Connector

Relay #	Pin #	Function**	Closed Contacts	Open Contacts
7	1,2	Thickness Set Point	THK SPT exceeded for two consecutive measurements	Entry of IDLE state
		or End of Film	When layer reaches the idle state	On a RESET or START of the next layer
8	3,4	Feedtime (Soak 2)	During Soak 2	Balance
9	5,6	Crystal Fail	When all crystals have been consumed	When crystal fail has been cleared
10	7,8	Alarms	When alarm conditions have been triggered; see section 4.3.1 on page 4-9 .	When alarm condition ceases
		or In Process	When a process is started	When in the STOP, READY, or IDLE states
11	9,10	Source 1/Source 2	At start of a layer utilizing Source 1 (toggle)	At start of layer utilizing Source 2

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Table 3-4 Aux I/O Connector (continued)

Relay #	Pin #	Function**	Closed Contacts	Open Contacts
12	11,12	END Deposit	When FINAL THK is exceeded for two consecutive measurements	Entry of READY state
** Function may be overwritten by Remote Communications Commands R15 - R18, see section 3.8.5 on page 3-26 .				

Table 3-5 Open Collector Outputs* (one of eight encoding)

Output #			Low	High
1	18	Crucible Select 1	If the active layer's designated crucible is 1, or 0	Balance
2	19	Crucible Select 2	If the active layer's designated crucible is 2	Balance
3	20	Crucible Select 3	If the active layer's designated crucible is 3	Balance
4	21	Crucible Select 4	If the active layer's designated crucible is 4	Balance
5	22	Crucible Select 5	If the active layer's designated crucible is 5	Balance
6	23	Crucible Select 6	If the active layer's designated crucible is 6	Balance
7	24	Crucible Select 7	If the active layer's designated crucible is 7	Balance
8	25	Crucible Select 8	If the active layer's designated crucible is 8	Balance
* The crucible select outputs are open collector type, 5 volt maximum with a capability of sinking 5 TTL loads (10 mA)				

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3.7.2 Inputs

Inputs are activated by pulling the specific input's terminal to ground (<0.8V) through a contact closure to common (GND) or with TTL/CMOS logic having current sink capability of 2 ma (1 low power TTL load). These ports are read every 250 ms; signals must be present during a read cycle.

Table 3-6 System I/O Connector

Input #	Pin #	Function	Description
	13,14,15, 16,17	Input Common (GND)	Used as reference for activating any of the inputs
1	18	START deposition	Detection of a falling edge duplicates front panel START
2	19	STOP deposition	Detection of a falling edge induces a STOP
3	20	END deposit	Detection of a falling edge terminates the Deposit state just as if the FINAL THK were achieved.
<i>Configuration switch #12 set for "Standard" Input Option:</i>			
4	21	SAMPLE INITIATE	Detection of a falling edge initiates a RateWatcher sample if the film is programmed for this feature.
5	22	SAMPLE INHIBIT	Application of a ground reference voltage maintains the RateWatcher in the Hold condition.
6	23	CRYSTAL FAIL INHIBIT	Application of a ground reference voltage prohibits the closure of the Crystal Fail Relay and the associated Stop.
7	24	ZERO thickness	Detection of a falling edge duplicates the front panel ZERO.
8	25	SOAK 2 HOLD	Application of a ground reference voltage extends the SOAK 2 state until the signal/closure is removed.

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Table 3-6 System I/O Connector (continued)

Input #	Pin #	Function	Description																																																							
<i>Configuration switch #12 set for "Film Select" Input Option:</i>																																																										
4	21	RESET																																																								
5	22	Select Film MSB																																																								
6	23	Select Film																																																								
7	24	Select Film																																																								
8	25	Select Film LSB																																																								
			<table border="1"> <thead> <tr> <th>pin22</th> <th>pin23</th> <th>pin24</th> <th>pin25</th> <th>Film #</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>0</td> <td>0</td> <td>X(don't care)</td> <td>1</td> </tr> <tr> <td>0</td> <td>0</td> <td>1</td> <td>0</td> <td>2</td> </tr> <tr> <td>0</td> <td>0</td> <td>1</td> <td>1</td> <td>3</td> </tr> <tr> <td>0</td> <td>1</td> <td>0</td> <td>0</td> <td>4</td> </tr> <tr> <td>0</td> <td>1</td> <td>0</td> <td>1</td> <td>5</td> </tr> <tr> <td>0</td> <td>1</td> <td>1</td> <td>0</td> <td>6</td> </tr> <tr> <td>0</td> <td>1</td> <td>1</td> <td>1</td> <td>7</td> </tr> <tr> <td>1</td> <td>0</td> <td>0</td> <td>0</td> <td>8</td> </tr> <tr> <td>1</td> <td>0</td> <td>0</td> <td>1</td> <td>9</td> </tr> <tr> <td>1</td> <td>X</td> <td>1</td> <td>X</td> <td>1</td> </tr> </tbody> </table>	pin22	pin23	pin24	pin25	Film #	0	0	0	X(don't care)	1	0	0	1	0	2	0	0	1	1	3	0	1	0	0	4	0	1	0	1	5	0	1	1	0	6	0	1	1	1	7	1	0	0	0	8	1	0	0	1	9	1	X	1	X	1
pin22	pin23	pin24	pin25	Film #																																																						
0	0	0	X(don't care)	1																																																						
0	0	1	0	2																																																						
0	0	1	1	3																																																						
0	1	0	0	4																																																						
0	1	0	1	5																																																						
0	1	1	0	6																																																						
0	1	1	1	7																																																						
1	0	0	0	8																																																						
1	0	0	1	9																																																						
1	X	1	X	1																																																						
	13	Input Common (GND)	Used as a reference for activating any of the inputs.																																																							
9	14	CRUCIBLE VALID	Application of a ground reference voltage from the crucible rotation mechanism is used to signal that the proper crucible has indexed into position and state sequencing may proceed.																																																							
	15,16,17	Input Common (GND)	Used as a reference for activating any of the inputs.																																																							

3.7.3 Chart Recorder

The chart recorder output has 12 bit resolution with one additional bit of sign information over the range of -10 to +10 volts. It can supply up to 5 milliamps and has an internal resistance of 100 ohms. The output is proportional to rate, thickness or rate deviation depending on the setting of the XTC/2's configuration switches; see [section 2.6.2 on page 2-19](#). The XTC/C's default recorder function is 0-100 Å/sec rate and is changed by sending the **R 38** command, [page 3-33](#). It is normal for ripple to appear on these outputs to a maximum of 5 mV at ~84 Hz. This output is updated every 250 milliseconds.

3.7.4 Source Outputs

The source outputs will drive +/- 10.00 volts into a 400 ohm load. The output is proportional (15 bits) to the required source power. It is normal for ripple to appear on these outputs to a maximum of 50mV at ~84 Hz. The polarity is set with a configuration switch; see [section 2.6.2 on page 2-19](#). This output is updated every 250 milliseconds.

3.8 Computer Communications

This instrument supports a number of standard and optional computer communications protocol formats. RS232 is standard, operating in either checksum or non-checksum as well as SECS II formats. It may also be configured to automatically output process data (data logging) upon reaching **FINAL THK**. Additionally, an IEEE communications option may be installed.

3.8.1 Communications Setup

To set up the remote communication interface, when powering up the XTC/2, hold down the 0 key. The following set of parameters can be entered using the digits, enter, and clear keys.

tyPE	(0 = INFICON Checksum, 1 = INFICON no checksum, 2 = SECS, 3 = Datalog)
(If SECS is chosen for tyPE the next 5 parameters are accessed):	
d Id	(Device ID 0-32767)
t1	(Timer 1 per SECS definition) (0-10.0 seconds)
t2	(Timer 2 per SECS definition) (0.2-25.0 seconds in 0.2 increments)
rtrY	(Retry limit per SECS definition) (0-31)
dUPL	(Duplicate block per SECS definition)
baUd	(0=1200, 1=2400, 2=4800, 3=9600)
IEEE	(IEEE address, 0-30) - requires optional hardware

When this list is complete, the READY message is flashed and the choice will be given to either repeat the list or continue with normal operation. Pressing ENTER will continue with normal operation. Pressing CLEAR will repeat the list.

NOTE: Do not turn the unit off while in the Communications Program Mode, otherwise the new parameter values will not be saved properly.

To set up the communication interface for the XTC/C, see the configuration switch setup (section 2.6.2 on page 2-19) and review the communication command section 3.8.5 on page 3-26. The cables used between the XTC and the host computer must be wired as depicted in the cable diagram in section 2.6.7 on page 2-26.

3.8.1.1 IEEE Settings for a National Instruments IEEE-GPIB Board

When establishing IEEE communications the following settings are found to work using a National Instruments IEEE-GPIB board. These values are set using the IBCONF.EXE file provided by National Instruments.

Figure 3-6 Board Characteristics

National Instruments	Board Characteristics	IBM AT, PS/2-25/30
Board: GPIB0		SELECT (use right/left arrow keys):
Primary GPIB Address	◀▶ 0	0 to 30
Secondary GPIB Address.....	NONE	
Timeout setting.....	T300ms	
EOS byte.....	0AH	
Terminate Read on EOS.....	yes	
Set EOI with EOS on Write.....	yes	
Type of compare on EOS.....	7-bit	
Set EOI w/last byte of Write.....	yes	
System Controller.....	yes	
Repeat addressing.....	no	
Disable Auto Serial Polling.....	yes	
High-speed timing.....	no	
Interrupt setting.....	7	
Base I/O Address.....	2C0H	
DMA channel (Arbitration).....	5	
F1: Help	F2: Explain Field	F6: Reset Value F9: Return to Map

Figure 3-7 Device Characteristics

National Instruments	Device Characteristics	IBM AT, PS/2-25/30	
Device: XTC2		SELECT (use right/left arrow keys):	
Access: GPIB0			
Primary GPIB Address	◀▶ 3	0 to 30	
Secondary GPIB Address.....	NONE		
Timeout setting.....	T300ms		
EOS byte.....	0AH		
Terminate Read on EOS.....	yes		
Set EOI with EOS on Write.....	yes		
Type of compare on EOS.....	7-bit		
Set EOI w/last byte of Write.....	no		
F1: Help	F2: Explain Field		F6: Reset Value F9: Return to Map

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3.8.2 Basic Command Structure

The following commands are available via the computer communications:

- E** Echo. Returns the sent message.
- H** Hello. Returns the model and software version number.
- Q** Query. Interrogates the programmable parameters and returns the value of parameter requested.
- U** Update. Replaces the particular parameter with the value sent.
- S** Status. Sends back pertinent information based on the specific request made.
- R** Remote. Perform an action based on the specific command given. Many of these mimic front panel keystrokes.

The send and receive protocol formats are described below and use the following abbreviations:

- STX Start of transmission character
- 00,NN . . The size of the command is 2 bytes long with 00 representing the high order Byte and NN representing the low order byte.
- ACK. . . . Command acknowledged character
- NAK. . . . Command not acknowledged character
- LF Line Feed (EOT byte for IEEE)
- CS Checksum
- CR Carriage Return

CHECKSUM FORMAT (Message Protocol)

- To XTC: STX 00 NN message_string CS
- From XTC: STX 00 NN ACK message_string CS (if success)
- or -
- STX 00 NN NAK error_code CS (if failure)

NONCHECKSUM FORMAT (Message Protocol) (RS232)

- To XTC: message_string ACK
- From XTC: message_string ACK (if success)
- or -
- error_code NAK (if failure)

3.8.3 Service Requests and Message Available

In the IEEE mode there are a number of events which will trigger service requests, a request by the instrument to transmit information to the host. The instrument does this by triggering the **RQS** bit of the Status Byte. A host initiated serial poll then identifies the requesting device by the presence of a 1 in the **RQS** (2^6) bit of the status byte. The particular service request generator event is encoded in bits $2^0 - 2^3$ inclusive, as shown below:

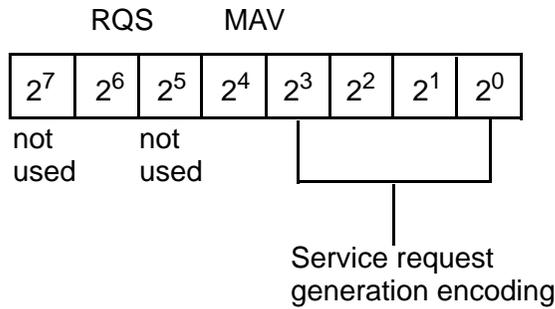


Table 3-7 Service Request Encoding

Generator Event	Code	Value
Final Thickness	0001	1
Instrument in STOP State	0010	2
End of a Layer	0011	3
STBY/ON sequence	0100	4
End of a Process	0101	5
Crystal Fail	0110	6
250ms DATA READY . Available only after R23 is issued, see page 3-33 . This is automatically cleared on crystal failure.	0111	7

It takes the instrument various lengths of time to formulate a correct response to queries for information. To avoid unnecessarily repeated bus traffic, it is suggested that the host monitor the MAV (message available) status bit to determine when a response for information is fully assembled and ready to transmit. See [section 3.8.7 on page 3-38](#) for a sample program utilizing these features.

3.8.4 Datalogging

The DATALOG data output represents the information concerning the latest "shutter open" to "shutter close" sequence.

Automatic data logging is enabled by choosing DATALOG for the communications type, see [section 3.8.1 on page 3-20](#). If DATALOG is chosen, the RS232 port is configured to output the DATALOG information only and cannot receive commands from a host computer. The IEEE option, if installed, will continue to work in the normal fashion.

The data is a series of ASCII strings, each separated by a "carriage return and line feed", in the order below:

- 1 Layer # (1-3)
- 2 Film # (1-9)
- 3 Rate = _____.__Å/s
- 4 Thickness = _____.____ kÅ [Last good thickness, if crystal failed]
- 5 Deposit Time = __:__ Min:Sec.
- 6 Average Power = ____%
- 7 Begin Frequency = _____ Hz
- 8 End Frequency = _____ Hz [negative of last good frequency if crystal fail]
- 9 Crystal Life = __%
- 10 End on Time Power or Normal Completion

NOTE: In addition—if the Layer is the first one of a process, a preface "Begin Process" followed by 2 blank lines is output. If the layer is the last one of the process, a post script "End Process", preceded by 2 blank lines is output.

Automatic datalogging is available only on the XTC/2; however, the datalog information string is available via the **S19** command for both the XTC/2 and XTC/C.

3.8.5 Computer Command Details

3.8.5.1 Echo Command

Echoes the message, i.e., returns the sent message.

The format is: **E** message string

3.8.5.2 Hello Command

The HELLO command will return the string "XTC/2 VERSION x.xx" where x.xx is the software revision code.

The format is: **H**

3.8.5.3 Query Command

The Query command returns information concerning current instrument parameter values.

The format of the query command is:

Q pp **F** - Query parameter pp of film **F** or **Q** pp **L** for layer parameters. A space is used as a delimiter between **Q** and pp as well as pp and **F**, where **F** (or **L**), is a digit between 1 and 9, **L** is a digit between 0 and 3, inclusive, and represents the interrogated film or layer number.

NOTE: If pp is set to 99, output all parameters in the order specified below; each parameter is separated by a space. This command allows a rapid block transfer of data which is convenient for downloading films.

Table 3-8 Parameter Definition Table (for Query and Update Commands)

PP	XTC/2 Parameter	Range
0	Rise Time 1	0 - 9959 or 00:00 - 99:59
1	Soak Power 1	0.0 - 100.0
2	Soak Time 1	(See 0)
3	Rise Time 2	(See 0)
4	Soak Power 2	(See 1)
5	Soak Time 2	(See 0)
6	Shutter Delay	1 or 0 or 'Y' or 'y' or 'N' or 'n'
7	New Rate	0.0 - 999.9
8	Rate Ramp Time	(See 0)
9	Idle Ramp	(See 0)
10	Idle Power	0.0 - 100.0
11	Time Power	(See 6)
12	Xtal Switch S	0 - 9
13	Xtal Switch Q	0 - 9
14	Tool Factor 1	10 - 500.0
15	Tool Factor 2	(See 14)
16	Deposition Rate	0 - 999.9
17	Final Thickness	0.0 - 999.000
18	Thickness Spt	(See 17)
19	Density	0.5 - 99.99
20	Z-Ratio	.1 - 9.999
21	Sensor	1 - 2
22	Source	1 - 2
23	Crucible	0 - 8
24	Control Gain	0.01- 99.99
25	Control TC	0.1 - 100
26	Control DT	0.1 - 100
27	Max Power	0.0 - 100.0
28	Sample	0 - 99
29	Hold Time	(See 0)
30-39	** NOT USED **	
40	Layer	1-3 ¹ , 0-9 ²
99	All	See note on page 3-25

¹ May be 0 for Q command; if 0, will return values for layers 1 - 3.
² 0 not allowed for layer 1.

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3.8.5.4 Update Command

The Update command replaces the current parameter value with the DATA Sent.

To update film parameters the format of the update command is:

U pp F vvv - Parameter **pp** of film **F**, value **vvv**.

Update parameter **pp** of film **F**, with value **vvv**, a space is used as a delimiter between the **pp** and **F** values as well as the **F** and **vvv** values, where **F** is a digit between 1 and 9. Refer to [Table 3-8 on page 3-27](#) for a numbered list of parameters and their limits.

NOTE: If **pp** is set to 99, the data is a list of all parameters in the order specified. This command allows a rapid block transfer of data which is convenient for downloading films. Each parameter value must be separated by a space.

To update layers the format of the update command is:

U 40 L v

Where 40 designates a layer is to be updated. The value **L** indicates which layer to update. The value of **L** can be 1, 2, or 3, and **v** designates the film number to insert into layer **L**.

For example, the update command

U 40 1 4

will enter film number 4 into layer 1.

3.8.5.5 Status Command

Sends back information based on specific request made.

The format of the status command is:

S xx Return the status (value) of **xx**

where:

S Is the literal **S**

xx One or two digit code per list below:

S0 Process information. All the information from **S1** to **S10**, separated by spaces.

S1 Rate (Å/s) currently read. **x.x** to **xxx.x** Å/s

S2 Power (%) currently output. **x.x** to **xxx.x** %

S3 Thickness (KÅ) currently accumulated. **x.xxxx** kÅ to **xxxx.xxxx** kÅ

S4. Phase currently in process. x

S4 Response Codes	
0	Ready phase
1	Source switch phase
2	Rise 1 phase
3	Soak 1 phase
4	Rise 2 phase
5	Soak 2 phase
6	Shutter delay phase
7	Deposit phase
8	Rate ramp phase
9	Manual phase
10	Time power phase
11	Idle ramp phase
12	Idle phase

S5. Phase time (mm:ss). xx:xx

S6. Active layer. x

S7. Active film x

S8. Active crystal. x

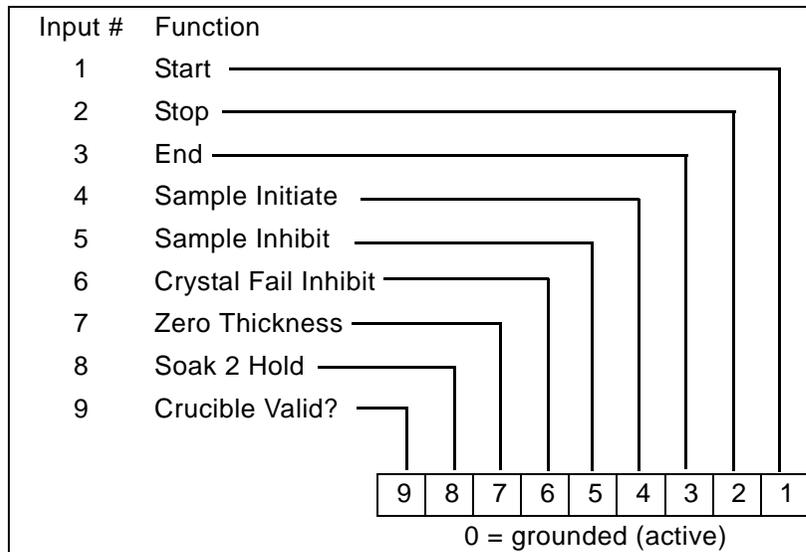
S9. Crystal life (%). x % to xx %

S10. Power source number. x (1 or 2)

S11 Output status - returns a string of 16 ASCII bytes, 1 per output. Each byte has an ASCII value of 0 or 1, corresponding to the output status.

Position	Outputs	
1	Source Shutter 1	1=open, 0=closed
2	Source Shutter 2	1=open, 0=closed
3	Sensor Shutter 1	1=open, 0=closed
4	Sensor Shutter 2	1=open, 0=closed
5	Stop	1=stop, 0=not stop
6	End of Process	1=end of process 0=not end of process
7	Thickness Setpoint	1=Thk Setpoint
8	Feedtime (Soak 2)	1=soak 2 phase
9	Crystal Fail	1=Xtal Fail
10	Alarms	1=Alarm Cond.
11	Source 1/Source 2 (toggle)	1=Source 2, 0=Source 1
12	End Deposit	1=closed
13	Crucible Select (LSB)	} binary value encoding
14	Crucible Select	
15	Crucible Select (MSB)	
16	Unused	

S12 Input status - returns 9 ASCII bytes, 1 per input. Each byte has an ASCII value of 0 or 1, corresponding to the input's status.



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- S13. Raw frequency - Frequency of crystal being read. xxxxxxx.x Hz [negative of last good frequency if failed]
- S14. Xtal Fail - Returns ASCII 1 if currently failed crystal, 0 if not.
- S15. Max Power - Returns ASCII 1 if currently outputting maximum power, 0 if not.
- S16. Crystal switching - Returns ASCII 1 if currently crystal switching, 0 if not.
- S17. End of process - Returns ASCII 1 if process has ended, 0 if not.
- S18. STOP - Returns ASCII 1 if process is in STOP.
- S19. DATALOG - Returns the datalog string, refer to [section 3.8.4 on page 3-25](#) for details. Data is separated by spaces instead of CR/LF.

The last byte returned identifies the End on Time Power or Normal Completion information as 1 or 0 respectively. Also, when using the **S19** command the "Begin Process" and "End Process" messages are not returned.

- S20. Present Configuration Switch Settings - returns 16 ASCII bytes with a value of 0 or 1, corresponding to the position of configuration switches 1-16; byte 1 corresponds to switch 1.

16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1 = Switch On															

Also see **S22** below.

NOTE: Switch settings do not take effect until a power STBY/Power On sequence takes place.

- S21. Error Flag - If more than one error code exists, the response string will return them all, each separated by a single space.

S21 Response Codes	
0	Error 0
2	Power Fail or STBY/ON sequence
9	Error 9
10	No Errors

- S22. Instrument configuration readout - the position of the configuration switches at the last **STBY/ON** sequence. Also see **S20** above and [section 2.6.2 on page 2-19](#).
- S30. Returns status of each crystal of a multi-head sensor.
- S31. Returns a rolling 6.25 second average (updated every 0.25 seconds) of the measurement rate.

3.8.5.6 Remote Command

The format of the remote command is:

R xx vv

where:

- R** Is the literal **R**
- xx Is the remote code per list below.
- vv. Is the associated value needed for some remote commands.
- R0** Start. Equivalent to pressing the **START** key.
- R1** Stop. Equivalent to pressing the **STOP** key.
- R2** Reset. Equivalent to pressing the **RESET** key.
- R3** Remote Lock On. Prohibits any parameter from being entered via the front panel.
- R4** Remote Lock Off. Clears remote lock condition.
- R5** Crystal fail inhibit on. Simulates remote input.
- R6** Crystal fail inhibit off. Simulates release of remote input.
- R7** Soak hold 2 on. Simulates remote input.
- R8** Soak hold 2 off. Equivalent release of remote input.
- R9** Manual on. Equivalent to front panel **MPWR** keystroke.
- R10** Manual off. Equivalent to front panel **MPWR** keystroke.
- R11** Set power level vv. Sets the active source's power to vv%.
- R12** Zero thickness. Simulates remote input or front panel **ZERO** keystroke.
- R13** Final thickness trigger. Simulates remote input.
- R14** CrystalSwitch. Equivalent to front panel **XTSW** keystroke.
- R15** Enter communication I/O mode - See **R16** (Only applies when in communication I/O mode)
- R16** Exit communication I/O mode - See **R15** (Only applies when in communication I/O mode)
- R17** Set (close) relay xx (xx = 1-12)
- R18** Clear (open) relay xx (xx = 1-12)
- R19** Turn backlight ON
- R20** Turn backlight OFF

- R21. Trigger beeper
- R22. Clear Error Flag
- R23. Set 250ms DATA Ready Service request (IEEE only).
- NOTE:** A crystal fail automatically clears the 250ms service request.
- R24. Clear 250ms DATA Ready Service request (IEEE only).
- R25. Set upper frequency limit to 6.027 MHz.

The following additional commands are available on the XTC/C only:

- R30. Test ON
- R31. Test OFF
- R32. Control Mode Deposit
- R33. Control Mode Etch
- R34. Stop on Alarms
- R35. No Stop on Alarms
- R36. Stop on Max Power
- R37. No stop on Max Power
- R38 x Recorder Type x (0 = Rate 0 to 100 Å/s,
 1 = Rate 0 to 1000 Å/s,
 2 = Thickness 0 to 100 Å,
 3 = Thickness 0 to 1000 Å,
 4 = Power,
 5 = Rate Deviation,
 6 = Rate 0 to 100 Å/s smoothed,
 7 = Rate 0 to 1000 Å/s smoothed)
- R39. Set SECS Timer 1 (0.1 - 10.0)
- R40. Set SECS Timer 2 (0.2 - 25.0)
- R41. Set SECS Max Retries (0-31)
- R42. Set SECS Duplicate Block to Yes
- R43. Set SECS Duplicate Block to No

3.8.6 Examples of RS232 Programs

3.8.6.1 Program Without Checksum

```

10 '-----XTC/2 RS232 COMMUNICATIONS PROGRAM WITHOUT CHECKSUM----
20 '
30 '-----THIS PROGRAM IS DESIGNED TO TRANSMIT INDIVIDUAL COMMANDS TO THE XTC/2
      AND ACCEPT THE APPROPRIATE RESPONSE FROM THE XTC/2, WRITTEN IN GWBASIC 2.32.
40 '
50 OPEN "COM1:9600,N,8,1,CS,DS" AS #1           : '--OPEN COMM PORT 1
60 NAK$ = CHR$(21): ACK$ = CHR$(6)           : '--DEFINE ASCII CODES
70 '
80 INPUT "ENTER COMMAND"; CMD$               : '--ENTER COMMAND TO XTC/2
90 GOSUB 130                                   : '--GOTO TRANSMIT COMMAND
                                          SUBROUTINE.
100 PRINT RESPONSE$                           : '--PRINT XTC/2 RESPONSE
110 GOTO 80                                    : '--LOOP BACK FOR ANOTHER
                                          COMMAND.

120 '
130 '-----TRANSMIT COMMAND AND RECEIVE RESPONSE SUBROUTINE----
140 '
150 '-----SEND COMMAND MESSAGE STREAM TO THE XTC/2----
160 PRINT #1, CMD$ + ACK$;
170 '
180 '-----RECEIVE RESPONSE MESSAGE FROM THE XTC/2----
190 RESPONSE$ = ""                            : '--NULL THE RESPONSE
200 TOUT = 3: GOSUB 260                       : ' STRING AND SET TIMER.
210 IF I$ = ACK$ THEN RETURN                  : '--IF THE END OF RESPONSE
220 IF I$ = NAK$ THEN RETURN                  : ' CHARACTER IS RECEIVED
                                          GOTO PRINT RESPONSE.
230 RESPONSE$ = RESPONSE$ + I$               : '--BUILD RESPONSE STRING
240 GOTO 200                                  : ' CHARACTER BY CHARACTER.
250 '
260 '-----READ SERIALY EACH CHARACTER FROM THE INSTRUMENT INTO VARIABLE I$----
270 ON TIMER (TOUT) GOSUB 300: TIMER ON
280 IF LOC(1) < 1 THEN 280 ELSE TIMER OFF: I$ = INPUT$(1,#1)
290 RETURN
300 TIMER OFF                                 : '--INDICATE IF A CHARACTER
310 RESPONSE$ = "RECEIVE TIMEOUT"            : ' IS NOT RECEIVED WITHIN
320 I$ = NAK$: RETURN 290                    : ' 3 SECS.

```

3.8.6.2 Program With Checksum

```

10 '--XTC/2 RS232 COMMUNICATIONS PROGRAM WITH CHECKSUM USING THE INFICON FORMAT--
20 '
30 '-----THIS PROGRAM IS DESIGNED TO TRANSMIT INDIVIDUAL COMMANDS TO THE XTC/2
      AND ACCEPT THE APPROPRIATE RESPONSE FROM THE XTC/2, WRITTEN IN GWBASIC 2.32.
40 '
50 OPEN "COM1:9600,N,8,1,cs,ds" AS #1           : '--OPEN COMM PORT 1
60 STX$ = CHR$(2) : NAK$ = CHR$(21) : ACK$ = CHR$(6) : '--DEFINE ASCII CODES
70 '
80 INPUT "ENTER COMMAND"; CMD$                 : '--ENTER COMMAND TO XTC/2
90 GOSUB 170                                   : '--GOTO TRANSMIT COMMAND SUBROUTINE
100 IF RESPONSE$ = "RECEIVE TIMEOUT" THEN 140
110 L = LEN(RESPONSE$): L = L-1                 : '--STRIP OFF THE ACK OR
120 RESPONSE$ = RIGHT$(RESPONSE$,L)           : ' NAK CHARACTER FROM THE
130 '                                           : ' RESPONSE STRING.
140 PRINT RESPONSE$                            : '--PRINT XTC/2 RESPONSE
150 GOTO 80                                    : '--LOOP BACK FOR ANOTHER COMMAND.
160 '
170 '----TRANSMIT COMMAND AND RECEIVE RESPONSE SUBROUTINE----
180 '
190 '--BUILD COMMAND MESSAGE STREAM AND SEND TO THE XTC/2--
200 SIZEM$ = CHR$(LEN(CMD$) / 256)             : '--CALCULATE THE 2 BYTE
210 SIZEL$ = CHR$(LEN(CMD$) MOD 256)          : ' SIZE OF THE COMMAND.
220 '
230 CHECKSUM = 0                               : '--INITIALIZE CHECKSUM TO
240 FOR X = 1 TO LEN(CMD$)                     : ' ZERO AND CALCULATE A
250 CHECKSUM = CHECKSUM + ASC(MID$(CMD$,X,1)) : ' CHECKSUM ON THE COMMAND
260 NEXT X                                     : ' STRING.
270 CHECKSUM$ = CHR$(CHECKSUM AND 255)         : '--USE LOW ORDER BYTE AS CHECKSUM.
280 '
290 PRINT #1, STX$ + SIZEM$ + SIZEL$ + CMD$ + CHECKSUM$
300 '
310 '----RECEIVE RESPONSE MESSAGE FROM THE XTC/2----
320 TOUT = 3: GOSUB 510                         : '--SET TIMER AND WAIT FOR
330 IF I$ <> STX$ THEN 290                       : ' START OF TRANSMISSION CHARACTER.
340 TOUT = 3: GOSUB 510                         : '--RECEIVE HIGH ORDER BYTE
350 SIZE = 256 * ASC(I$)                         : ' OF TWO BYTE RESPONSE SIZE.
360 TOUT = 3: GOSUB 510                         : '--RECEIVE LOW ORDER BYTE
370 SIZE = SIZE + ASC(I$)                       : ' OF TWO BYTE RESPONSE          SIZE.
380 CHECKSUM = 0                               : '--SET CHECKSUM TO ZERO
390 RESPONSE$ = ""                              : ' AND NULL THE RESPONSE
400 FOR I = 1 TO SIZE                           : ' STRING.BUILD THE
410 TOUT = 3: GOSUB 510                         : ' RESPONSE STRING AND
420 RESPONSE$ = RESPONSE$ + I$                  : ' CALCULATE THE CHECKSUM
430 CHECKSUM = CHECKSUM + ASC(I$)               : ' CHARACTER BY CHARACTER.
440 NEXT I
450 TOUT = 3: GOSUB 510                         : '--RECEIVE THE CHECKSUM
460 N = ASC(I$)                                 : ' CHARACTER AND COMPARE
470 Z = (CHECKSUM AND 255)                      : ' IT TO THE LOW ORDER
480 IF N <> Z THEN PRINT "RESPONSE CHECKSUM ERROR" : ' BYTE OF THE CALCULATED
490 RETURN                                       : ' CHECKSUM.
500 '
510 '----READ SERIALY EACH CHARACTER FROM THE INSTRUMENT INTO VARIABLE I$----
520 ON TIMER (TOUT) GOSUB 550: TIMER ON
530 IF LOC(1) < 1 THEN 530 ELSE TIMER OFF: I$ = INPUT$(1,#1)
540 RETURN
550 TIMER OFF                                   : '--INDICATE IF A CHARACTER
560 RESPONSE$ ="RECEIVE TIMEOUT": RETURN 570    : ' IS NOT RECEIVED WITHIN
570 RETURN 490                                 : ' 3 SECS.

```

3.8.6.3 Example of SEMI II Program

```

10 'XTC/2 RS232 COMMUNICATIONS PROGRAM USING THE SECS FORMAT
20 '---THIS PROGRAM IS DESIGNED TO TRANSMIT---
30 '----INDIVIDUAL COMMANDS TO THE XTC/2-----
40 CLS
50 '
60 '
70 OPEN "COM1:2400,N,8,1,CS,DS" FOR RANDOM AS #1
80 EOT$ = CHR$(4): ENQ$ = CHR$(5): ACK$ = CHR$(6): NAK$ = CHR$(21)
90 TOUT = 3
100 C = 0:CHECKSUM = 0: CHEKSUMM$ = CHR$(0): CHEKSUML$ = CHR$(0)
110 INPUT "ENTER COMMAND"; CMD$
120 CMDLEN = LEN(CMD$):          ' CALCULATE THE COMMAND LENGTH
130 '
140 '--ADD THE TWO BYTE PREAMBLE TO THE COMMAND--
150 PRE$ = CHR$(65) + CHR$(CMDLEN)
160 CMD$ = PRE$ + CMD$
170 CMDLEN = CMDLEN + 2
180 '
190 '--BUILD LENGTH BYTE, HEADER, TEXT, AND CHECKSUM BLOCK---
200 '
210 '-BUILD HEADER--
220 DID = 257:                  ' DEVICE ID
230 'RBIT = 0,                  ' MESSAGE DIRECTION IS FROM HOST TO DEVICE
240 '
250 '--DETERMINE THE STREAM AND FUNCTION CODES--
260 '
270 STREAM$ = CHR$(64):        ' USER DEFINED STREAM CODE
280 FUNCTION$ = CHR$(65):      ' USER DEFINED FUNCTION CODE
290 '
300 '
310 WBIT$ = CHR$(128):         'RESPONSE FROM XTC/2 REQUIRED
320 STREAM$ = CHR$(ASC(WBIT$) + ASC(STREAM$))
330 '
340 '--ENTER THE BLOCK BYTES--
350 '
360 BYTE5$ = CHR$(128):        ' LAST BLOCK IN THE SERIES
370 BYTE6$ = CHR$(1):         ' ONLY BLOCK IN THE SERIES
380 '
390 '--ENTER THE SYSTEM BYTES--
400 '
410 BYTE7$ = CHR$(0): BYTE8$ = CHR$(0): BYTE9$ = CHR$(0): BYTE10$ = CHR$(1)
420 '
430 '---CALCULATE THE LENGTH BYTE---
440 LTHBYT = CMDLEN + 10: LTHBYT$ = CHR$(LTHBYT)
450 '
460 '---CALCULATE THE CHECKSUM---
470 FOR X = 1 TO CMDLEN
480 CHECKSUM = CHECKSUM + ASC(MID$(CMD$, X, 1))
490 NEXT X
500 BYTE1$ = CHR$(DID / 256)
510 BYTE2$ = CHR$(DID MOD 256)
520 CHECKSUM = ASC(BYTE1$) + ASC(BYTE2$) + ASC(STREAM$) + ASC(FUNCTION$) + ASC(BYTE5$)
      + ASC(BYTE6$) + ASC(BYTE7$) + ASC(BYTE8$) + ASC(BYTE9$) + ASC(BYTE10$) + CHECKSUM
530 CHEKSUMM$ = CHR$(FIX(CHECKSUM / 256))
540 CHEKSUML$ = CHR$(CHECKSUM MOD 256)
550 '---HOST BID FOR LINE / DEVICE BID FOR LINE---
560 '
570 PRINT #1, ENQ$;
580 I$ = "": RESPONSE$ = ""
590 C = C + 1
600 ON TIMER(TOUT) GOSUB 1000: TIMER ON

```

```

610 IF LOC(1) < 1 THEN 610 ELSE TIMER OFF: I$ = INPUT$(1, #1)
620 IF C = 3 THEN 660
630 IF I$ = ACK$ THEN GOTO 580
640 IF I$ = NAK$ THEN RESPONSE$ = "COMMAND NOT ACKNOWLEDGED": GOTO 1010
650 IF I$ = EOT$ THEN 690 ELSE REPOSNSE$ = "DEVICE NOT ACKNOWLEDGED": GOTO 1010
660 IF I$ = ENQ$ THEN 790 ELSE RESPONSE$ = "DEVICE DID NOT BID FOR LINE": GOTO 1010
670 '
680 '
690 '---SEND COMMAND TO XTC/2--
700 '
710 '
720 HEADER$ = BYTE1$ + BYTE2$ + STREAM$ + FUNCTION$ + BYTE5$ + BYTE6$ + BYTE7$ + BYTE8$
      + BYTE9$ + BYTE10$
730 PRINT #1, LTHBYT$, HEADER$, CMD$, CHEKSUMM$, CHEKSUML$;
740 GOTO 580
750 '
760 '
770 '---WAIT FOR DATA FROM XTC/2---
780 '
790 '---FIND SIZE OF RESPONSE--
800 '
810 PRINT #1, EOT$;
820 I$ = ""
830 ON TIMER(TOUT) GOSUB 1000: TIMER ON
840 IF LOC(1) < 1 THEN 840 ELSE TIMER OFF: I$ = INPUT$(1, #1)
850 S = ASC(I$): L = S - 13
860 S = S + 2
870 '
880 '---RECEIVE RESPONSE TO COMMAND---
890 '
900 I$ = "": RESPONSE$ = ""
910 FOR R = 1 TO S
920 ON TIMER(TOUT) GOSUB 1000: TIMER ON
930 IF LOC(1) < 1 THEN 930 ELSE TIMER OFF: I$ = INPUT$(1, #1)
940 RESPONSE$ = RESPONSE$ + I$
950 NEXT R
960 PRINT #1, ACK$;
970 RESPONSE$ = MID$(RESPONSE$, 13, L)
980 '
990 GOTO 1010
1000 TIMER OFF: RESPONSE$ = "RECEIVE TIMEOUT"
1010 PRINT RESPONSE$
1020 '
1030 GOTO 90

```

3.8.7 Example of IEEE488 Program

```

10 '-----XTC/2 GPIB COMMUNICATIONS PROGRAM-----
20 '-----THIS PROGRAM IS DESIGNED TO TRANSMIT INDIVIDUAL COMMANDS TO THE XTC/2
    AND ACCEPT THE APPROPRIATE RESPONSE FROM THE XTC/2, WRITTEN IN GWBASIC 2.32.
30 '
40 '----THE NEXT 5 LINES DEFINE THE IEEE DRIVERS USED AND ARE SPECIFIC TO THE
    PARTICULAR IEEE BOARD IN YOUR COMPUTER AND THE LANGUAGE USED-----
50 '
60 CLEAR ,55000! : IBINIT1 = 55000! : IBINIT2 = IBINIT1 + 3
70     BLOAD "bib.m",IBINIT1
80 CALL IBINIT1(IBFIND,IBTRG,IBCLR,IBPCT,IBSIC,IBLOC,IBPPC,IBBNA,IBONL,IBRSC,
    IBSRE,IBRSV,IBPAD,IBSAD,IBIST,IBDMA,IBEOS,IBTMO,IBEOT,IBRDF,IBWRTF)
90 CALL IBINIT2(IBGTS,IBCAC,IBWAIT,IBPOKE,IBWRT,IBWRTA,IBCMD,IBCMDA,IBRD,IBRDA,
    IBSTOP,IBRPP,IBRSP,IBDIAG,IBXTRC,IBRDI,IBWRTI,IBRDIA,IBWRTIA,IBSTA%,IBERR%,IBCNT%)
100 '
110 GPIB$="GPIB0" :CALL IBFIND(GPIB$,GPIB%)           '--OPEN BOARD FOR COMM
120 CALL IBSIC(GPIB%)                                 '--SEND INTERFACE CLEAR
130 XTC2$="XTC2" : CALL IBFIND(XTC2$,XTC2%)           '--OPEN DEVICE 0
140 V% = &HA                                         '--SET THE END OF STRING
150 CALL IBEOS(GPIB%,V%)                              ' BYTE TO LINE FEED
160 V%=1 : CALL IBEOT(XTC2%,V%)                      '--ASSERT EOI ON WRITE
170 V%=12 : CALL IBTMO(XTC2%,V%)                     '--SET THREE SEC TIMEOUT
180 INPUT "ENTER COMMAND";COMMAND$                  '--ENTER COMMAND TO XTC/2
190 CALL IBCLR(XTC2%)                                 '--CLEAR THE XTC/2 COMM
200 GOSUB 240                                         '--GOTO TRANSMIT COMMAND
                                                    SUBROUTINE.
210 PRINT I$                                         '--PRINT XTC/2 RESPONSE
220 GOTO 180                                         '--LOOP BACK FOR ANOTHER COMMAND.
230 '
240 '----TRANSMIT COMMAND & RECEIVE RESPONSE SUBROUTINE----
250 '
260 '----SEND COMMAND MESSAGE STREAM TO THE XTC/2----
270 COMMAND$ = COMMAND$ + CHR$(&HA)
280 CALL IBWRT(XTC2%,COMMAND$)
290 '
300 '----RECEIVE RESPONSE MESSAGE FROM THE XTC/2----
310 '
320 I$=SPACE$(40) : CALL IBRD(XTC2%,I$)
330 IF (IBSTA% AND &H4000) THEN 340 ELSE 350         '--INDICATE IF A RESPONSE
340 PRINT "RECEIVE TIMEOUT": GOTO 180                ' IS NOT RECEIVED WITHIN
350 RETURN                                           ' 3 SECS.

```

To implement serial polling of the Message Available (MAV) bit the following lines may be added to the IEEE488 program listed above.

```

285 CALL IBRSP (XTC2%,SPR%)
287 B = SPR% / 16: B = INT(B)
289 IF B = 1 THEN 290 ELSE 285

```

After sending a command to the XTC/2 the Status Byte is polled. The response to the command is retrieved only after the MAV bit is set ($2^4 = 16$).

To implement serial polling of the Request for Service bit you need only test for the RQS bit to be set.

For example:

```
(serial poll) CALL IBRSP (XTC2%,SPR%)
```

```
      B = SPR% / 64 : B = INT(B)
```

```
      IF B = 1 THEN (continue prog) ELSE (serial poll)
```

If the RQS bit is set, the program may then be made to read the first 4 bits of the Status Byte (2⁰ through 2³) to determine what event generated the service request. Once this is determined the appropriate action may be taken.

3.9 Co-Deposition (Two Unit Interconnection)

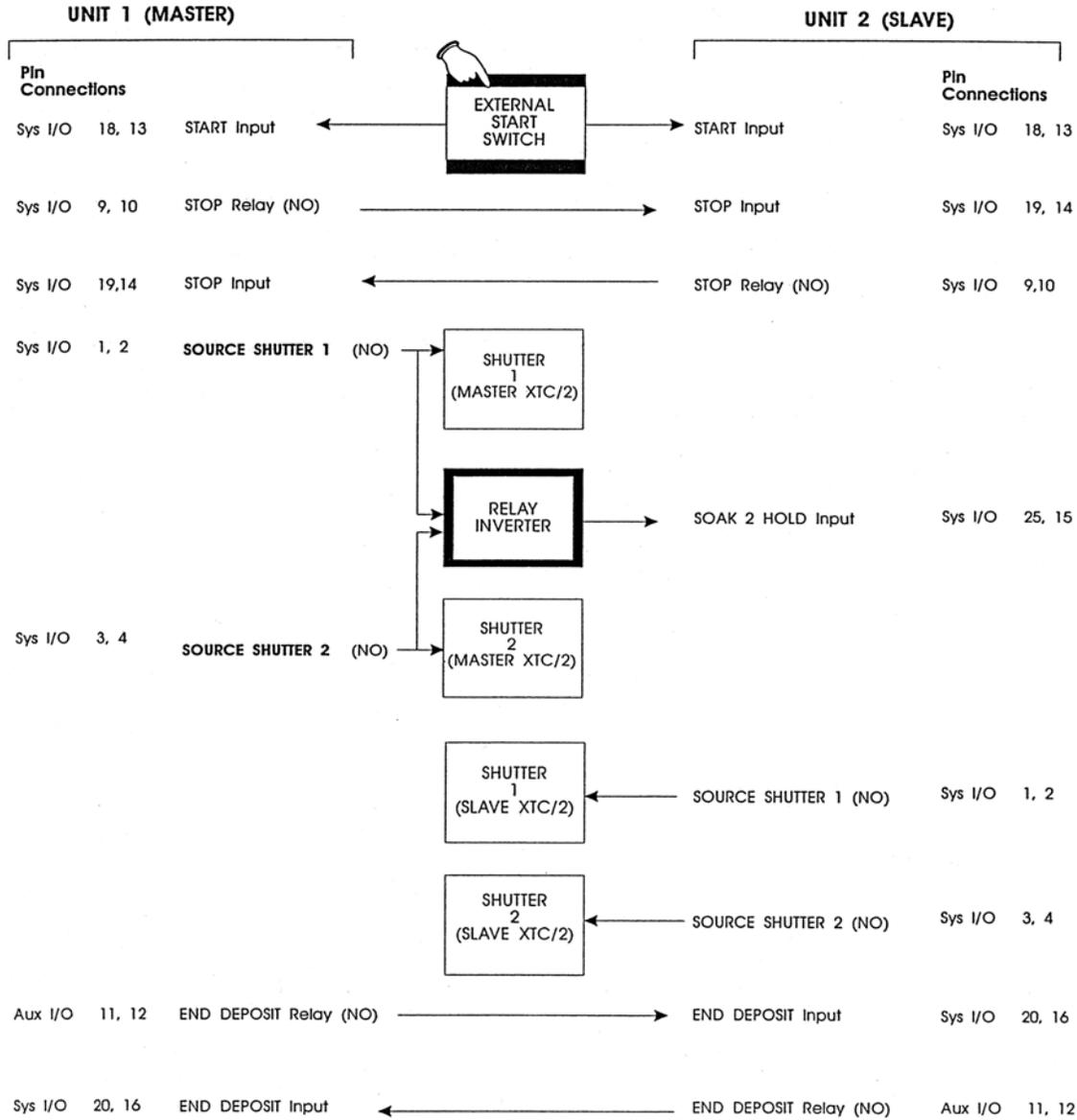
It is possible to control two (or more) sources simultaneously by interconnecting multiple XTC units. This is most easily accomplished by interconnecting the inputs and outputs of the units as shown in [Figure 3-8 on page 3-40](#).

Two user installed components are suggested. An "External Start" switch is used to synchronize the initiation of the two units' films by simultaneously applying a signal to the **START** input on the System I/O. The relay inverter is used to ensure that both units enter the **DEPOSIT** state simultaneously.

When using the suggested configuration:

- ♦ A **STOP** condition in either unit stops the other unit. Pushing the **STOP** key on either instrument stops both instruments.
- ♦ The unit that first reaches **FINAL THK** triggers the End Deposit input of the other unit.
- ♦ The unit designated "slave" must be programmed to reach the end of the **SOAK 2** state before the "master" to avoid a delay upon the termination of the Soak Hold.
- ♦ The operator must ensure that both units are in the **READY** state before pressing the External Start Switch.
- ♦ If a **STOP** is encountered and a rework layer is not desired (see [section 4.4 on page 4-10](#)), a **RESET** command must be individually given to each unit.
- ♦ If there is material cross sensitivity (if an instrument's transducer receives material from more than one source) the **TOOLING** or **FINAL THK** parameter(s) must be adjusted to account for this condition.
- ♦ It may be necessary to adjust the Z-Ratio to account for the mixing of materials on the sensors. This is especially important if maintaining composition over extended runs is critical.

Figure 3-8 Interconnecting Two XTC/2 Units for Co-Deposition



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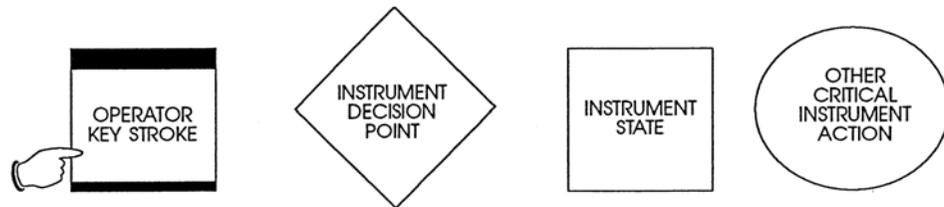
Chapter 4

Programming System Operation Details

4.1 State and Measurement System Sequencing

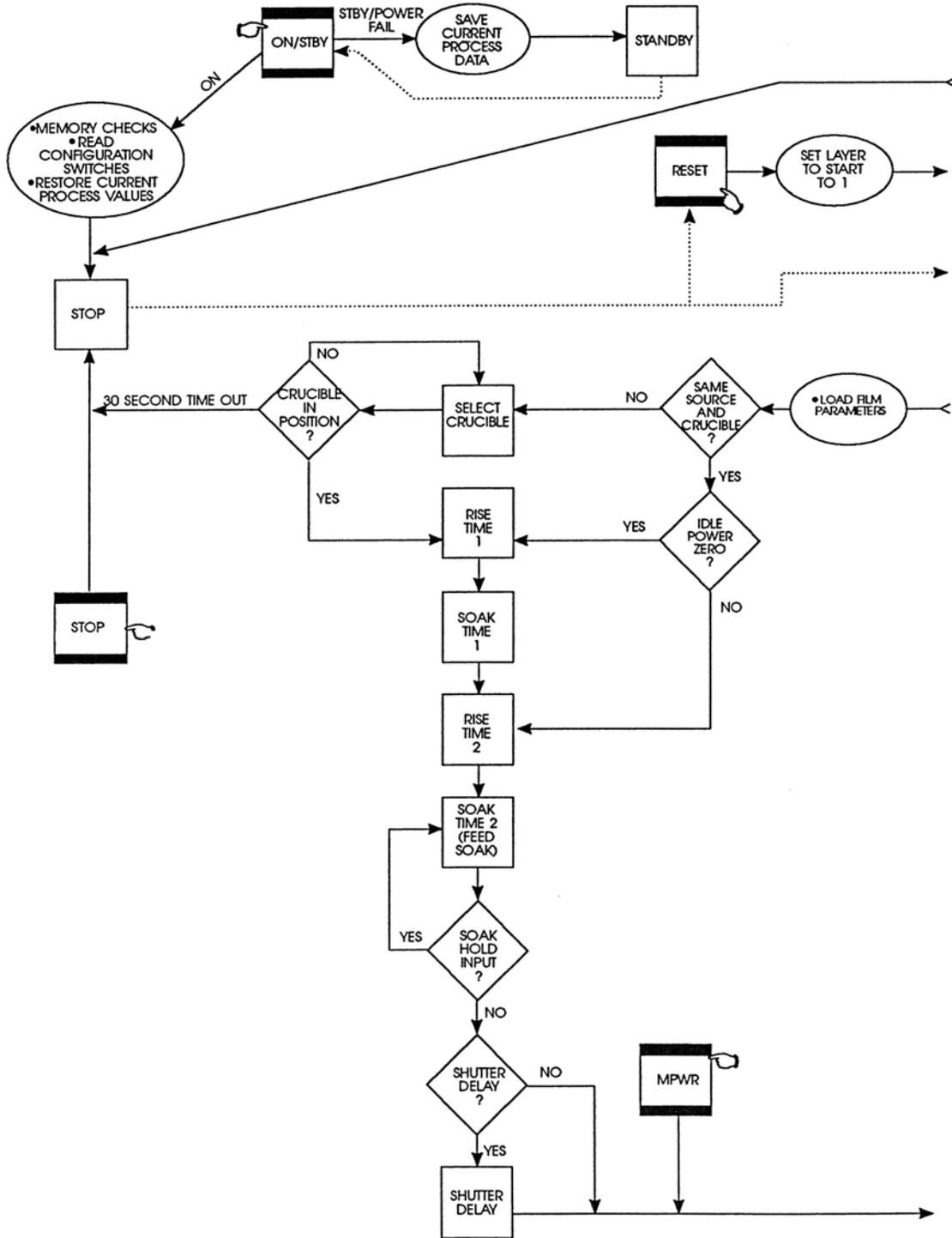
The following pages give an overview of the instrument's operational flow. There are only three basic execution loops; two of which are essentially independent: 1) the Display Loop; and 2) the Measurement and Control Processing Loop. The third loop, State Processing, is, however, the most visible to the operator as it directs the instrument's interaction with the coating system. Because of the time critical nature of the Measurement and Control Loop it may be thought of as the essence of the instrument with the state sequencing and display functions nested within its operation. The following symbols are used in these flow charts:

Figure 4-1 Symbols Used in Flow Charts



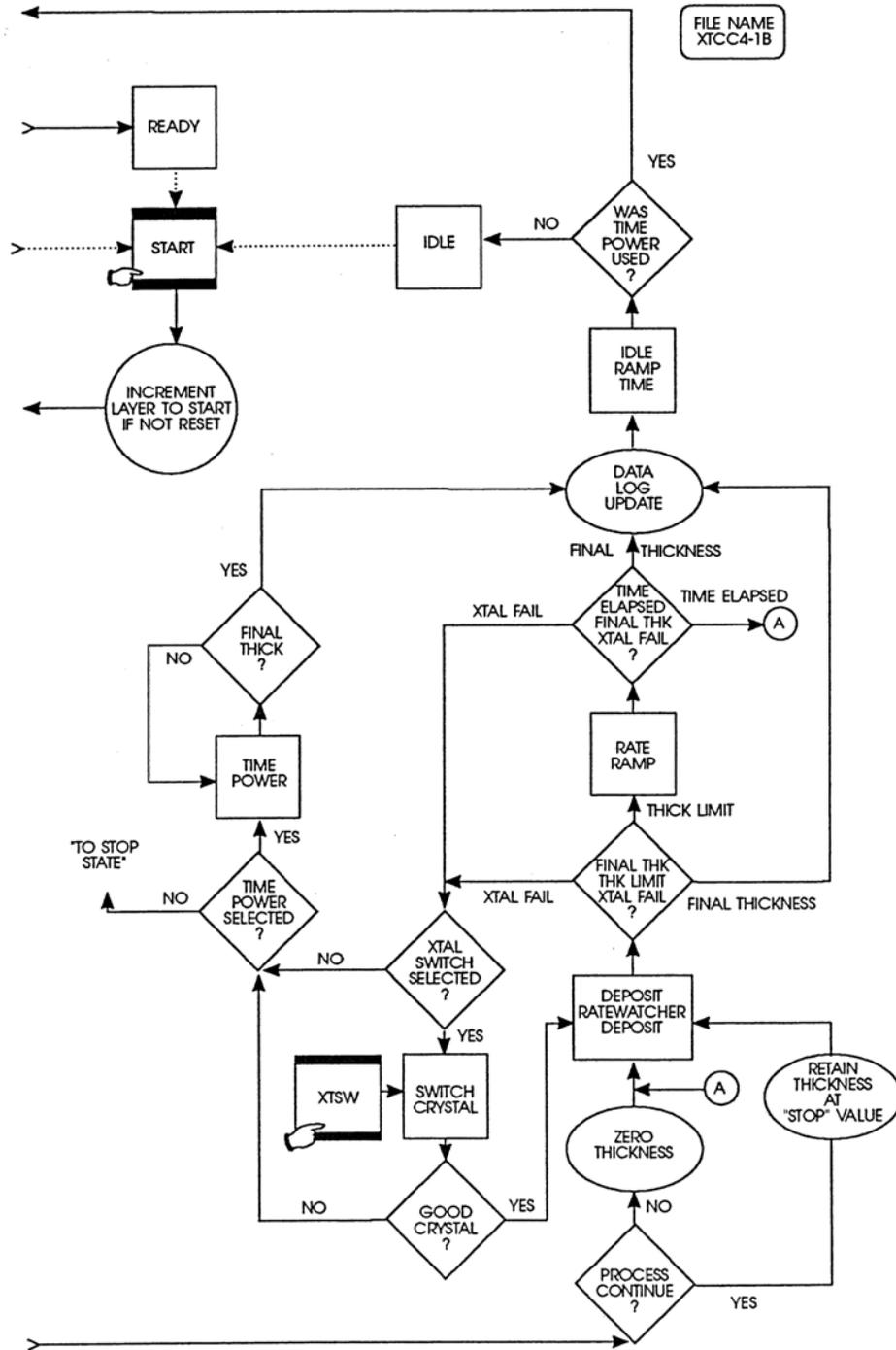
NOTE: The flow diagrams presented, while generally accurate, are not complete from the standpoint of containing enough information to cover all possible eventualities. They are presented as a means of quick overview of the instrument's operations.

Figure 4-2 State Diagram for a Film



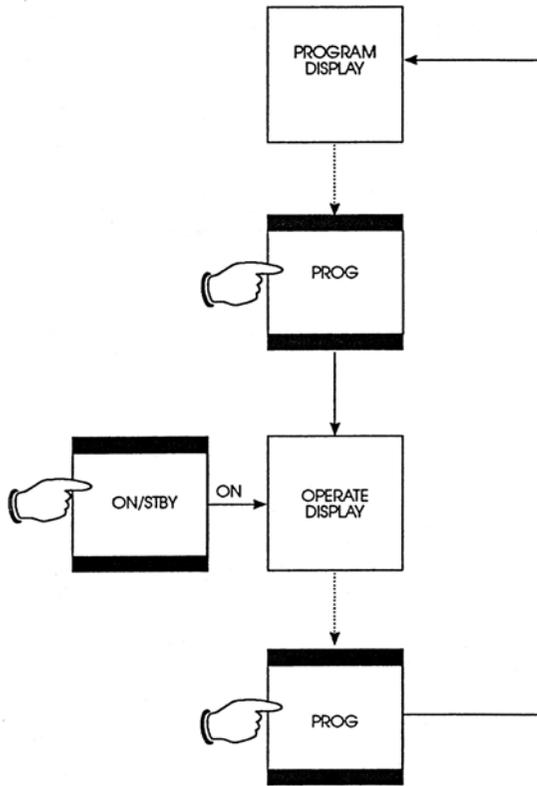
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Figure 4-3 State Diagram for a Film (continued)



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Figure 4-4 Display Loop



The Measurement and Control Loop is characterized by its time-critical nature. No matter what else is happening, the instrument will measure the crystal's frequency and update the Control Loop voltage and all other outputs every 250 milliseconds.

Cable compensation processing is used to match the crystal, transducer, feed through and in-vacuum cables to the drive circuit.

Sweep processing frequency scans the system for the fundamental resonance of the crystal. Once this resonance is found normal frequency tracking is implemented.

4.2 State Descriptions and Parameter Limits

Operating the XTC as a film thickness/rate controller requires programming the film sequence parameters. A film sequence begins with a **START** command and ends when the film in process reaches the idle state. Any process control that occurs between these events is determined by the values programmed in the possible parameters. A film sequence consists of many possible states, with a state being defined as one process event. These states are described below; also, see [Figure 4-2 on page 4-2](#). The parameters that affect each state are listed in brackets at the end of the state description.

Table 4-1 State Descriptions

STATE	CONDITION	RELAY CONTACT STATUS		
		Source Shutter	Sensor Shutter	Feed
NOTE: 1 through 7 are Pre-Deposit States.				
1.READY	Will accept a START command.	Open	Open	Open
2.SELECT CRUCIBLE/SWITCH CRYSTAL	Instrument advances to next state when "crucible in position" input is low. If IDLE PWR of previous layer is not equal to zero, power is set to zero before crucible position changes. If a sensor other than the one last used is selected, then the switch to that sensor will occur. [Crucible #, Sensor #, Source #]	Open	Open	Open
3.RISE TIME 1	Source rising to Soak Power 1 level. Rise Time 1]	Open	Open	Open
4.SOAK TIME 1	Source maintained at Soak Power 1 level. [Soak Time 1, Soak Power 1]	Open	Open	Open
5.RISE TIME 2 (feed ramp)	Source rising to Soak Power 2 level. [Rise Time 2]	Open	Open	Open
6.SOAK TIME 2 (feed soak)	Source maintained at Soak Power 2 level. [Soak Time 2, Soak Power 2]	Open	Open	Closed
7.SOAK HOLD	Source maintained at Soak Power 2 level. [Soak Hold Input]	Open	Open	Open
NOTE: 8 through 14 are Deposit states.				
8.SHUTTER DELAY	Rate control. Advances to Deposit State once the Source is in Rate Control within 5% [Shutr Dly Y]	Open	Closed	Open
9.DEPOSIT	Rate control. [Dep Rate, Final Thk, Ctl Gain, Ctl Tc, Ctl Dt]	Closed	Closed	Open

Table 4-1 State Descriptions (continued)

STATE	CONDITION	RELAY CONTACT STATUS		
		Source Shutter	Sensor Shutter	Feed
10. RATE RAMP TIME	Rate control, desired rate changing. [Thick Spt, New Rate, R.Ramp Time]	Closed	Closed	Open
11. RATEWATCHER (SAMPLE)	Rate control. [Sample %]	Closed	Closed	Open
12. RATEWATCHER (HOLD)	Constant power, based on last sample's average power. [Hold Time]	Closed	Open	Open
13. MANUAL	Source power controlled by hand held controller.	Closed	Closed	Open
14. TIME-POWER	Crystal failed; source maintained at average control power prior to crystal failure. [Time Pwr Y]	Closed	Closed	Open
NOTE: 15 through 16 are Post-Deposit states.				
15. IDLE RAMP	Source changing to Idle Power. [Idle Ramp]	Open	Open	Open
16a. IDLE POWER (=0%)	Source maintained at zero power; will accept a START command. [Idle Pwr]	Open	Open	Open
16b. IDLE POWER (>0%)	Source resting at Idle Power; will accept a START command.	Open	Open	Open

NOTE: The **STOP** state—instrument will accept a **START** provided a Crystal Fail has not occurred. See also [section 4.16 on page 4-26](#).

The following variable parameters and their limits are listed below. If a value outside the stated limits is attempted, the message **ERR 1** is displayed.

Table 4-2 Limits for Film Parameters

PARAMETER	LIMITS	UNITS
Rise Time 1, 2	00:00 - 99:59	MIN:SEC
Soak PWR 1, 2	0.0 - 100	%
Soak Time 1, 2	00:00 - 99:59	MIN:SEC
Shutr DLY	Yes or No	--
NEW RATE	0.000 - 999.9	KÅ
R RAMP TIME	00:00 - 99:59	MIN:SEC
IDLE RAMP	00:00 - 99:59	MIN:SEC
IDLE PWR	0.0 - 100	%
TIME PWR	Yes or No	--
XTAL SWCH S, Q	0 - 9	Whole Numbers
TOOL FACT 1,2	10.0 - 500	% (see note 1)
DEP RATE	0.000 - 999.9	Å/SEC
FINAL THK	0.000 - 999.9	KÅ
THK SPT	0.000 - 999.9	KÅ
DENSITY	0.500 - 99.99	GM/CC
Z-RATIO	0.100 - 9.999	--
SENSOR #	1 or 2	--
SOURCE #	1 or 2	--
CRUCIBLE #	0 - 8	Whole Numbers (see note 2)
CTL GAIN	00.01 - 100.0	(Å/SEC)/%
CTL TC	0.1 - 100	SEC
CTL DT	0.1 - 100	SEC
MAXPWR	0.0 - 100	%
SAMPLE	0 - 99	%
HOLD TIME	00:00 - 99:59	MIN:SEC

Notes:

1. If configured for dual sensor, TOOL FACT 1 applies to primary sensor, TOOL FACT 2 applies to secondary sensor. If configured for single or CrystalSix sensor(s), TOOL FACT 1 is used regardless of whether sensor 1 or 2 is active.
2. Set to 0 for single crucible operation. If non-zero, instrument waits until Crucible Valid input goes low before going into Rise.

4.3 Alarms and Stops

There are a number of unusual instrument situations that may require operator attention. These situations are detected and then treated as **ALARMS** or if very serious, **STOPS**.

Both alarms and stops are indicated by a separate relay closure. An alarm condition is not fatal, the instrument will continue the layer or process to normal termination. A **STOP** is fatal, immediately halting the process. If desired, the user may set the **STOP ON ALARM** configuration switch (see [section 2.6.2 on page 2-19](#)) to configure the instrument to treat an **ALARM** the same as **STOP**; i.e., halting processing upon detection of the abnormal condition.

4.3.1 Alarms

The following conditions are considered **ALARMS** by the instrument and close the **ALARM RELAY**.

- ◆ Crucible hearth selection is not validated by the **CRUCIBLE VALID** input within 30 seconds.
- ◆ Rate control not established during the first 60 seconds of **SHUTTER DELAY** (or 20X **CTL TC** if **PID** loop is used).
- ◆ Rate has been out of control in **DEPOSIT** for 60 seconds (or 20X **CTL TC** if **PID** loop is used).
- ◆ The source power has constantly exceeded the **MAX PWR** parameter for 5 seconds. This is also indicated by the MAX POWER annunciator blinking.

4.3.2 Stops

The following actions or conditions produce a **STOP** state. This condition is indicated by the **STOP** annunciator on the XTC/2 or the **STOP LED** on the XTC/C and the closure of the **STOP** relay.

- ◆ Pressing the front panel switch on the XTC/2.
- ◆ Activating the **STOP** external input.
- ◆ A **CRYSTAL FAIL** detected during any pre-deposit phase (when crystal switching is not available).
- ◆ A **CRYSTAL FAIL** detected during the **DEPOSIT** state if the **TIME PWR** parameter is set to **N** (when crystal switching is not available).
- ◆ Following the **POST-DEPOSIT** states of a layer that completed the **DEPOSIT** state in **TIME PWR**.
- ◆ Any of the **ALARM** conditions listed in Section 4.3.1 if the **STOP ON ALARM** or **STOP ON MAX PWR** configuration switch is activated.

4.4 Recovering From "STOPS"

These instruments have the ability to complete a process (recover) from a **STOP** without manually reprogramming any film or process parameters. Recovery from a **STOP** (generated by an operator or any machine induced condition) requires only that the **START** command be given (be sure that the **CONTINUE** annunciator is visible on the display). The film in process at the time of the **STOP** will again be executed from the beginning, but the displayed thickness will not be "zeroed" upon reentry of the **DEPOSIT** state. Instead, the thickness that was accumulated at the time of the generation of the **STOP** will be used. Thickness will accumulate in the normal fashion from that point. All processing will occur in the normal fashion from the reentry of the deposit state, forward. In this manner a "repair" layer may be added to the previous run to bring the film to the specified thickness.

If it is not desired to recover, the process may be reset to the beginning of layer one by issuing a **RESET** command prior to a **START** command. The **CONTINUE** annunciator will not be visible on the operating display after the **RESET** command is given. This procedure may be used if the layer in question cannot be successfully repaired by adding a second layer of the same material to achieve final thickness specification.

NOTE: A **RESET** command may be given by pressing the front panel reset key when the display is in the operate mode, or through the remote communications.

4.5 Tuning the Control Loop

The function 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; **CTL GAIN**, **CTL TC** and **CTL DT** used to accomplish this. It is convenient to think of sources as falling into two categories "fast" or "slow". Fast sources use an integrating type controller while slow sources are better controlled with a PID type. A more extensive discussion of control loops is presented in [section 5.6 on page 5-12](#). The tuning parameters are affected by source level, rate, sweep range or beam density, tooling and source condition.

NOTE: The use of a chart recorder, especially when beginning a new application is highly recommended. Set the recorder output to "rate" and use it to monitor the response to small changes in the **DEP RATE**.

NOTE: If you do not know if the source is fast or slow, it is straight forward to measure the delay with the chart recorder. Using manual power control, establish rate and allow it to become steady. When the chart recorder pen crosses some convenient reference point, increase the source power a few percent (~5% if possible). Allow the source to again stabilize. Graph the delay time, as is shown in [Figure 5-7 on page 5-13](#), to determine if the source is "fast" or "slow". Run the recorder at a chart speed sufficiently fast to accurately measure time. Delay times greater than 1 second characterize the source as "slow".

4.5.1 Tuning a Fast Source

A fast source, for the purpose of this discussion, is a deposition source that has not more than a one second delay (lag) between the control voltage change (into the source's power supply) and the measurement system's ability to sense that change has taken place. In general, fast sources are: all electron beam types (unless a hearth liner is used), some very small filament sources and sputtering sources.

If the source response has been characterized as "FAST", as suggested in the NOTES in [section 4.5](#), it is easy to set the INTEGRATING TYPE control parameters as follows:

CTL DT. since this is a fast source, set this parameter to 0.1 and leave it there.

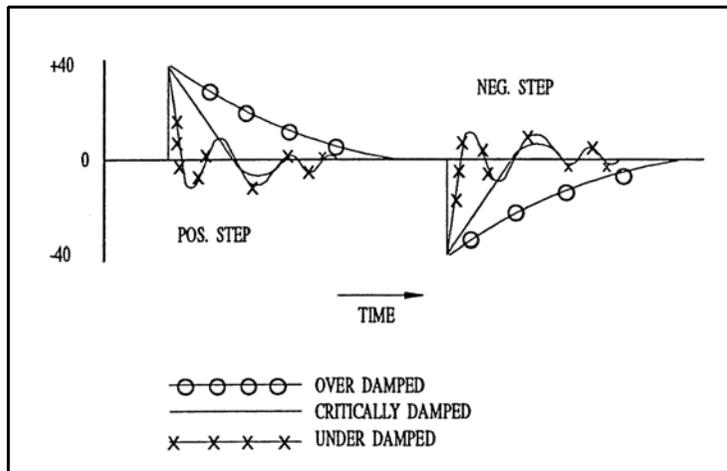
CTL TC. set this parameter to 0.1 and leave it there.

CTL GAIN . . approximate the process gain by dividing the increase in deposition rate (Å/sec) by the increase in source power (%). Set this parameter to this computed value. Optimize this value by changing the value in use. Remember that increasing the value of this parameter reduces the controller change for a given error in the deposition RATE.

NOTE: If satisfactory control cannot be established using only **CTL GAIN** the source is probably not a "fast" source.

The response of a system with too little controller gain (its **CTL GAIN** value is too large) is characterized as over damped as shown in [Figure 4-6](#). Decrease the **CTL GAIN** value until the system oscillates as is shown by the under damped curve. Proper control is established by an intermediate value that approximates the critically damped curve.

Figure 4-6 Examples of Damped Curves



4.5.2 Tuning a Slow Source

A slow source, for the purpose of this discussion, is a deposition source that has more than a one second delay (lag) between the control voltage change (into the source's power supply) and the measurement system's ability to sense that change has taken place. Most thermal sources are slow sources. A typical fast source is an electron beam heated type that does not use a hearth liner.

If the source response has been characterized as "SLOW" (as suggested in the NOTES in [section 4.5 on page 4-11](#)); review [section 5.6 on page 5-12](#) and then set the PID control parameters as follows:

CTL GAIN = K_p , enter this value into the parameter

CTL TC = T_1 , enter this value into the parameter

CTL DT = L , enter this value into the parameter

As illustrated in [Figure 5-7 on page 5-13](#), the control dead time, L , is the time delay between a change in the source's power setting and a noticeable change in deposition rate. The control time constant, T_1 is $(T_{0.632} - L)$ where $T_{0.632}$ is the time between a change in the source's power setting and the time to achieve 63.2% of the new equilibrium rate.

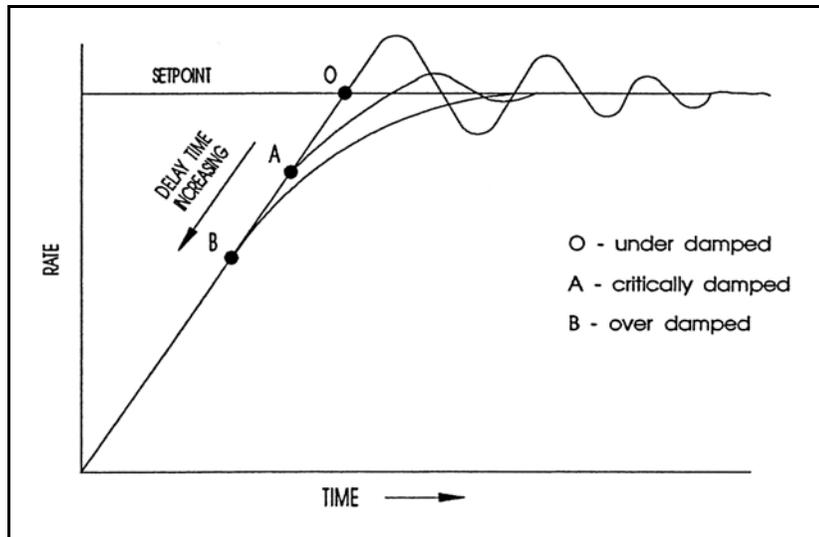
K_p is then the ratio of the change in rate over the change in source power setting.

$$K_p = \frac{(\text{change in output})}{(\text{change in control signal})} = \frac{\Delta \dot{A} / \text{sec}}{\Delta \% \text{Pwr}} \quad [1]$$

These values may be adjusted slightly in use to optimize the tuning. The tuning may change because of process variations. Usually **CTL TC** and **CTL DT** do not need to be changed.

NOTE: Remember that increasing the value of **CTL GAIN** reduces the controller change for a given rate error.

Figure 4-7 Examples of Delay Settings



4.5.3 Setting Maximum Power

The MAX PWR parameter is generally used to ensure that no significant damage can take place when a deposition source under rate control experiences an unusual event. By placing a limit on the most power allowed to be applied to the source, serious damage might be avoided if, for example, material is depleted. Without this protection Rate Control would keep adding power until the full 100% were applied. This is frequently catastrophic! It is normal to set this parameter at a value that is 2-5% more than the normal power required during deposition. Exceeding maximum power can result in a STOP or Alarm condition; refer to [section 4.3 on page 4-9](#).

4.6 Setting S&Q Parameters (Soft Crystal Failures)

At some point during deposition the crystal may become unstable or erratic yet continue to oscillate within the instrument's acceptable frequency range of 6.0 MHz to 5.0 MHz. The resulting rate control will be poor and thickness measurements may be inaccurate. By programming non-zero values for **S** and/or **Q**, various improvements in process control can be achieved. The instrument can be made to automatically switch to a different crystal and continue the deposition normally, complete the run in the **TIME-POWER** mode or even terminate the process whenever the programmed threshold of instability is exceeded. As the **Q** and **S** factors are programmed to larger values the level of instability tolerated prior to switching is lowered.

4.6.1 Q-Factor (Quality)

The Q-Factor is a measure of the quality of the rate control of the active process. When the Q-Factor is activated the instrument senses the amount of rate deviation from the desired programmed rate. Setting **Q** between 1 and 9 activates an algorithm which sets threshold limits on allowed rate deviation. If the rate deviation relative to the programmed rate is greater than the programmed threshold limit, the **Q** counter is incremented. If the rate deviation is less than the programmed threshold, the **Q** counter is decremented. **Q** is not allowed to have negative values. If the **Q** counter exceeds a value of 50, the instrument will then automatically crystal switch, complete the process on **TIME-POWER** or **STOP** the process. The quality limits (or band of allowed rate deviation) are shown in [Table 4-3](#). This deviation is computed on each individual reading of the crystal during the deposit phase, i.e., every 250 ms.

Table 4-3 Quality Limits

Q-Factor	Threshold of Rate Deviation (%)
0	Disabled
1	30.0
2	25.0
3	20.0
4	15.0
5	12.5
6	10.0
7	7.5
8	5.0
9	2.5

Example

If the Programmed rate is: 45 Å/s and the actual rate is: 40 Å/s, then:

$$\text{Deviation (\%)} = \frac{45 - 40}{45} \times 100\% = 11.1\% \quad [2]$$

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4.6.2 S-Factor (Stability)

Normally, as material is deposited on a crystal its operating frequency decreases. It is from this change in frequency (over the measurement time period) that the instrument derives its thickness measurement and rate control functions.

There are times when the crystal may become unstable and will experience a positive frequency shift over the measurement time period. The S-Factor can then be used as a measure of the crystal's instability.

When the S-Factor is activated, and a positive frequency shift occurs, the magnitude of the positive shift is accumulated in the S-register. A limit is placed on the total cumulative positive frequency shift by programming the S-Factor between 1 and 9. When the limit is exceeded the instrument will fail the crystal and effect a CrystalSwitch, Complete on Time Power, or STOP, depending on the instrument configuration.

Maximum accumulations for selected S-Factors are listed in [Table 4-4](#). To prevent random noise from accumulating in the S-register a minimum positive frequency shift of 25 Hz is required.

Table 4-4 Maximum Accumulations for Selected S-Factors

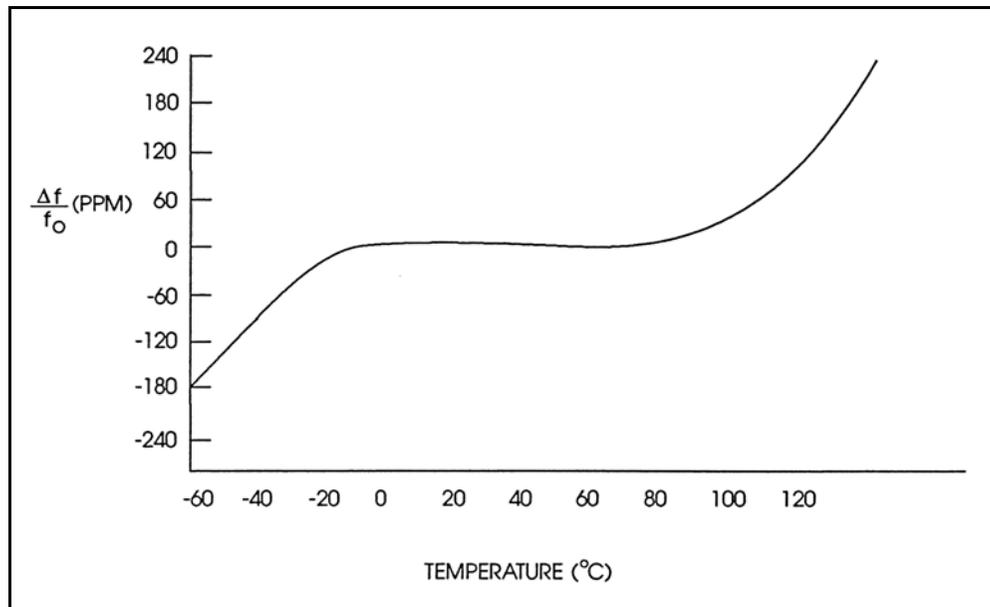
S-Factor	Pos. Frequency Accumulation
0	Disabled
1	5000 (max single shift 1250)
2	1000
3	500
4	400
5	200
6	200 (max single shift 100)
7	100
8	100
9	25

There are many reasons for a crystal to exhibit a positive frequency shift. For example, when a crystal is near the end of its life it is prone to instabilities that may result in a temporary increase in crystal frequency. Also positive frequency shifts may occur due to film stress relieving or a film tearing off a crystal.

Additionally, temperature effects may cause positive frequency excursions. A crystal subjected to temperatures over 100 °C is more sensitive to small changes in temperature inducing frequency changes. When heat is applied inside a chamber and/or when the shutter is opened (exposing the crystal to the hot source), the crystal frequency will shift higher until thermal equilibrium is obtained. When the active process ends and/or the shutter closes, the crystal frequency will shift in a negative direction due to cooling.

Figure 4-8 shows temperature versus frequency relationship for an AT cut crystal.

Figure 4-8 Frequency Change vs. Temperature for an AT crystal cut at 35°20'



4.6.3 Determining Q and S Values

The **Q** and **S** Factors are used to ensure that the evaporation process is always under the best possible rate control a crystal can provide. The process engineer can program values between 0 and 9 for these parameters. Thus, when the primary crystal reaches a point where its behavior is objectionable it will be disabled and the proper switch/time-power/stop decision made. The tolerance of instabilities becomes increasingly smaller as **Q** and **S** increase towards 9. They are independent parameters and may be treated one at a time.

If the crystal fails and no backups are available, the **TIME PWR** parameter determines whether the process should stop (N) or complete on time-power (Y), [or crystal switch if a dual or CrystalSix crystal sensor head is employed].

Q and **S** can be observed when the display is in the operate mode and the **LIFE** key is depressed. The value in the **S** accumulator replaces the **TIME** display. When the life key is released, the **Q** value replaces the **S** value in the **TIME** display for about 1 second.

With a new crystal, the value in the **Q** accumulator will usually be one or zero if the **Q** parameter is programmed properly. As a crystal deteriorates, larger values will appear as the **Q** accumulator builds up or counts down. The switch point occurs when the **Q** accumulator equals 50. The designated count of 50 requires that the rate deviation instability be sustained for several seconds. This is so the algorithm does not trip out for short-lived events. The **Q**

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accumulator does not retain its values, but rather, builds up when the rate deviation exceeds its set tolerance and counts down to zero when the rate deviation is within its programmed tolerance band.

The **S** accumulator shows the total magnitude of only the positive frequency shifts (in Hz) from the moment the start button is pushed until that film is completed and the next film layer is started. When the **S** value exceeds the set point, the crystal is disabled. Unlike the **Q** accumulator, the **S** values are retained and added to the accumulator whenever the positive frequency shift is greater than 25 Hz. Table 4.4 shows the accumulated frequency shift required to trigger the switch.

One problem is E-B gun arcing. If the **S** value constantly increments during arcs it usually indicates poor grounding and the **S** factor should be disabled until this problem is corrected.

Improved rate and thickness information results from programming non-zero values for **Q** and **S**. The trade off is between improved process control and lower crystal utilization. By observing the behavior on the operating display a determination can be made, after several runs, whether or not the programmed values provide a desirable compromise.

INFICON's laboratory experiments have shown the following values to be useful and they can serve as general guidelines.

Table 4-5 Representative S and Q Factor Values

SOURCE	MATERIAL	S-FACTOR	Q-FACTOR
2" E-B gun w/liner	Cu	7	7
2" E-B gun	Cu	5	7
1-1/8" E-B gun	Al	4	4
1-1/8" E-B gun	Ni	4	3
Integral W-Al ₂ O ₃	Cu	6	7

If the process/crystal behavior is unknown and you want to employ the **Q** and **S** factors, start with **S = Q = 5** and watch their behavior on the display by pressing the **LIFE** switch. Monitor and fine tune these parameters until the desired level of rate control is ensured.

Often during process setup, the initial settings of the **Q** factor may soft fail the crystal sensor. This can be caused by process delays in getting the system under control (i.e., slow response sources or SOAK2 power levels poorly set). The crystal sensor's state of soft failure can be cleared or reset by changing or re-entering the value of the **Q** or **S** factor parameter.

For example, if the **Q** factor parameter has a value of 5 and the rate control varies by more than $\pm 12.5\%$ this causes the **Q** counter to increment. When it reaches the value of 50 the crystal is "Soft Failed" due to the crystal quality algorithm. This "Q" failed crystal can be cleared by re-entering the parameter value 5 for the **Q** factor parameter or by changing it to another value.

4.7 Rate Ramps

Each film program includes a rate change parameter. It may be used to generate a precise linear variation in the evaporation rate. "Rate Ramps" execute during the deposit state of the film. They are initiated when the **THICK STP** parameter of the film program is reached. If the rate ramp state terminates before the film reaches **FINAL THK**, the instrument will return to the deposit phase.

The slope of a rate ramp is determined by the following equation: delta rate per sec = **(NEW RATE - DEP RATE)** divided by **RAMP TIME**. If a ramp parameter is changed during the ramp, a new slope will be calculated, taking into consideration the time the ramp has already been in process.

4.7.1 Rate Ramp to Zero Rate

It is sometimes desirable to ramp to zero rate for alloy phasing purposes, completing the film processing as if a final thickness had been achieved. Rate ramps, however, are ordinarily deleted by entering zero for the **NEW RATE**. Therefore, in order to implement this type of film termination, program the **NEW RATE** value of the rate ramp to 0.1 Å/sec. When this rate value is achieved, the film program will proceed as if a **FINAL THK** limit had been reached.

While a rate ramp is being processed, the **DEP RATE** parameter's internal value is continuously updated to match the slope of the Rate Ramp.

NOTE: If the **TIME-POWER** state is entered, a rate ramp will not be executed; with the film completing at the programmed **FINAL THK**.

4.8 Use of the Hand Controller (Option)

A hand held controller is provided as an option. The controller serves as a wired remote to manually control power, switch crystals and produce a **STOP**.

The controller is attached to the instrument with a coiled cord and attaches with a modular plug to the front panel of the instrument. The **POWER/STOP** switch located at the top of the controller is asymmetrical to increase awareness of the direction of power increment and decrement.

Power is affected (only when in Manual mode) by moving the **POWER/STOP** switch laterally. A **STOP** is produced by plunging the **POWER/STOP** switch down.

When in **READY**, a crystal switch is activated by depressing the red button on the body of the controller. This action alternates the active crystal of a dual head configuration or advances the active crystal of a CrystalSix to the next available good crystal. This may be done any time the instrument is not in **STOP**.

NOTE: Upon leaving the **MANUAL POWER** state the instrument enters the **DEPOSIT** state. The deposition will terminate if the **FINAL THK** parameter value has been exceeded.

The ship kit includes a convenience hook for the controller that can be attached to the instrument or other accessible location.

4.9 Setting the Soak and Idle Power Levels

These instruments provide 0 to +/- 10 Volts source power control from the **SOURCE #** connectors on the rear panel. The voltage output is proportional to the percent power display with 50% power outputting 5 volts. The control voltage polarity is set by the appropriate configuration switch, refer to [section 2.6.2 on page 2-19](#)

NOTE: The maximum voltage output is limited by the value of the **MAX PWR** parameter of each film.

4.9.1 Setting Soak Power 1 Parameters

SOAK PWR 1 is typically set at a level that produces a source temperature just below significant evaporation. This is easily translated into a power percentage (**SOAK PWR 1**) with the help of the hand held controller or the Δ/∇ keys when in manual power mode. Slowly bring the power level to a level where melting is just beginning and then note the power percentage value on the LCD display. Use this value for the **SOAK PWR 1** setting. This power level may also be used in fast coaters for a non-zero Idle Power. Set the associated Rise Time and Soak Time to insure that the melting does not cause violent turbulence but does not waste excessive time.

4.9.2 Setting Soak Power 2 Parameters

SOAK PWR 2 is typically set at a level that is just below the power that is used for maintaining the selected evaporation rate. This is determined by manually bringing the power level up to the desired rate and then entering automatic rate control. Allow the source to stabilize, then note the average power on the display. Use this value or one slightly lower for the **SOAK PWR 2** value. Set the associated rise and soak times long enough to insure that the melting does not cause violent spattering, but short enough that expensive materials are not wasted.

4.9.3 Setting Idle Power Parameters

After a deposit has completed, it may be necessary to slowly reduce the source's power to zero or to some non-zero value. The **IDLE RAMP** parameter defines the time spent in linearly tapering the power from the value at the end of deposit to the **IDLE PWR** value.

4.10 Implementing RateWatcher

It is easy to set up to automatically sample the deposition rate periodically and then maintain the proper source power level necessary to keep the Auto Control Rate at the set point for extended periods of time. With inherently stable deposition sources; such as the planar magnetron, an occasional check of the rate (with the associated automatic recomputation of the necessary power level) is all that is needed.

This "sample and hold" type of control can supersede the fully active type of rate control that normally limits the utility of the crystal monitor for in-line or load locked systems.

The RateWatcher feature requires a two parameter entry.

First, the Process Engineer must decide on the **SAMPLE** percent. This parameter sets the accuracy that must be maintained over the 5 second interval.

NOTE: The minimum accuracy range settings are internally limited to 0.5 Å/sec difference between the setpoint and the just sampled rate. This avoids unnecessary power changes.

Second, the **HOLD TIME** must be programmed. This is the length of time between the completion of the last sample period (or the achievement of rate control) and the initiation of the next sample period. The process engineer may set the interval up to a maximum of 99:59 for automatic operation. If longer intervals or periodic samples are needed **SAMPLE INITIATE** and **SAMPLE INHIBIT** inputs are available on the **SYSTEM I/O** connector. During **HOLD** periods, thickness is accumulated at the Auto Control Rate (**DEP RATE**) and power is held at the internally computed Time-Power value. During **SAMPLE** periods, the power will not be changed unless two consecutive samples fall out of the specified accuracy range (1-99%).

Entering a **HOLD TIME** of 00:00 disables the RateWatcher feature.

NOTE: The RateWatcher function is disabled if the sensor type is configured for a Dual or CrystalSix sensor head. See [section 4.15.1 on page 4-25](#).

4.11 Crystal Fail

Whenever the ModeLock measurement system is unable to effectively identify and drive a monitor crystal, a special set of sweep and find instructions are executed. This sequence takes up to five seconds as it is repeated a number of times. This sequence of events is depicted in the "Measurement and Control Processing Loop" flow chart, [Figure 4-5 on page 4-5](#).

If the measurement system is unable to recover, the message XTAL FAIL is displayed. The action next taken by the instrument is dependent on the value of the **TIME-POWER** parameter as described in [section 4.12 on page 4-22](#).

Sometimes a monitor crystal will spontaneously recover if its temperature is reduced or sufficient time passes and the stress induced by the coating is naturally relieved. Even with the XTAL FAIL message displayed the measurement system will continue to attempt to find the fundamental resonant mode's frequency. This message will disappear when the crystal recovers or is replaced.

Additional information on crystal failures is presented in [section 6.3.2 on page 6-4](#). The ModeLock oscillator is more fully explained in [section 5.5.5 on page 5-9](#) and [section 5.5.6 on page 5-11](#).

4.12 Completing on TIME-POWER

When used as a controller this instrument has the ability to complete a deposition normally if a crystal fails during the deposit phase. Depending on the setting of the **TIME-PWR** parameter, the unit will either complete on **TIME-POWER (Y)**, or **STOP (N)** on crystal fail. When set up to complete on **TIME-POWER** and a crystal fail is encountered the instrument will establish an average power-based on the values output to the source prior to the crystal failure. This average power is used while thickness is accumulated at the **DEP RATE**. The deposition will terminate normally. The thickness accuracy will depend on the duration of the **TIME-POWER** phase. A shorter duration of **TIME-POWER** will increase the Final Thickness accuracy; longer durations will decrease accuracy. This feature has no utility when used in a monitor only situation.

4.13 Crystal Fail Inhibit

In many coating plants the crystal fail output relay closure is given major importance and causes the entire system to shut down. This can cause problems when the crystal is changed as part of the normal reloading procedure. This potential conflict is resolved by utilizing the crystal fail inhibit input; refer to [section 2.6.4 on page 2-23](#). When this input is activated the crystal fail relay will not close on crystal fail.

The crystal fail inhibit input is ignored if the instrument is in the Deposit state.

The front panel messages and instrument operation still work normally. The operator may now change the crystal and verify that it is operating without inducing a major process interruption.

The crystal fail inhibit input may be switched manually or automatically by using the **END DEPOSIT** relay; refer to [section 2.6.5 on page 2-24](#).

4.14 Shutter Delay

SHUTR DLY is used to establish rate control before exposing the substrates to the evaporant. The sensing crystal must be exposed to the deposition source during the Shutter Delay state for this to be accomplished. Shutter delay is accessed by programming the **SHUTR DLY** parameter to **Y** (yes). The control loop attempts to establish rate control at the end of the pre-deposition film states. However, the source shutter opening is delayed for a period of time to insure stable rate control. When rate control has been established (within 5% or 0.5 Å of the **DEP RATE** value), the shutter opens, the accumulated thickness is zeroed, and the substrates are immediately exposed to an evaporant that is under tight rate control. With proper adjustment of the control loop parameters, the delay time can be kept to a minimum. If the instrument is unable to establish rate control in 60 seconds (or 20x **CTL TC** if the PID Loop is used and **CTL TC** is greater than 3.0), the alarm relay on the **AUX I/O** will close. Also the instrument may be set up to automatically **STOP** on this alarm condition if the appropriate configuration switch is turned on; refer to [section 2.6.2 on page 2-19](#).

4.15 Crystal Switch Details

A crystal switch will automatically occur when:

- ◆ The instrument is configured for a dual head, a layer is running on the primary sensor, and the primary crystal fails.
- ◆ The instrument is configured for a CrystalSix, a layer is running, and there is at least one good crystal left in the carousel when the active crystal fails.
- ◆ The instrument is configured for a dual head or single heads, a START is executed and the designated primary sensor is different than the last sensor run. This switch will take place before entering a RISE 1 or RISE 2 state.

NOTE: When using a dual head, a layer cannot START if the primary crystal for that layer is failed, unless the "start layer without backup crystal" configuration switch is activated; see [section 2.6.2 on page 2-19](#) and [section 4.16 on page 4-26](#).

- ◆ A soft crystal failure is generated; refer to [section 4.6 on page 4-14](#).

A crystal switch will **NOT** automatically occur:

- ◆ In STOP, READY or IDLE.
- ◆ When the designated primary sensor is already failed at the START of a layer. A STOP will occur unless the "proceed without backup" configuration switch is chosen; see [section 4.16 on page 4-26](#).
- ◆ When the secondary crystal of a dual head fails. (A TIME-POWER or STOP will occur.)

A crystal switch can be manually executed via the front panel, handheld controller, or remote communications any time the system is configured for Dual or CrystalSix.

NOTE: The primary sensor # of a Dual head is the sensor programmed in the film's parameters. The secondary sensor is the other sensor. On the XTC/2 Display, the active crystal's number is illuminated. If the primary crystal has failed, the active crystal's number (backup) flashes to indicate that there is no backup.

CrystalSix crystals are all read on power up to determine how many good crystals are present. On power up, when configured for a CrystalSix sensor, the XTC/2 display will be blank except for the CrystalSwitch and STOP annunciators. Once the initialization is complete the XTC/2 will automatically go to the Operate Display. On the XTC/2 Display, the annunciators of the good crystals are illuminated, with the active crystal's number flashing. The XTC/2 will identify a CrystalSix switcher fail by turning off all the crystal annunciators. A CrystalSix switcher fail will occur if the CrystalSix carousel fails to rotate properly.

NOTE: The crystal fail annunciator is illuminated when no more good crystals remain for both the XTC/2 and the XTC/C.

4.15.1 Sensor Shutter / CrystalSwitch Output

The function of the Sensor Shutter outputs depend on the Configuration switch settings on the back of the unit. (Refer to [Table 2-2 on page 2-20](#) for a list of configuration switch setting definitions.) If a single head sensor type is chosen the Sensor Shutter relay contacts are set to be Normally Open. The Sensor Shutter relay contacts close (opening the shutter) when entering the Deposit state, Shutter Delay state, or during the Sample period of the RateWatcher function.

If a Dual sensor type is chosen, the Sensor Shutter relay now functions as a CrystalSwitch relay. The contacts are set to be Normally Open. The Sensor Shutter relay contacts close upon initiating a CrystalSwitch. This actuates the shutter mechanism, toggling the shutter, exposing Sensor 2's crystal and covering Sensor 1's crystal. A second CrystalSwitch function will open the contacts, toggling the shutter, exposing Sensor 1's crystal and covering Sensor 2's crystal. Due to the change in function of the relay output from that of Sensor Shutter to one of CrystalSwitch, RateWatcher is disabled when the unit is configured for a Dual sensor.

NOTE: When configured for a dual sensor, sensor 1's shutter relay is used for the CrystalSwitch function. Sensor 2's shutter relay is disabled.

If a CrystalSix sensor type is chosen the Sensor Shutter relay functions as a CrystalSwitch relay. The operation of the relay contacts is different than when the sensor is a Dual head. In this case the relay contacts are pulsed closed for one second, opened for one second, closed for one second, then opened. When connected properly, the first one second closure will advance the CrystalSix carousel into an intermediate position between two crystals. Opening the closure for one second allows the ratchet mechanism to relax whereupon the second contact closure advances the next crystal into the proper position. The intermediate position between two crystals is important in automatically verifying the proper operation of the CrystalSix sensor head. Due to the change in function of the relay output from that of Sensor Shutter to one of CrystalSwitch, RateWatcher is disabled when the unit is configured for a CrystalSix sensor.

4.16 Start Layer Without Backup Crystal Configuration

These instruments allow the option of automatically continuing a Process with the "backup" sensor. In normal operation if the sensor fails during the Process, the Process is automatically stopped and the crystal must be replaced in order to continue. With Configuration Switch 11 on, the user is allowed to continue the Process with the second, "backup", sensor. All CrystalSwitching or Complete on Time Power functions work normally. The following examples further elucidate various situations.

For example if using two single sensors and a crystal fails during the Layer, the Layer will Complete on Time Power or **STOP**, XTAL FAIL, whichever is programmed. If Configuration Switch 11 is on, the "backup" crystal is good, and **START** is pressed, either the Layer will be continued, or the next Layer is started.

If using a Dual head and a crystal fails while the Layer is in Deposit, the instrument will "crystal switch" to the secondary crystal of the Dual Head and complete the Layer. Then, with Configuration Switch 11 on, pressing **START** will begin the next Layer in the Process using the "backup" crystal, even though that Layer's primary crystal is failed. When using a CrystalSix sensor, all 6 crystals must fail prior to using the "backup" crystal.

If using two single sensors or a dual sensor, whenever the "backup" crystal is in use the XTAL # annunciator will flash. When using a CrystalSix, the annunciator for the crystal currently in use will flash as always.

Additionally, if the instrument switches to the "backup" crystal during the Process it will continue using the "backup" crystal until the Process is **RESET**, even if the primary crystal is replaced. This may be circumvented by manually crystal switching to the primary crystal once the failed crystal is replaced.

4.17 Crystal Life and Starting Frequency

Crystal life is displayed as a percentage of the monitor crystal's frequency shift relative to the 1 MHz frequency shift allowed by the instrument. This quantity is useful as an indicator of when to change the monitor crystal to safeguard against crystal failures during deposition. It is normal to change a crystal after a specific amount of crystal life (% change) is consumed.

It is not always possible to use a monitor crystal to 100% of crystal life. Useful crystal life is highly dependent on the type of material being deposited and the resulting influence of this material on the quartz monitor crystal. For well behaved materials, such as copper, at about 100% crystal life the inherent quality, Q, of the monitor crystal degrades to a point where it is difficult to maintain a sharp resonance and therefore the ability to measure the monitor crystal's frequency deteriorates.

When depositing dielectric or optical materials, the life of a gold, aluminum or silver quartz monitor crystal is much shorter; as much as 10 to 20%. This is due to thermal and intrinsic stresses at the quartz-dielectric film interface, which are usually exacerbated by the poor mechanical strength of the film. For these materials, the inherent quality of the quartz has very little to do with the monitor crystal's failure.

It is normal for a brand new quartz monitor crystal to display a crystal life anywhere from 0 to 5% due to process variations in producing the crystal. Naturally, this invites the question: "Is a brand new crystal indicating 5% life spent inferior to a crystal indicating 1% life spent?"

If a new crystal indicates 5% life spent, it means that either the quartz blank is slightly thicker than normal (more mechanical robustness), or the gold electrode is slightly thicker than normal (better thermal and electrical properties), or both. In either case, its useful life with regard to material deposition should not be adversely affected. To verify this assertion, laboratory testing was performed on crystals which covered the crystal life range in question. Results indicate that a brand new crystal which indicates 3 to 5% life spent is just as good, if not better than a crystal indicating 0 to 2% life spent.

As a consequence, it is important to consider the change in crystal life ($\Delta\%$), not just the absolute crystal life (%) indicated.

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Chapter 5

Calibration and Measurement

5.1 Importance of Density, Tooling and Z-ratio

The quartz crystal microbalance is capable of precisely measuring the mass added to the face of the oscillating quartz crystal sensor. The instrument's knowledge of the density of this added material (specified by the film's DENSITY parameter) allows 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 5.2](#).

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 factor is accounted for by the film's TOOLING parameter. The tooling factor can be experimentally established by following the guidelines in [section 5.3 on page 5-2](#).

Z-RATIO is a parameter that corrects the frequency change to thickness transfer function for the effects of acoustic impedance mismatch between the crystal and the coated material.

5.2 Determining Density

NOTE: The bulk density values retrieved from the [Table of Densities and Z-ratios, see Appendix A](#), 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 this substrate.
- 2 Set density to the bulk value of the film material or to an approximate value.
- 3 Set Z-ratio to 1.000 and tooling to 100%.
- 4 Place a new crystal in the sensor and make a short deposition (1000-5000 Å), using manual control.
- 5 After deposition, remove the test substrate and measure the film thickness with either a multiple beam interferometer or a stylus-type profilometer.

- 6 Determine the new density value with the following equation:

$$\text{Density}(\text{gm}/\text{cm}^3) = D_1 \left(\frac{T_x}{T_m} \right) \quad [1]$$

where:

D_1 = Initial density setting

T_x = Thickness reading on the display

T_m = Measured thickness

- 7 A quick check of the calculated density may be made by programming the instrument with the new density value and observing that the displayed thickness is equal to the measured thickness, provided that the instrument's thickness has not been zeroed between the test deposition and entering the calculated density.

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

5.3 Determining Tooling

- 1 Place a test substrate in the system's substrate holder.
- 2 Make a short deposition and determine actual thickness.
- 3 Calculate tooling from the relationship:

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

where

T_m = Actual thickness at substrate holder

T_x = Thickness reading on the display

TF_i = Initial tooling factor

- 4 Round off percent tooling to the nearest 0.1 %.
- 5 When entering this new value for tooling into the program, T_m will equal T_x if calculations are done properly.

NOTE: It is recommended that a minimum of three separate evaporations be made when calibrating tooling. Variations in source distribution and other system factors will contribute to slight thickness variations. An average value tooling factor should be used for final calibrations.

5.4 Laboratory Determination of Z-ratio

A list of Z-values for materials commonly used is available in the [Table of Densities and Z-ratios](#), see [Appendix A](#). For other materials, Z 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/cm³) of deposited film

μ_f = shear modulus (dynes/cm²) of deposited film

d_q = density of quartz (crystal) (2.649 gm/cm³)

μ_q = shear modulus of quartz (crystal) (3.32 x 10¹¹ dynes/cm²)

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

Laboratory results indicate that Z-values of materials in thin-film form are very close to the bulk values. However, for high stress producing materials, Z-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** Using the calibrated density and 100% tooling, make a deposition such that the percent crystal life display will read approximately 50%, or near the end of crystal life for the particular material, whichever is smaller.
- 2** Place a new substrate next to the sensor and make a second, short deposition (1000 - 5000 Å).
- 3** Determine the actual thickness on the substrate (as suggested in density calibration).
- 4** Adjust Z-ratio value in the instrument to bring the thickness reading in agreement with actual thickness.

For multiple layer deposition (for example, two layers), the Z-value 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 material 1's Z-value for both layers.
- ◆ If the thickness of layer 1 is thin compared to layer 2, use material 2's Z-value 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 values for deposition of layer 2 and subsequent layers.

5.5 Measurement Theory

5.5.1 Basics

The Quartz Crystal deposition Monitor, or QCM, utilizes the piezoelectric sensitivity of a quartz monitor crystal's resonance to added mass. The QCM uses this mass sensitivity to control the deposition rate and final thickness of a vacuum deposition. When a voltage is applied across the faces of a properly shaped piezoelectric crystal, the crystal is distorted and changes shape in proportion to the applied voltage. At certain discrete frequencies of applied voltage, a condition of very sharp electro-mechanical resonance is encountered. When mass is added to the face of a resonating quartz crystal, the frequency of these resonances are reduced. This change in frequency is very repeatable and is precisely understood for specific oscillating modes of quartz. This heuristically easy to understand phenomenon is the basis of an indispensable measurement and process control tool that can easily detect the addition of less than an atomic layer of an adhered foreign material.

In the late 1950's it was noted by Sauerbrey^{1,2} and Lostis³ that the change in frequency, $\Delta F = F_q - F_c$, of a quartz crystal with coated (or composite) and uncoated frequencies, F_c and F_q respectively, is related to the change in mass from the added material, M_f , as follows:

$$\frac{M_f}{M_q} = \frac{(\Delta F)}{F_q} \quad [5]$$

where M_q is the mass of the uncoated quartz crystal.

1.G. Z. Sauerbrey, Phys. Verhand .8, 193 (1957)

2.G. Z. Sauerbrey, Z. Phys. 155,206 (1959)

3.P. Lostis, Rev. Opt. 38,1 (1959)

Simple substitutions lead to the equation that was used with the first “frequency measurement” instruments:

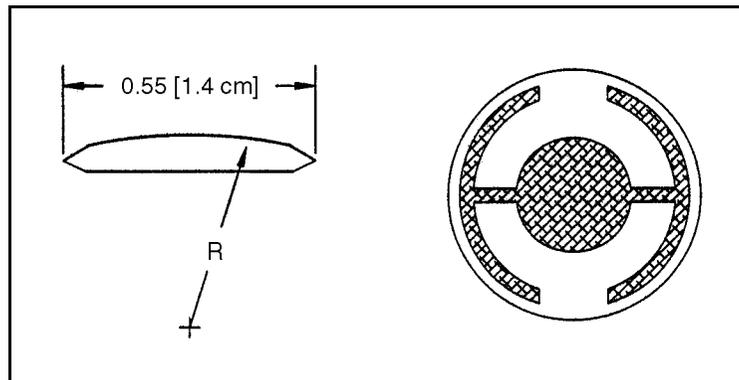
$$T_f = \frac{K(\Delta F)}{d_f} \quad [6]$$

where the film thickness, T_f , is proportional (through K) to the frequency change, ΔF , and inversely proportional to the density of the film, d_f . The constant, $K = N_{at}d_q/F_q^2$; where $d_q (= 2.649 \text{ gm/cm}^3)$ is the density of single crystal quartz and $N_{at} (=166100 \text{ Hz cm})$ is the frequency constant of AT cut quartz. A crystal with a starting frequency of 6.0 MHz will display a reduction of its frequency by 2.27 Hz when 1 angstrom of Aluminum (density of 2.77 gm/cm^3) is added to its surface. In this manner the thickness of a rigid adlayer is inferred from the precise measurement of the crystal’s frequency shift. The quantitative knowledge of this effect provides a means of determining how much material is being deposited on a substrate in a vacuum system, a measurement that was not convenient or practical prior to this understanding.

5.5.2 Monitor Crystals

No matter how sophisticated the electronics surrounding it, the essential device of the deposition monitor is the quartz crystal. The quartz resonator shown in [Figure 5-1](#) has a frequency response spectrum that is schematically shown in [Figure 5-2](#). The ordinate represents the magnitude of response, or current flow of the crystal, at the specified frequency.

Figure 5-1 Quartz Resonator

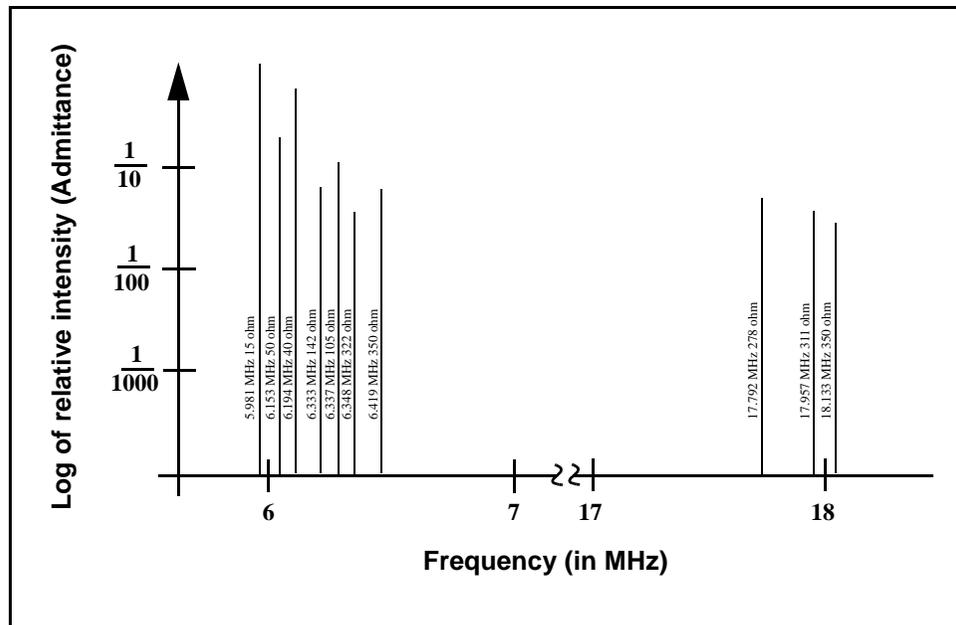


The lowest frequency response is primarily a “thickness shear” mode that is called the fundamental. The characteristic movement of the thickness shear mode is for displacement to take place parallel to the major monitor crystal faces. In other words, the faces are displacement antinodes as shown in [Figure 5-3](#). The responses located slightly higher in frequency are called anharmonics; they are a combination of the thickness shear and thickness twist modes. The response at about three times the frequency of the fundamental is called the third quasiharmonic. There are also a series of anharmonics slightly higher in frequency associated with the quasiharmonic.

The monitor crystal design depicted in Figure 5-1 is the result of several significant improvements from the square crystals with fully electroded plane parallel faces that were first used. The first improvement was to use circular crystals. This increased symmetry greatly reduced the number of allowed vibrational modes. The second set of improvements was to contour one face of the crystal and to reduce the size of the exciting electrode. These improvements have the effect of trapping the acoustic energy. Reducing the electrode diameter limits the excitation to the central area. Contouring dissipates the energy of the traveling acoustic wave before it reaches the edge of the crystal. Energy is not reflected back to the center where it can interfere with other newly launched waves, essentially making a small crystal appear to behave as though it is infinite in extent. With the crystal's vibrations restricted to the center, it is practical to clamp the outer edges of the crystal to a holder and not produce any undesirable effects. Contouring also reduces the intensity of response of the generally unwanted anharmonic modes; hence, the potential for an oscillator to sustain an unwanted oscillation is substantially reduced.

The use of an adhesion layer has improved the electrode-to-quartz bonding, reducing "rate spikes" caused by micro-tears between the electrode and the quartz as film stress rises. These micro-tears leave portions of the deposited film unattached and therefore unable to participate in the oscillation. These free portions are no longer detected and the wrong thickness consequently inferred.

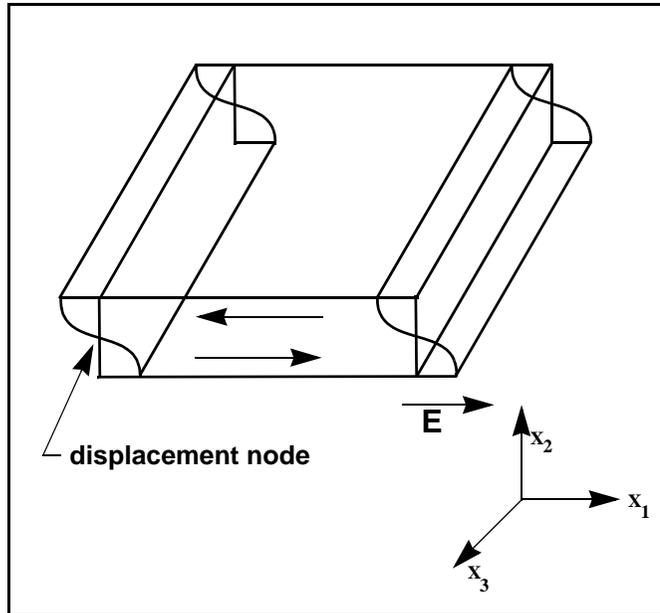
Figure 5-2 Frequency Response Spectrum



The "AT" resonator is usually chosen for deposition monitoring because at room temperature it can be made to exhibit a very small frequency change due to temperature changes. Since there is presently no way to separate the frequency change caused by added mass (which is negative) or even the frequency changes caused by temperature gradients across the crystal or film

induced stresses, it is essential to minimize these temperature-induced changes. It is only in this way that small changes in mass can be measured accurately.

Figure 5-3 Thickness Shear Displacement



5.5.3 Period Measurement Technique

Although instruments using equation [6] were very useful, it was soon noted they had a very limited range of accuracy, typically holding accuracy for ΔF less than $0.02 F_q$. In 1961 it was recognized by Behrndt⁴ that:

$$\frac{M_f}{M_q} = \frac{(T_c - T_q)}{T_q} = \frac{(\Delta F)}{F_c} \quad [7]$$

where T_c and T_q are the periods of oscillation of the crystal with film and the bare crystal respectively. The period measurement technique was the outgrowth of two factors; first, the digital implementation of time measurement, and second, the recognition of the mathematically rigorous formulation of the proportionality between the crystal's thickness, l_q , and the period of oscillation, $T_q = 1/F_q$. Electronically the period measurement technique uses a second crystal oscillator, or reference oscillator, not affected by the deposition and usually much higher in frequency than the monitor crystal. This reference oscillator is used to generate small precision time intervals which are used to determine the oscillation period of the monitor crystal. This is done by using two pulse accumulators. The first is used to accumulate a fixed number of cycles, m , of the monitor crystal. The second is turned on at the same time and

4.K. H. Behrndt, J. Vac. Sci. Technol. 8, 622 (1961)

accumulates cycles from the reference oscillator until m counts are accumulated in the first. Since the frequency of the reference is stable and known, the time to accumulate the m counts is known to an accuracy equal to $\pm 2/F_r$ where F_r is the reference oscillator's frequency. The monitor crystal's period is $(n/F_r)/m$ where n is the number of counts in the second accumulator. The precision of the measurement is determined by the speed of the reference clock and the length of the gate time (which is set by the size of m). Increasing one or both of these leads to improved measurement precision.

Having a high frequency reference oscillator is important for rapid measurements (which require short gating times), low deposition rates and low density materials. All of these require high time precision to resolve the small, mass induced frequency shifts between measurements. When the change of a monitor crystal's frequency between measurements is small, that is, on the same order of size as the measurement precision, it is not possible to establish quality rate control. The uncertainty of the measurement injects more noise into the control loop, which can be counteracted only by longer time constants. Long time constants cause the correction of rate errors to be very slow, resulting in relatively long term deviations from the desired rate. These deviations may not be important for some simple films, but can cause unacceptable errors in the production of critical films such as optical filters or very thin layered superlattices grown at low rates. In many cases the desired properties of these films can be lost if the layer to layer reproducibility exceeds one, or two, percent. Ultimately, the practical stability and frequency of the reference oscillator limits the precision of measurement for conventional instrumentation.

5.5.4 Z-Match Technique

After learning of fundamental work by Miller and Bolef⁵, which rigorously treated the resonating quartz and deposited film system as a one-dimensional continuous acoustic resonator, Lu and Lewis⁶ developed the simplifying Z-Match equation in 1972. Advances in electronics taking place at the same time, namely the micro-processor, made it practical to solve the Z-Match equation in "real-time". Most deposition process controllers sold today use this sophisticated equation that takes into account the acoustic properties of the resonating quartz and film system as shown in [equation \[8\]](#).

$$T_f = \left(\frac{N_{at} d_q}{\pi d_f F_c Z} \right) \arctan \left(Z \tan \left[\frac{\pi(F_q - F_c)}{F_q} \right] \right) \quad [8]$$

where $Z = (d_q u_q / d_f u_f)^{1/2}$ is the acoustic impedance ratio and u_q and u_f are the shear moduli of the quartz and film, respectively. Finally, there was a fundamental understanding of the frequency-to-thickness conversion that could

5. J. G. Miller and D. I. Bolef, J. Appl. Phys. **39**, 5815, 4589 (1968)

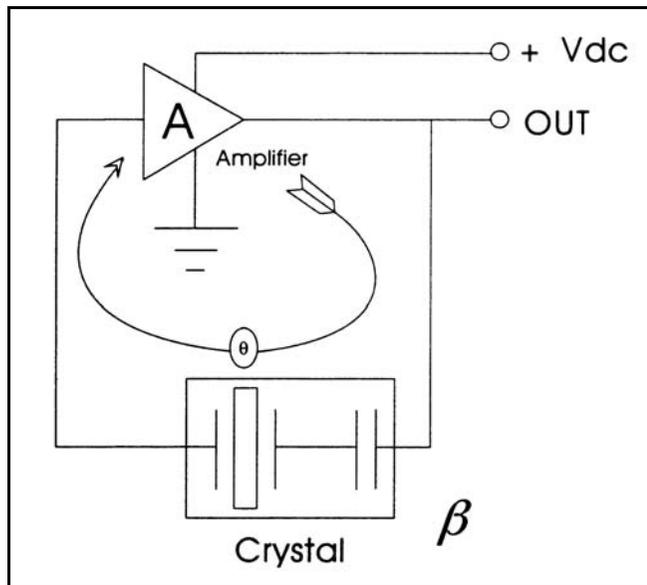
6. C. Lu and O. Lewis, J Appl. Phys. **43**, 4385 (1972)

yield theoretically correct results in a time frame that was practical for process control. To achieve this new level of accuracy requires only that the user enter an additional material parameter, Z , for the film being deposited. This equation has been tested for a number of materials, and has been found to be valid for frequency shifts equivalent to $F_f = 0.4F_q$. Keep in mind that [equation \[6\]](#) was valid to only $0.02F_q$ and [equation \[7\]](#) was valid only to $\sim 0.05F_q$.

5.5.5 Active Oscillator

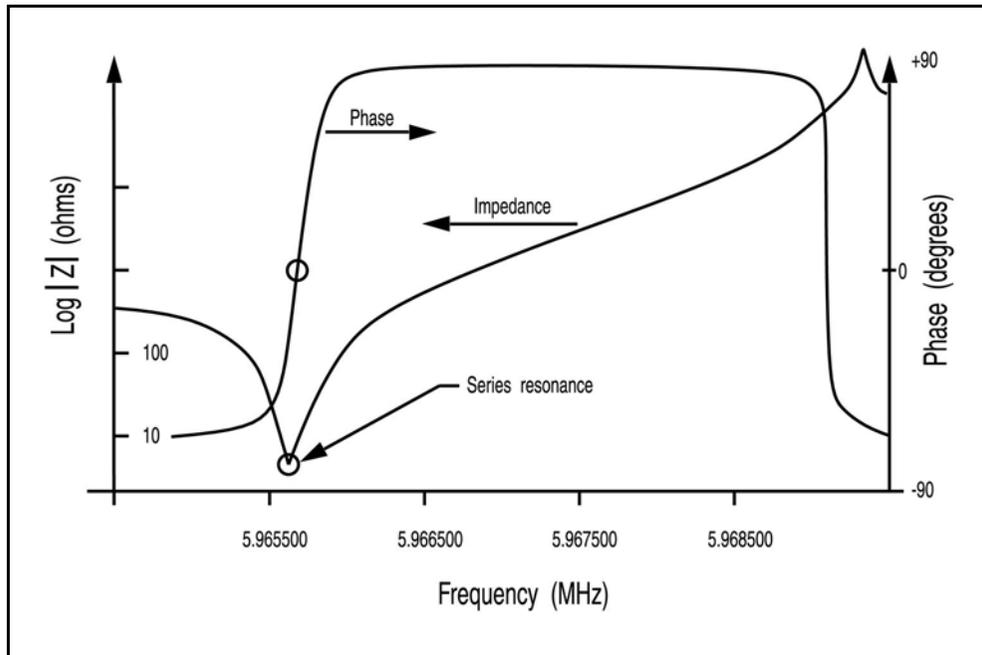
All of the instrumentation developed to date has relied on the use of an active oscillator circuit, generally the type schematically shown in [Figure 5-4](#). This circuit actively keeps the crystal in resonance, so that any type of period or frequency measurement may be made. In this type of circuit, oscillation is sustained as long as the gain provided by the amplifiers is sufficient to offset losses in the crystal and circuit and the crystal can provide the required phase shift.

Figure 5-4 Active Oscillator Circuit



The basic crystal oscillator's stability is derived from the rapid change of phase for a small change in the crystal's frequency near the series resonance point, as shown in [Figure 5-5](#).

Figure 5-5 Crystal Frequency Near Series Resonance Point



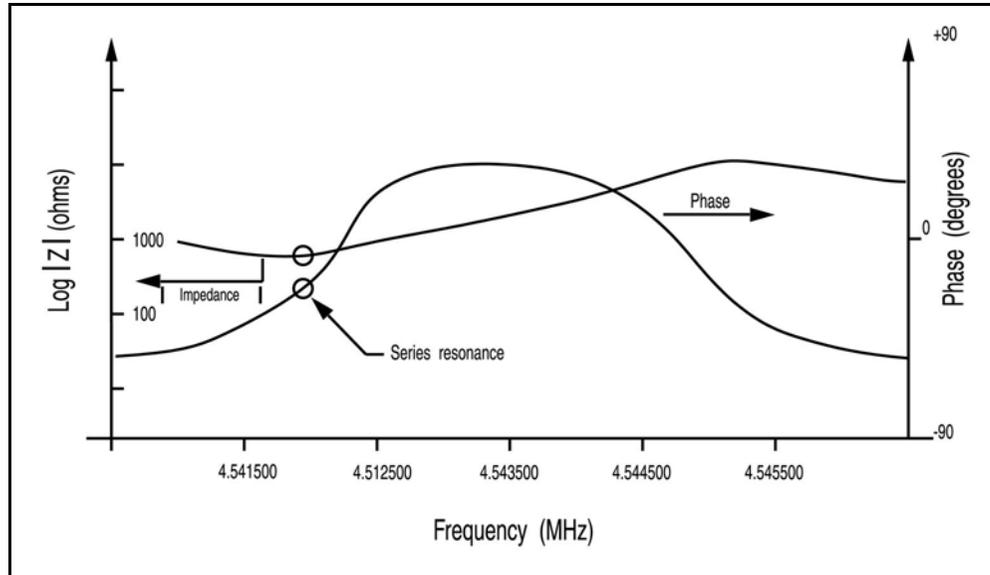
The active oscillator circuit is designed so the crystal is required to produce a phase shift, θ , of 0 degrees, which allows it to operate at the series resonance point. Long- and short-term frequency stabilities are a property of crystal oscillators because very small frequency changes are needed to sustain the phase shift required for oscillation. Frequency stability is provided by the quartz crystal even though there are long term changes in electrical component values caused by temperature or aging or short-term noise-induced phase jitter.

As mass is added to a crystal, its electrical characteristics change. [Figure 5-6 on page 5-11](#) is the same plot as [Figure 5-5](#) overlaid with the response of a heavily loaded crystal. The crystal has lost the steep slope displayed in [Figure 5-5](#). Because the phase slope is less steep, any noise in the oscillator circuit translates into a greater frequency shift than that which would be produced with a new crystal. In the extreme, the basic phase/frequency shape is not preserved and the crystal is not able to provide a full 90 degrees of phase shift.

The impedance, $|Z|$, is also noted to rise to an extremely high value. When this happens it is often more favorable for the oscillator to resonate at one of the anharmonic frequencies. This condition is sometimes short lived, with the oscillator switching between the fundamental and anharmonic modes, or it may continue to oscillate at the anharmonic. This condition is known as mode hopping and in addition to annoying rate noise can also lead to false termination of the film because of the apparent frequency change. It is important to note that the controller will frequently continue to operate under these conditions; in fact there is no way to tell this has happened except that the film's thickness is

suddenly apparently thinner by an amount equivalent to the frequency difference between the fundamental and the anharmonic that is sustaining the oscillation.

Figure 5-6 Heavily Loaded Crystal



5.5.6 ModeLock Oscillator

INFICON has created a new technology⁷ that eliminates the active oscillator and its limitations. This new system constantly tests the crystal's response to an applied frequency in order to not only determine the resonant frequency, but also to verify that the crystal is oscillating in the desired mode. This new system is essentially immune to mode hopping and the resulting inaccuracies. It is fast and accurate, determining the crystal's frequency to less than .05 Hz at a rate of 4 times per second. Because of the system's ability to identify and then measure particular crystal modes, it is now possible to offer new features that take advantage of the additional informational content of these modes.

This "intelligent" measurement system uses the phase/frequency properties of the quartz crystal to determine the resonant frequency. It operates by applying a synthesized sine wave of specific frequency to the crystal and measuring the phase difference between the applied signal's voltage and the current passing through the crystal. At series resonance, this phase difference is exactly 0 degrees; that is, the crystal behaves like a pure resistance. By separating the applied voltage and the current returned from the crystal and monitoring the output of a phase comparator it is possible to establish whether the applied frequency is higher or lower than the crystal's resonance point. At frequencies well below the fundamental, the crystal's impedance is capacitive and at

7.US Patent 5,117,192 (May 27 1992)

frequencies slightly higher than resonance it is inductive in nature. This information is useful if the resonance frequency of a crystal is unknown. A quick sweep of frequencies can be undertaken until the output of the phase comparator changes, marking the resonance event.

For AT crystals we know that the lowest frequency event encountered is the fundamental. The events slightly higher in frequency are anharmonics. This information is useful not only for initialization, but also for the rare case when the instrument loses track of the fundamental. Once the frequency spectrum of the crystal is determined the instrument's task is to follow the changing resonance frequency and to periodically provide a measurement of the frequency for subsequent conversion to thickness.

The use of the "intelligent" measurement system has a series of very apparent advantages when compared to the previous generation of active oscillators; namely immunity from mode hopping, speed of measurement, precision of measurement, and the ability to measure heavily loaded (damped) crystals.

5.6 Control Loop Theory

The instrumental advances in measurement speed, precision and reliability would not be complete without a means of translating this improved information into improved process control. For a deposition process, this means keeping the deposition rate as close as possible to the desired rate. The purpose of a control loop is to take the information flow from the measurement system and to make power corrections that are appropriate to the characteristics of the particular evaporation source. When properly operating, the control system translates small errors in the controlled parameter, or rate, into the appropriate corrections in the manipulated parameter, power. The controller's ability to quickly and accurately measure and then react appropriately to the small changes keeps the process from deviating very far from the set point.

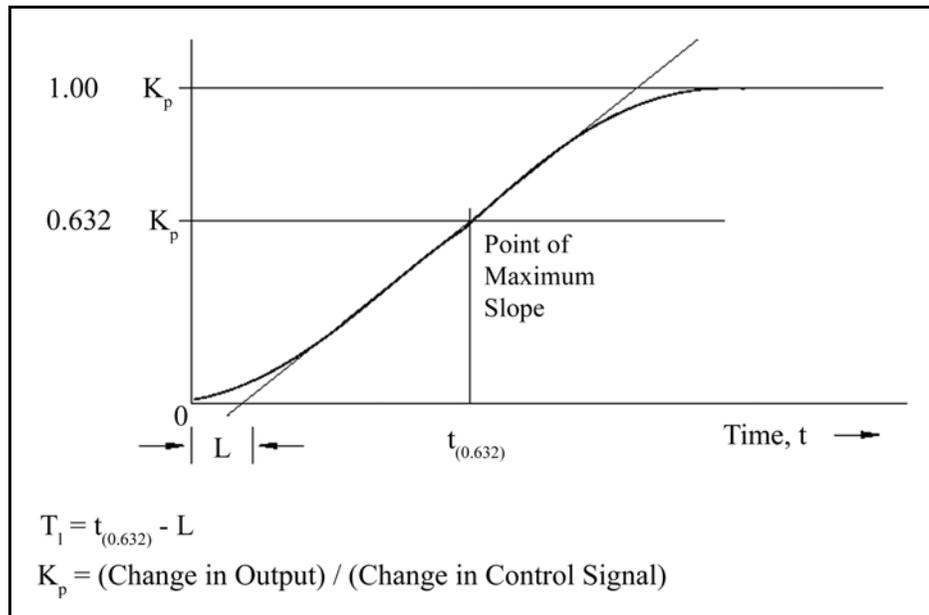
The controller model most commonly chosen for converting error into action is called PID. In the PID, P stands for proportional, I stands for integral and D stands for derivative action. Certain aspects of this model will be examined in detail a little further on.

Knowledge of the responses of the evaporation source can be found by repetitively observing the system response to a disturbance under a particular set of controller settings. After observing the response, improved controller parameters are estimated and then tried again until satisfactory control is obtained. Control, when it is finally optimized, essentially matches the parameters of the controller model to the characteristics of the evaporation source.

In general, it is not possible to characterize all processes exactly; some approximation must be applied. The most common is to assume that the dynamic characteristics of the process can be represented by a first-order lag plus a dead time. The Laplace transform for this model (conversion to the s domain) is approximated as:

$$\frac{\text{Output}}{\text{Input}} = \frac{K_p \exp(-Ls)}{T_1 s + 1} \quad [9]$$

Figure 5-7 Response of Process To An Open Loop Step Change
(At $t=0$ Control Signal is Increased)



Three parameters are determined from the process reaction curve. They are the steady state gain, K_p , the dead time, L , and the time constant, T_1 . Several methods have been proposed to extract the required parameters from the system response as graphed in Figure 5-7. These are: a one point fit at 63.2% of the transition (one time constant); a two point exponential fit; and a weighted least-square-exponential fit. From the above information a process is sufficiently characterized so that a controller algorithm may be customized.

A controller model used extensively is the PID type, shown in Laplace form in equation [10].

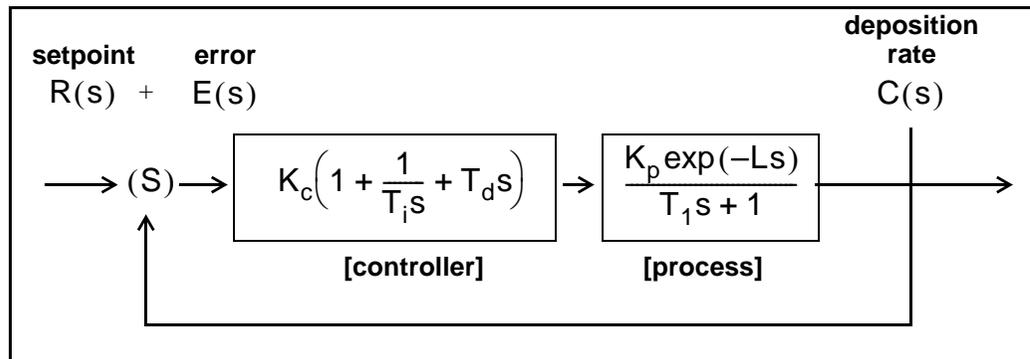
$$M(s) = K_c \left(1 + \frac{1}{T_i s} + T_d s \right) E(s) \quad [10]$$

Where

- ◆ $M(s)$ = manipulated variable or power
- ◆ K_c = controller gain (the proportional term)
- ◆ T_i = integral time
- ◆ T_d = derivative time
- ◆ $E(s)$ = process error

Figure 5-8 represents the controller algorithm and a process with first order lag plus a dead time. The process block implicitly includes the dynamics of the measuring devices and the final control elements, in our case the evaporator power supply. $R(s)$ represents the rate setpoint. The feedback mechanism is the error generated by the difference between the measured deposition rate, $C(s)$, and the rate set point, $R(s)$.

Figure 5-8 PID Controller Block Diagram



The key to using any control system is to choose the proper values of K_c , T_d and T_i . Optimum control is a somewhat subjective quantity as noted by the presence of several mathematical definitions as shown below.

The integral of the squared error (ISE) is a commonly proposed criterion of performance for control systems. It can be described as:

$$ISE = \int e^2(t) dt \quad [11]$$

where error = e = setpoint minus the measured rate. The ISE measure is relatively insensitive to small errors, but large errors contribute heavily to the value of the integral. Consequently, using ISE as a criterion of performance will result in responses with small overshoots but long settling times, since small errors occurring late in time contribute little to the integral.

The integral of the absolute value of the error (IAE) has been frequently proposed as an alternate criterion of performance:

$$IAE = \int |e(t)| dt \quad [12]$$

This criterion is more sensitive to small errors, but less sensitive to large errors, than ISE.

Graham and Lathrop⁸ introduced the integral of time multiplied by the absolute error (ITAE) as a criterion of performance:

$$ITAE = \int t|e(t)| dt \quad [13]$$

ITAE is insensitive to the initial and somewhat unavoidable errors, but it will weight heavily any errors occurring late in time. Optimum responses defined by ITAE will consequently show short total response times and larger overshoots than with either of the other criteria. It has been found that this criteria is generally most useful for deposition process control.

Since the process response characteristics depend on the position of the system (i.e. deposition rate for this discussion), the process response is best measured at the desired operating point of the system. This measured process information (i.e. process gain, K_p , time constant, T_1 , and dead time, L) is used to generate the best fitting PID control loop parameters for the specific system.

The most satisfactory performance criterion for deposition controllers is the ITAE. There will be overshoot, but the response time is quick, and the settling time is short. For all of the above integral performance criteria, controller tuning relations have been developed to minimize the associated errors. Using manually entered or experimentally determined process response coefficients, ideal PID controller coefficients can be readily calculated for the ITAE criteria as shown below.

$$K_c = (1.36/K_p)(L/T_1)^{-0.947} \quad [14]$$

$$T_i = (1.19T_1)(L/T_1)^{0.738} \quad [15]$$

$$T_d = (0.381T_1)(L/T_1)^{0.995} \quad [16]$$

For slow systems, in order to help avoid controller windup (windup is the rapid increase in control signal before the system has the chance to respond to the changed signal), the time period between manipulated variable (control voltage) changes is lengthened. This allows the system to respond to the previous controller setting change, and aggressive controller settings can be

8. Graham, D., and Lanthrop, R.C., "The Synthesis of Optimum Transient Response: Criteria and Standard Forms, Transactions IEEE, vol. 72 pt. II, November 1953.

used. A secondary advantage is that immunity to process noise is increased since the data used for control is now comprised of multiple readings instead of a single rate measurement, taking advantage of the mass integrating nature of the quartz crystal.

With process systems that respond quickly (short time constant) and with little to no measurable dead time, the PID controller often has difficulty with the deposition process noise (beam sweep, fast thermal shorts of melt to crucible, etc.). In these situations a control algorithm used successfully is an integral/reset type of controller. This type of controller will always integrate the error, driving the system towards zero error. This technique works well when there is little or no dead time. If this technique is used on a process with measurable lag or dead time, then the control loop will tend to be oscillatory due to the control loop over-compensating the control signal before the system has a chance to respond.

Chapter 6

Adjustments and Problems

The only user serviceable adjustment is the LCD contrast (see below). There are no user serviceable components inside the instrument enclosures.



There are potentially lethal voltages inside this instrument's enclosure. The source of these voltages is from the line power and also from the system and Aux I/O connections.

6.1 LCD Contrast Adjustment (XTC/2 only)

The LCD contrast is optimized for "above the display" viewing angles and adjusted at the factory. It may be better optimized on site for use in positions that place the instrument in extreme viewing angles.

To adjust for best possible contrast in the installed position use a potentiometer adjustment tool or small common screwdriver carefully inserted through the front panel (see [section 2.4 on page 2-10](#), Item 11) and turn clockwise or counter clockwise to obtain the best possible display contrast for your viewing angle.

6.2 Error Messages

The following error codes are generated and displayed by the XTC/2.

6.2.1 Powerup Errors

ERR 0 Film parameters lost on power up. This may be cleared by pressing any key. All film and layer parameters will have to be re-entered.

ERR 9 Process data lost on power up. This is cleared by pressing any key. Automatic process recovery will not be possible.

NOTE: Upon detection of power failure, all current layer and process data is normally saved for process recovery use on subsequent deposition system recovery.

6.2.2 Parameter Update Errors

- ERR 1 Parameter out of range; the value attempted to be entered was outside of the instrument's acceptable range. This is cleared with the  key. Refer to [Table 4-2 on page 4-8](#) for parameter ranges.
- LOC Parameter entry (or alteration) attempted while the PARAMETER LOCK configuration switch is set or the parameters are locked out through remote communications. LOC is also displayed when attempting to update certain parameters (sensor, source, layer) during an active process.

6.2.3 Other Errors

- Err 7 Processor out of time error. It is not expected that this error will be seen by a user.

6.3 Troubleshooting Guide

If the instrument fails to work, or appears to have diminished performance, the following Symptom/Cause chart may be helpful.

  **WARNING**

There are no user serviceable components within the instrument case.

Potentially lethal voltages are present when the line cord, system I/O or aux I/O are connected.

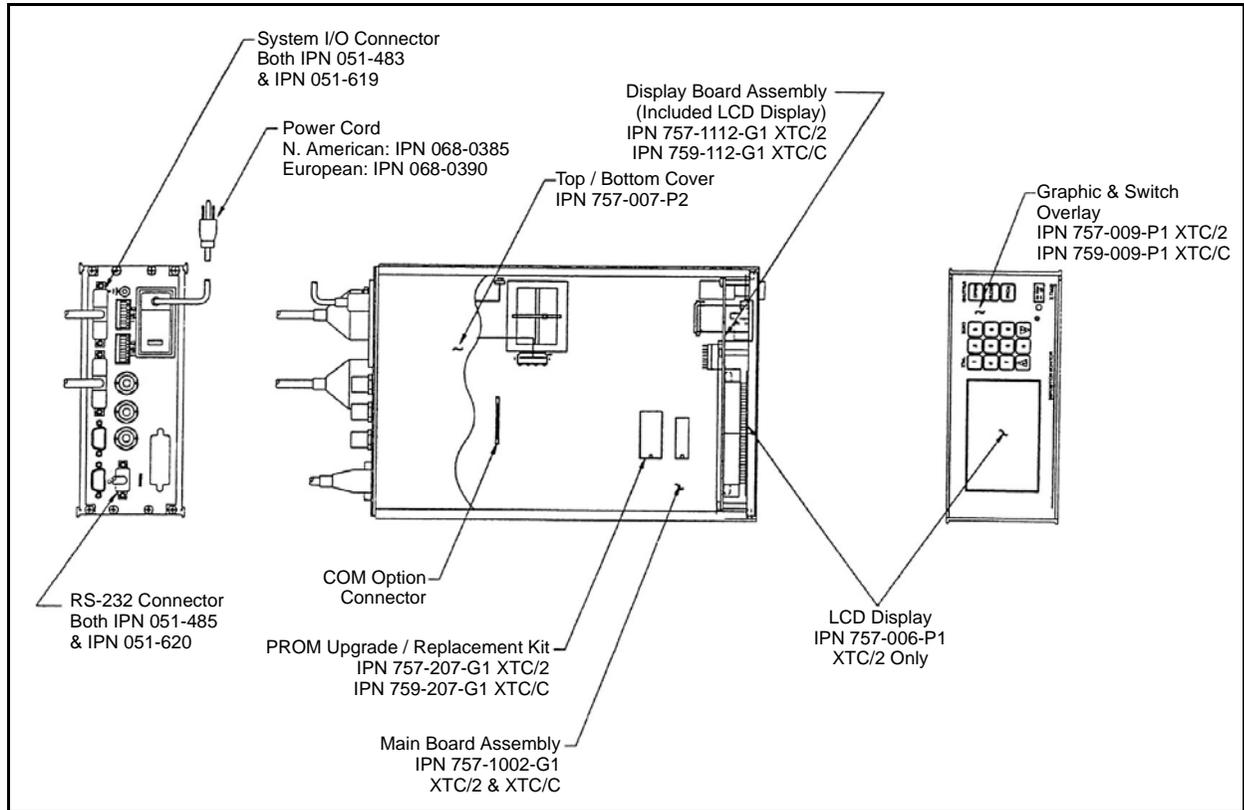
Refer all maintenance to qualified personnel.

 **CAUTION**

This instrument contains delicate circuitry which is susceptible to transients. Disconnect the line cord whenever making any interface connections. Refer all maintenance to qualified personnel.

6.3.1 Major Instrument Components, Assemblies and Mating Connectors

Figure 6-1 Components, Assemblies and Mating Connectors



6.3.2 Troubleshooting the Instrument

Table 6-1 Troubleshooting the Instrument

SYMPTOM	CAUSE	REMEDY
1. power on LED not illuminated	a. blown fuse/circuit breaker tripped	a. have qualified personnel replace fuse/reset circuit breaker
	b. electrical cord unplugged from wall or back of instrument	b. re-connect power cord
	c. incorrect line voltage	c. have qualified personnel verify line voltage, verify the instrument is configured for the correct voltage
2. unit "locks" up	a. cover or back panels not attached to the instrument.	a. ensure all covers and panels are in place and securely fastened
	b. high electrical noise environment	b. re-route cables to reduce noise pickup (1 ft. away from high power conducting lines makes a sizeable reduction in the amount of noise entering the instrument), keep all ground wires short with large surface area to minimize ground impedance
	c. poor grounds or poor grounding practice	c. verify proper earth ground, use appropriate ground strap, eliminate ground loops by establishing the correct system grounding, verify proper instrument grounding
3. instrument does not retain parameters on power down (loss of parameters on power up)	a. faulty static RAM	a. SRAM battery has a normal life expectancy of ten years, contact INFICON service department
	b. power supply problem	b. contact INFICON service department
4. some keys on front panel function while others do not	a. faulty keypad or faulty keypad ribbon cable	a. contact INFICON service department
5. all keys on the front panel fail to function	a. instrument is "locked" up	a. turn power to OFF or to STBY, then to on, see item 2 above

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Table 6-1 Troubleshooting the Instrument (continued)

SYMPTOM	CAUSE	REMEDY
6. control voltage output does not function properly	a. DAC board damaged from applying voltage to the control voltage output	a. ensure cable connection to the DAC board does not have a potential across the contacts, contact INFICON service department
	b. reversed polarity of control voltage relative to that accepted by the source power supply	b. verify source output polarity of DAC and the required input polarity of the source power supply, refer to the instruction manual to reconfigure the instrument if necessary
	c. improper control cable fabrication	c. check for correct cable wiring in the appropriate section of the manual
7. LCD display dull or blank	a. brightness/contrast adjustment required	a. refer to manual for location of adjustment potentiometer, adjust as required
	b. LCD Power supply problem	b. contact INFICON service department
8. poor rate control	a. control loop parameters improperly selected	a. refer to the instruction manual section on tuning control loop parameters
	b. electron beam sweep frequency "beating" with the instrument's measurement frequency	b. adjust the sweep frequency so it is not a multiple of the instruments measurement frequency
9. crystal fail always on	a. XIU/oscillator not connected	a. verify proper sensor/oscillator connections
	b. XIU/oscillator malfunctioning	b. if available, insert a known working XIU/oscillator in place of the suspect one; if XIU/oscillator is confirmed bad, contact INFICON service department
	c. defective cable from feedthrough to XIU/oscillator or from instrument to XIU/oscillator	c. use an ohm meter or DVM to check electrical continuity or isolation as appropriate
	d. poor electrical contact in the transducer, feedthroughs, or in-vacuum cable	d. use an ohm meter or DVM to check electrical continuity or isolation as appropriate
	e. failed crystal/no crystal	e. replace crystal/insert crystal
	f. two crystals placed in the same crystal holder	f. remove one of the crystals

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6.3.3 Troubleshooting Transducers/Sensors

NOTE: The most useful tool for diagnosing sensor head problems is the DVM (Digital Volt Meter). Disconnect the short oscillator cable from the feedthrough and measure the resistance from the center pin to ground. If the reading is less than 1-2 megaohms, the source of the leakage should be found and corrected. Likewise, with the vacuum system open check for center conductor continuity, a reading of more than 1 ohm from the feedthrough to the transducer contact indicates a problem. Cleaning contacts or replacing the in-vacuum cable may be required.

A somewhat more thorough diagnosis may be performed with the optional Crystal Sensor Emulator, 760-601-G1. See [section 6.5 on page 6-18](#) for a discussion of its use and diagnostic capabilities.

NOTE: A more detailed troubleshooting guide is shipped with the sensor. Refer to that manual for more detailed information in some cases.

Table 6-2 Troubleshooting Transducers/Sensors

SYMPTOM	CAUSE	REMEDY
1. large jumps of thickness reading during deposition	a. mode hopping due to defective crystal	a. replace crystal. use ModeLock measurement system
	b. stress causes film to peel from crystal surface	b. replace crystal or try silver coated crystal; consult factory
	c. particulate or "spatter" from molten source striking crystal	c. thermally condition the source thoroughly before deposition, use a shutter to protect the crystal during source conditioning
	d. scratches or foreign particles on the crystal holder seating surface (improper crystal seating)	d. clean and polish the crystal seating surface on the crystal holder
	e. small pieces of material fell on crystal (for crystal facing up sputtering situation)	e. check the crystal surface and blow it off with clean air
	f. small pieces of magnetic material being attracted by the sensor magnet and contacting the crystal (sputtering sensor head)	f. check the sensor cover's aperture and remove any foreign material that may be restricting full crystal coverage

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Table 6-2 Troubleshooting Transducers/Sensors (continued)

SYMPTOM	CAUSE	REMEDY
2. crystal ceases to oscillate during deposition before it reaches its "normal" life	a. crystal struck by particulate or "spatter" from molten source	a. thermally condition the source thoroughly before deposition, use a shutter to protect the crystal during source conditioning
	b. material on crystal holder partially masking crystal cover aperture	b. clean crystal holder
	c. existence of electrical short or open condition	c. using an ohm meter or DVM, check for electrical continuity in the sensor cable, connector, contact springs, connecting wire inside sensor, and feedthroughs
	d. check for thermally induced electrical short or open condition	d. see "c" above
NOTE: Crystal life is highly dependent on process conditions of rate, power radiated from source, location, material, and residual gas composition.		
3. crystal does not oscillate or oscillates intermittently (both in vacuum and in air)	a. intermittent or poor electrical contact (contacts oxidized)	a. use an ohm meter or DVM to check electrical continuity, clean contacts
	b. leaf springs have lost retentivity (ceramic retainer, center insulator)	b. rebend leaves to approximately 60°. See section 6.3.5 on page 6-12 .
	c. RF interference from sputtering power supply	c. verify earth ground, use ground strap adequate for RF ground, change location of instrument and oscillator cabling away from RF power lines, connect instrument to a different power line
	d. cable/oscillator not connected, or connected to wrong sensor input	d. verify proper connections, and inputs relative to programmed sensor parameter
4. crystal oscillates in vacuum but stops oscillation after open to air	a. crystal was near the end of its life; opening to air causes film oxidation which increases film stress	a. replace crystal
	b. excessive moisture accumulates on the crystal	b. turn off cooling water to sensor prior to venting, flow warm water through sensor while chamber is open

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Table 6-2 Troubleshooting Transducers/Sensors (continued)

SYMPTOM	CAUSE	REMEDY
<p>5. thermal instability: large changes in thickness reading during source warm-up (usually causes thickness reading to decrease) and after the termination of deposition (usually causes thickness reading to increase)</p>	<p>a. inadequate cooling water/cooling water temperature too high</p> <p>b. excessive heat input to the crystal</p> <p>c. crystal not seated properly in holder</p> <p>d. crystal heating caused by high energy electron flux (often found in RF sputtering)</p> <p>e. poor thermal transfer from water line to body (CrystalSix sensor)</p> <p>f. poor thermal transfer (Bakeable)</p>	<p>a. check cooling water flow rate, be certain that cooling water temperature is less than 30 °C; refer to appropriate sensor manual</p> <p>b. if heat is due to radiation from the evaporation source, move sensor further away from source and use sputtering crystals for better thermal stability; install radiation shield</p> <p>c. clean or polish the crystal seating surface on the crystal holder</p> <p>d. use a sputtering sensor head</p> <p>e. use a new water tube whenever the clamping assembly has been removed from the body; if a new water tube is not available, use a single layer of aluminum foil between the cooling tube and sensor body, if your process allows</p> <p>f. use Al or Au foil washer between crystal holder and sensor body</p>
<p>6. poor thickness reproducibility</p>	<p>a. variable source flux distribution</p> <p>b. sweep, dither, or position where the electron beam strikes the melt has been changed since the last deposition</p>	<p>a. move sensor to a more central location to reliably sample evaporant, ensure constant relative pool height of melt, avoid tunneling into the melt</p> <p>b. maintain consistent source distribution by maintaining consistent sweep frequencies, sweep amplitude and electron beam position settings</p>

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Table 6-2 Troubleshooting Transducers/Sensors (continued)

SYMPTOM	CAUSE	REMEDY
	<p>c. material does not adhere to crystal</p> <p>d. cyclic change in rate</p>	<p>c. make certain the crystal's surface is clean; avoid touching crystal with fingers, make use of an intermediate adhesion layer</p> <p>d. make certain source's sweep frequency is not "beating" with the measurement frequency [nearly the same frequency or a near multiple of the measurement (4 Hz)]</p>
7. large drift in thickness (greater than 200 Å for a density of 5.00 g/cc) after termination of sputtering	<p>a. crystal heating due to poor thermal contact</p> <p>b. external magnetic field interfering with the sensors magnetic field (sputtering sensor)</p> <p>c. sensor magnet cracked or demagnetized (sputtering sensor)</p>	<p>a. clean or polish the crystal seating surface on the crystal holder</p> <p>b. rotate sensor magnet to proper orientation with external magnetic field, refer to sputtering sensor manual IPN 074-157</p> <p>c. check sensor magnetic field strength, the maximum field at the center of the aperture should be 700 gauss or greater</p>
8. CrystalSix, crystal switch problem (does not advance or not centered in aperture)	<p>a. loss of pneumatic supply, or pressure is insufficient for proper operation</p> <p>b. operation has been impaired as a result of material accumulation on cover</p> <p>c. improper alignment</p> <p>d. 0.0225" diameter orifice not installed on the supply side of solenoid valve assembly</p>	<p>a. ensure air supply is regulated at 80-90 PSI</p> <p>b. clean material accumulation as needed, refer to CrystalSix manual IPN 074-155 for maintenance</p> <p>c. realign as per instructions in CrystalSix manual IPN 074-155</p> <p>d. install orifice as shown in the CrystalSix manual IPN 074-155</p>

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6.3.4 Troubleshooting Computer Communications

Table 6-3 Troubleshooting Computer Communications

SYMPTOM	CAUSE	REMEDY
1. communications cannot be established between the host computer and the instrument	<ul style="list-style-type: none"> a. improper cable connection b. BAUD rate in host computer not the same as the instrument c. incompatible protocols being used d. incorrect device address (GPIB or SECS protocol) 	<ul style="list-style-type: none"> a. verify for correct cable wiring as described in the manual b. verify BAUD rate in the host's applications program, verify BAUD rate in the instrument c. verify the instrument protocol: RS232, SECS, GPIB, DATALOG, CHECKSUM, matches host d. verify device address in host's applications program, (or in IBCONF file for National Instrs. GPIB) and verify instrument address
2. error code returned	<ul style="list-style-type: none"> a. A = illegal command b. B = illegal value c. C = illegal ID d. D = illegal command format e. E = no data to retrieve 	<ul style="list-style-type: none"> a. the command sent was not valid; verify command syntax as shown in the instrument's manual (placement of spaces within the command string are important) b. the parameter's value sent is outside the range for the given parameter, verify parameter's range c. the command sent was for a parameter which doesn't exist; verify the correct parameter number d. the command sent is not valid; verify command syntax as shown in the instrument's manual (placement of spaces within the command string are important) e. some parameters may not be in use, depending on the value of other parameters

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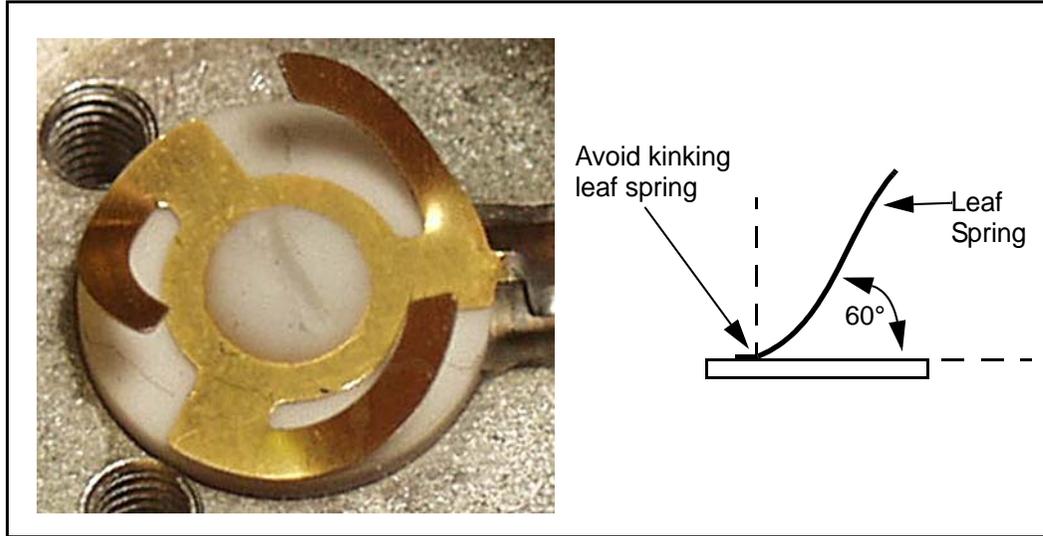
Table 6-3 Troubleshooting Computer Communications (continued)

SYMPTOM	CAUSE	REMEDY
	f. F = cannot change value now	f. the command sent is for a parameter that cannot be changed while the instrument is executing a Process; place the instrument in the READY state in order to change the value.
	g. G = bad checksum	g. checksum value does not match the value sent by the host's application program, may be caused by noise on the RS232 cable or the checksum is not calculated properly by the applications program.
	h. O = data overrun	h. I/O port unable to keep up with data transfer rate; lower BAUD rate, increase speed of host's applications program by using a compiled version of the program, streamlining program execution, a faster CPU

6.3.5 Leaf Spring Concerns

Spring conditions should be observed as part of the routine maintenance interval. Insufficient bends or deformities in the spring contacts in the sensor body are common causes of crystal problems. Lift each leaf spring up approximately 60°. See [Figure 6-2](#).

Figure 6-2 Shaping the Leaf Spring



6.4 Replacing the Crystal

The procedure for replacing the crystal is basically the same with all transducers, except the CrystalSix.

CAUTION

Always use clean nylon lab gloves and plastic tweezers for handling the crystal (to avoid contamination which may lead to poor adhesion of the film to the electrode).

Do not rotate the ceramic retainer assembly after it is seated (as this will scratch the crystal electrode and cause poor contact).

Do not use excessive force when handling the ceramic retainer assembly since breakage may occur.

NOTE: Certain materials, especially dielectrics, may not adhere strongly to the crystal surface and may cause erratic readings.

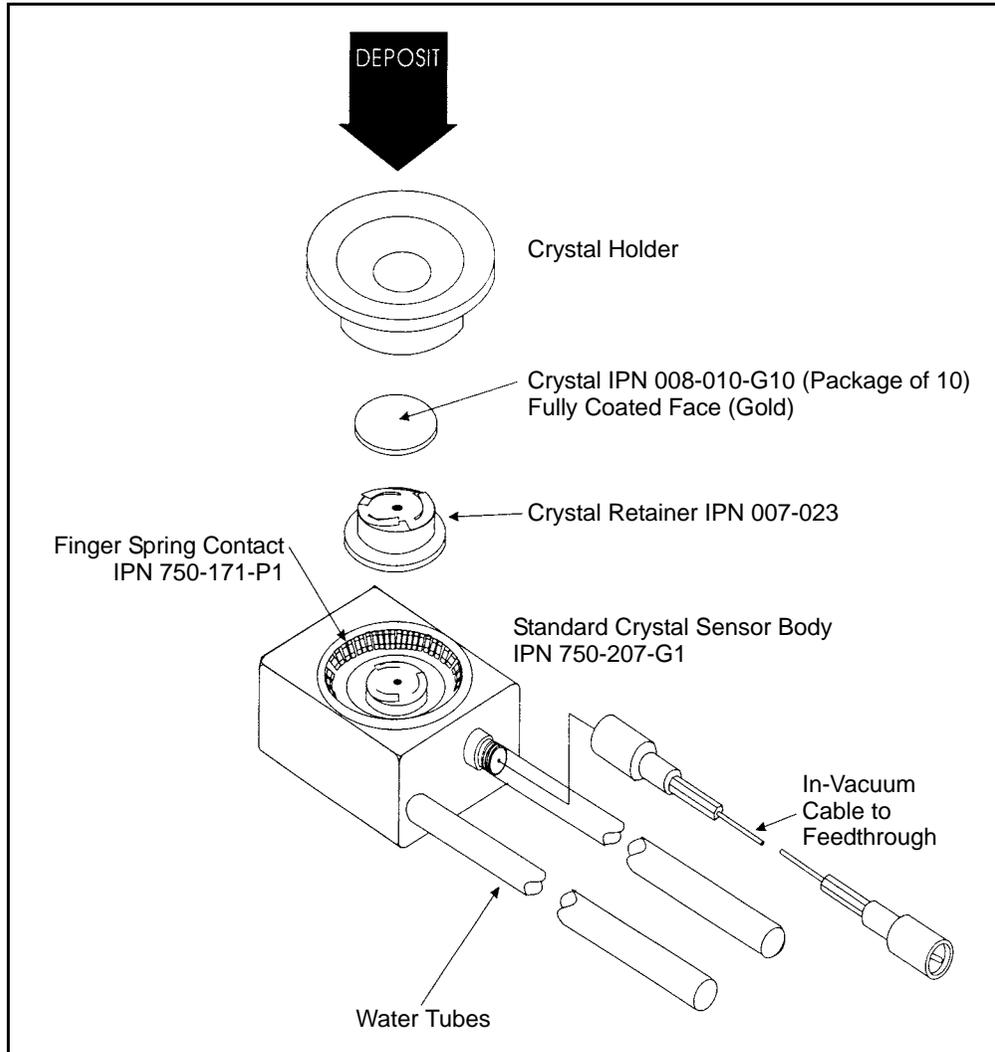
Thick deposits of some materials, such as SiO₂, Si, and Ni will normally peel off the crystal when it is exposed to air, as a result of changes in film stress caused by gas absorption. When you observe peeling, change the crystals.

6.4.1 Standard and Compact

Follow the procedure below to replace the crystal in the Standard and Compact sensor:

- 1** Gripping the crystal holder with your fingers, pull it straight out of the sensor body.
- 2** Gently pry the crystal retainer from the holder (or use crystal snatcher; see [Figure 6-6 on page 6-17](#)).
- 3** Turn the retainer over and the crystal will drop out.
- 4** Install a new crystal, with the patterned electrode face up.
- 5** Push the retainer back into the holder and replace the holder in the sensor body.

Figure 6-3 Standard Crystal Sensor (Exploded)



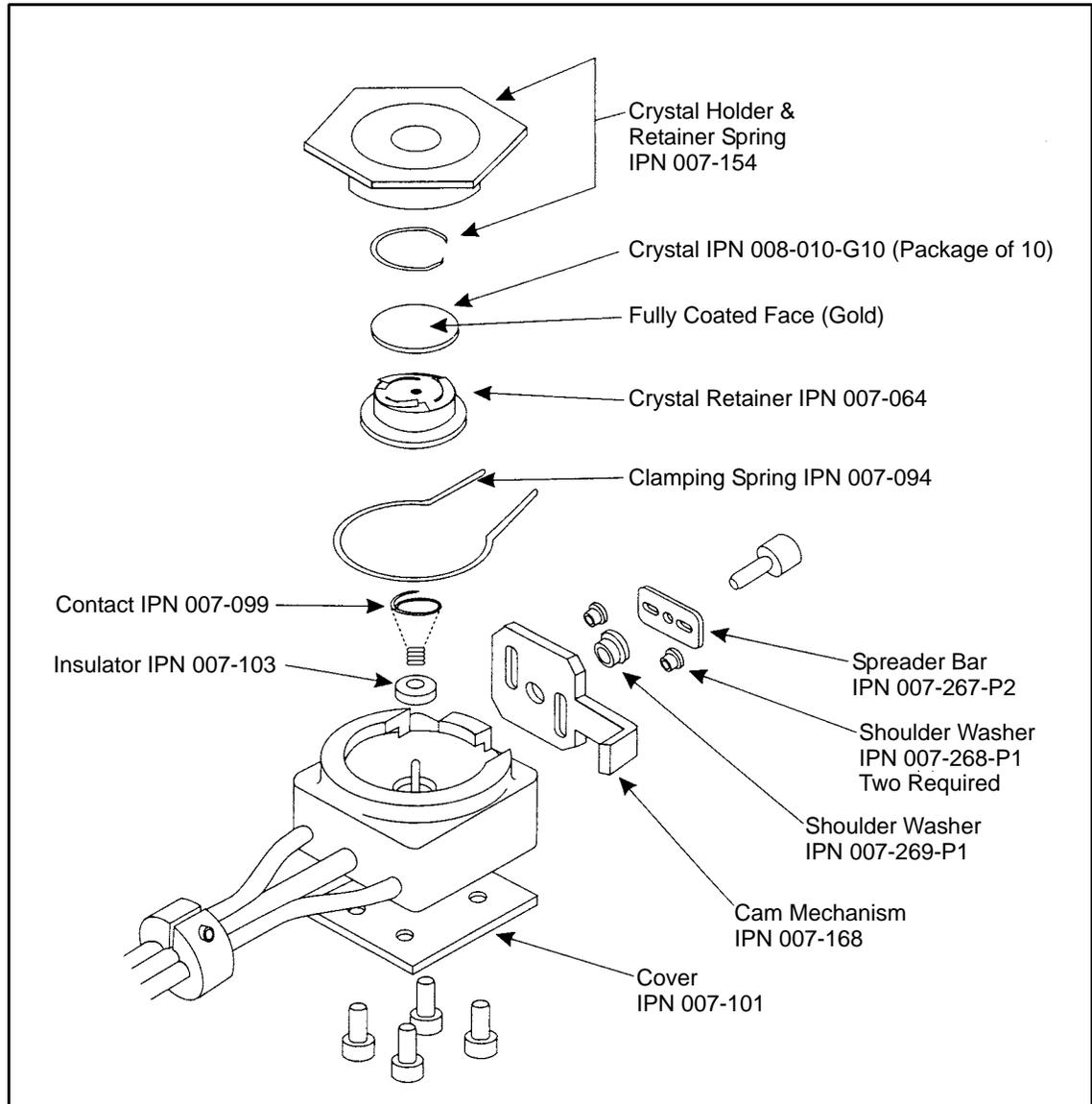
6.4.2 Shuttered and Dual Sensors

There is no difference in the crystal changing procedure between shuttered and non-shuttered Standard and Compact sensors, since the shutter pivots away from the crystal opening when the shutter is in the relaxed state.

6.4.3 Bakeable Sensor

For the Bakeable sensor, the procedure is the same as the regular crystal except that you must first unlock the cam assembly by flipping it up. Once the crystal has been replaced, place a flat edge of the holder flush with the cam mechanism and lock it in place with the cam (Figure 6-4).

Figure 6-4 Bakeable Crystal Sensor (Exploded)



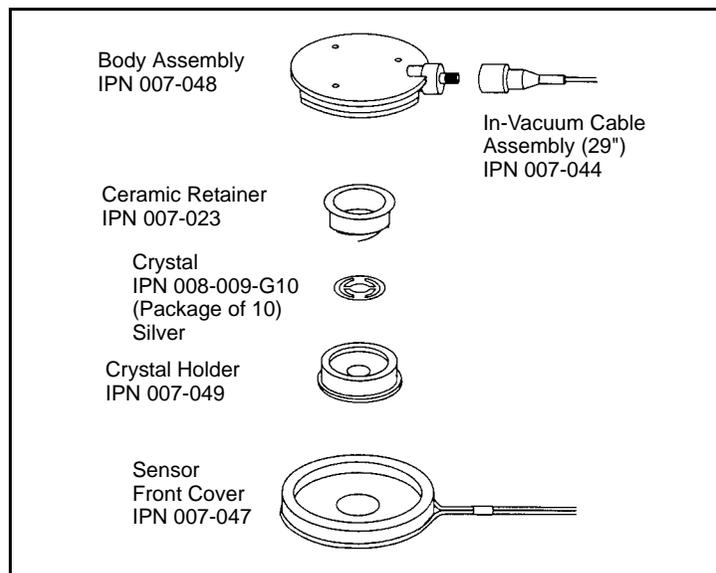
IPN 074-183X

6.4.4 Sputtering Sensor

Observe the general precautions (section 6.4 on page 6-13) for replacing crystals and follow the instructions below to replace the crystal in a sputtering sensor.

- 1 Grip the body assembly with your fingers and pull it straight out to separate it from the water-cooled front part. (You may have to disconnect the sensor cable in order to separate the parts.) See Figure 6-5.
- 2 Pull the crystal holder straight out from the front of the sensor.
- 3 Remove the ceramic retainer from the crystal holder by pulling it straight out with the crystal snatcher (see section 6.4.5 on page 6-17).
- 4 Turn the crystal holder over so that the crystal drops out.
- 5 Install a new crystal into the crystal holder with the patterned electrode facing the back and contacting the leaf springs on the ceramic retainer. (Use only special crystals for sputtering, IPN 008-009-G10.)
- 6 Put the ceramic retainer back into the crystal holder and put the holder into the front cover of the sensor.
- 7 Align the position of the back part so that the connector matches with the notch on the front of the sensor. Snap the two parts together. Reconnect the sensor cable if it has been disconnected.

Figure 6-5 Sputtering Crystal Sensor (Exploded)



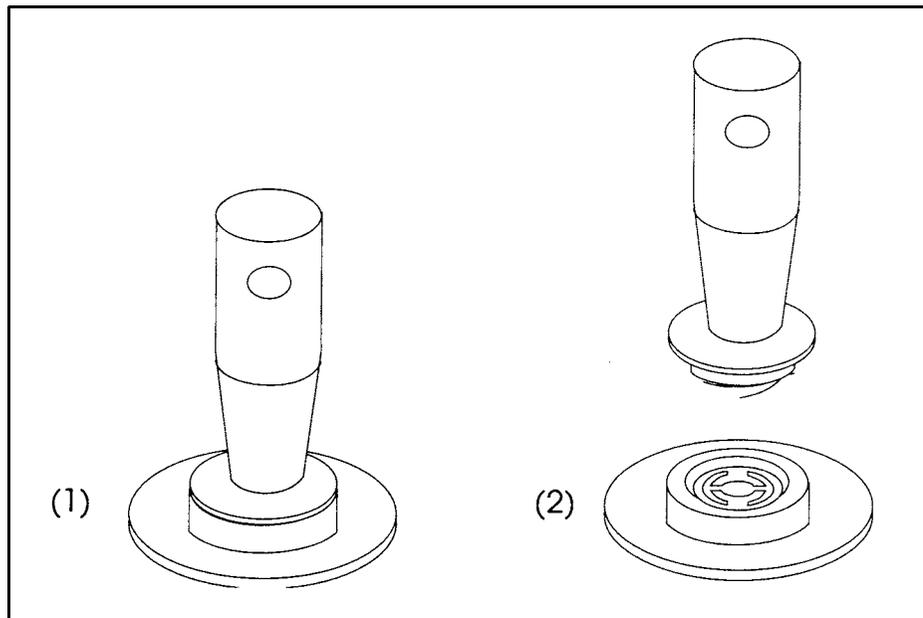
IPN 074-183X

6.4.5 Crystal Snatcher

To use the crystal snatcher supplied with the sensor follow the instructions below:

- 1 Insert crystal snatcher into ceramic retainer (1) and apply a small amount of pressure. This locks the retainer to the snatcher and allows the retainer to be pulled straight out (2).
- 2 Re-insert the retainer into the holder after the crystal has been changed.
- 3 Release the crystal snatcher with a slight side-to-side motion.

Figure 6-6 Use of Crystal Snatcher



6.4.6 CrystalSix

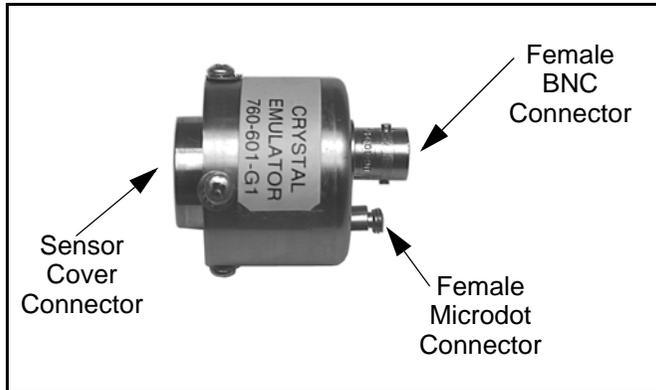
See the manual (IPN 074-155) for specific instructions for this device.

6.5 Crystal Sensor Emulator IPN 760-601-G1 or 760-601-G2

NOTE: 760-601-G1 (obsolete) is not compatible for use with an IC/5 and IC/4. 760-601-G2 is fully compatible with all thin film deposition controllers.

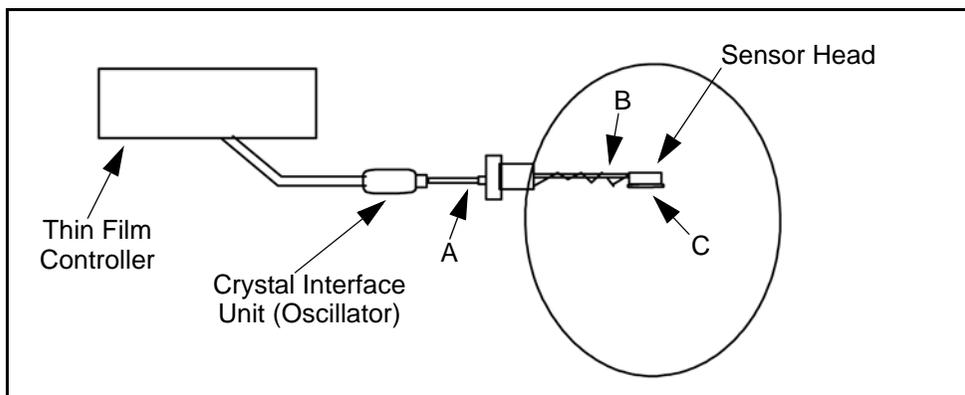
The Crystal Sensor Emulator option is used in conjunction with the Thin Film Deposition Controller to rapidly diagnose problems with the Deposition Controller's measurement system. See [Figure 6-7](#).

Figure 6-7 Crystal Sensor Emulator



The Crystal Sensor Emulator may be attached at various points in the measurement system, from the oscillator to the sensor head. It provides a known "good" monitor crystal with known "good" electrical connections. Using the emulator and the controller in a systematic manner provides a fast means of isolating measurement system, cable, or sensor problems. See [Figure 6-8](#).

Figure 6-8 Crystal Sensor Emulator's Attachment Points



CAUTION

This product is designed as a diagnostic tool, and is not intended for use in vacuum. Do not leave the Crystal Sensor Emulator installed in the vacuum system during processing.

6.5.1 Diagnostic Procedures

The following diagnostic procedures employ the Crystal Sensor Emulator to analyze a constant Crystal Fail message. The symptom is a Crystal Fail message that is displayed by the Deposition Controller even after the monitor crystal has been replaced with a new "good" monitor crystal.

NOTE: The "Unable To Auto Z" message will be displayed if the Crystal Sensor Emulator is attached to a deposition controller and you are attempting to use the Auto Z feature. This is to be expected and is normal.

6.5.1.1 Measurement System Diagnostic Procedure

- 1 Refer to [Figure 6-8 on page 6-18](#). Remove the six-inch BNC cable from the Feed-Through at point A.
 - 2 Connect the Crystal Sensor Emulator to the 6 inch BNC cable at Point A.
 - ♦ If the XTAL Fail message disappears after approximately five seconds, the measurement system is working properly. Re-install the six-inch BNC cable to the Feed-Through. Go to [section 6.5.1.2](#).
 - ♦ If the XTAL Fail message remains, continue at step 3.
 - 3 Disconnect the six-inch BNC cable from the Oscillator and from the Emulator.
 - 4 Visually inspect the six-inch BNC cable to verify that the center pins are seated properly.
 - 5 Use an Ohm meter to verify the electrical connections on the six-inch BNC cable.
 - ♦ There must be continuity (<0.2 ohms) between the center pins.
 - ♦ There must be isolation (>10 megohms) between the center pins and the connector shield.
 - ♦ There must be continuity between the connector shields.
- Replace the six-inch BNC cable if it is found to be defective and repeat Step 2 of this procedure.
- 6 If the six-inch BNC cable is not defective, re-connect the six-inch cable to the oscillator and to the Crystal Sensor Emulator. If the XTAL Fail message remains, contact INFICON's Service Department.

6.5.1.2 Feed-Through Or In-Vacuum Cable Diagnostic Procedure

- 1 Refer to [Figure 6-8 on page 6-18](#). Remove the In-Vacuum cable from the Sensor Head at point B.
- 2 Connect the Crystal Sensor Emulator to the In-Vacuum cable.
 - ♦ If the XTAL Fail message disappears after approximately five seconds, the Feed-Through and In-Vacuum Cable are working properly. Re-install the In-Vacuum cable to the Sensor Head. Go to [section 6.5.1.3 on page 6-21](#).
 - ♦ If the XTAL Fail message remains, continue at step 3.
- 3 Disconnect the In-Vacuum cable from the Feed-Through and the Emulator. Disconnect the six-inch BNC cable from the Feed-Through.
- 4 Using an Ohm Meter, verify electrical continuity from the BNC center pin on the Feed-Through to the Microdot center pin on the Feed-Through. A typical value would be less than 0.2 ohms.
- 5 Verify electrical isolation of the center pin on the Feed-Through from the electrical ground (Feed-Through body). A typical value would be in excess of 10 megohms.

If the Feed-Through is found to be defective, replace the Feed-Through, re-attach the BNC and In-Vacuum cables, and repeat this procedure starting at Step 2, otherwise continue at step 6.

- 6 Verify electrical continuity from center pin to center pin on the In-Vacuum cable.
- 7 Verify that the center pin of the In-Vacuum cable is electrically isolated from the In-Vacuum cable shield.

If the In-Vacuum cable is found to be defective, replace the In-Vacuum cable. Re-attach the BNC and In-Vacuum cables, and repeat this procedure starting at Step 2, otherwise continue at step 8.

- 8 Connect the In-Vacuum Cable to the Feed-Through.
- 9 Verify electrical continuity from the center pin on the BNC connector of the Feed-Through to the center pin on the un-terminated end of the In-Vacuum cable.
- 10 Verify electrical isolation from the center pin to electrical ground (Feed-Through body).

If the Feed-Through/In-Vacuum cable system is found to be defective, look for defective electrical contacts at the Feed-Through to In-Vacuum cable connection. Repair or replace the Feed-Through as necessary. Re-attach the BNC and In-Vacuum cables and repeat this procedure starting at step 2. Otherwise, continue at step 11.

- 11** Connect the six-inch BNC cable to the Feed-Through and disconnect it from the Crystal Interface Unit (or Oscillator)
- 12** Verify electrical continuity from the center pin of the Microdot connector on the Feed-Through to the un-terminated end of the six-inch BNC cable.
- 13** Verify electrical isolation from the center pin to electrical ground (Feed-Through body).

If the Feed-Through/six-inch BNC cable system is found to be defective, look for defective contacts at the Feed-Through to BNC cable connection. Repair or replace the Feed-Through as necessary, re-attach the BNC cable to the XIU and In-Vacuum cable to the Crystal head and repeat this procedure starting at step 2.

6.5.1.3 Sensor Head Or Monitor Crystal Diagnostic Procedure

- 1** Remove the Crystal Cover from the Sensor Head.
- 2** Refer to [Figure 6-7 on page 6-18](#). Connect the Crystal Sensor Emulator to the Sensor Head at Point C.
 - ♦ If the XTAL Fail message disappears after approximately 5 sec. then the Sensor Head is operating properly. Re-insert the Crystal Cover into the Sensor Head and go to [section 6.5.1.3 on page 6-21](#).
 - ♦ If the XTAL Fail message remains, continue at step 3.
- 3** Disconnect the In-Vacuum cable from the Sensor Head and the Feed-Through. Remove the Crystal Sensor Emulator from the Sensor Head.
- 4** Using an Ohm meter, verify the electrical connections on the Sensor Head.
 - ♦ Verify there is electrical continuity from the center pin contact on the Microdot connector on the Sensor Head to the finger spring contact in the Sensor Head.
 - ♦ There must be electrical isolation between the center pin of the Microdot connector and the Sensor Head body.

If the Sensor Head is found to be defective, contact INFICON's Service Department to have the Sensor Head repaired.

5 Connect the In-Vacuum Cable to the Sensor Head.

- ◆ Verify there is continuity (<0.2 ohm) from the finger spring contact in the Sensor Head to the center pin on the un-terminated end of the In-Vacuum cable.
- ◆ Verify there is isolation (>10 megohm) between the finger spring contact and the In-Vacuum cable shield.

If the Sensor Head or the In-Vacuum cable system is found to be defective, look for defective contacts at the In-Vacuum cable to Sensor Head connection, repair or replace the Sensor Head as necessary. Re-attach the In-Vacuum cable to the Feed-Through and repeat this procedure starting at step 2.

6 Ensure that the leaf springs in the Sensor Head and those in the ceramic retainer are bent to an angle of approximately 60 degrees from flat.**6.5.1.4 System Diagnostics Pass But
Crystal Fail Message Remains**

If the system is operating properly, yet the Crystal Fail message is still displayed, perform the following tasks.

- 1** On the ceramic retainer verify that the center rivet is secure. Repair or replace the ceramic retainer as necessary.
- 2** Inspect the inside of the Crystal Cover for build-up of material. Clean or replace the Crystal Cover as necessary.

After verifying the Sensor Head contacts, the Sensor Head/In-Vacuum cable connection, and the ceramic retainer contacts, re-assemble the system. If the Crystal Fail message remains, replace the monitor crystal with a good monitor crystal. Verify that the monitor crystal works properly by inserting it into a known good measurement system. If you continue to experience problems, contact an INFICON Applications Engineer for Technical Support.

6.5.2 % XTAL Life

The Crystal Sensor Emulator contains a quartz crystal having a fundamental frequency at 5.5 MHz. With the Crystal Sensor Emulator connected, the % XTAL Life display should read approximately 45% for XTC/2 and XTC/B deposition controllers which allow a 1.0 MHz frequency shift.

6.5.3 Sensor Cover Connection

The Crystal Sensor Emulator can be used to verify the measurement system for INFICON's Thin Film Deposition Controllers and Monitors, including the IC6000, XTC, IC/4 Plus, IC/4 MPT, XTC/2, XTC/C, XTM/2, and the IC/5.

NOTE: 760-601-G1 (obsolete) is not compatible for use with an IC/5 and IC/4. 760-601-G2 is fully compatible with all thin film deposition controllers.

However, the Crystal Sensor Emulator's Sensor Cover Connector is compatible with some sensor heads, and is incompatible with others. This is discussed in the following sections.

6.5.3.1 Compatible Sensor Heads

The Sensor Cover Connection will fit the sensor heads shown in [Table 6-4](#).

Table 6-4 Compatible Sensor Heads

Sensor Head	Part Number
Standard Sensor Head	750-211-G1
Standard Sensor Head with Shutter	750-211-G2
Compact Sensor Head	750-213-G1
Compact Sensor Head with Shutter	750-213-G2
Dual Sensor Head	750-212-G2

6.5.3.2 Incompatible Sensor Heads

The Sensor Heads for which the Crystal Sensor Emulator's Sensor Cover Connector will not fit are shown in [Table 6-5](#).

Table 6-5 Incompatible Sensor Heads

Sensor Head	Part Number
UHV Bakeable Sensor Head (12 inch)	007-219
UHV Bakeable Sensor Head (20 inch)	007-220
UHV Bakeable Sensor Head (30 inch)	007-221
UHV Bakeable Sensor Head w/ Shutter (12 inch)	750-012-G1
UHV Bakeable Sensor Head w/ Shutter (20 inch)	750-012-G2
UHV Bakeable Sensor Head w/ Shutter (30 inch)	750-012-G3
Sputtering Sensor Head	007-031
CrystalSix Sensor Head with position select	750-446-G1
CrystalSix Sensor Head	750-260-G1

NOTE: The Crystal Sensor Emulator's Sensor Cover will not fit the crystal holder opening of the older style INFICON transducers that have the "soldered" finger springs.

6.5.4 Specifications

Dimensions

1.58 in. diameter x 1.79 in.
(4.01 cm diameter x 4.55 cm)

Temperature Range

0 to 50 °C

Frequency

760-601-G1: 5.5 MHz \pm 30ppm at room temperature

760-601-G2: 5.5 MHz \pm 1ppm at room temperature

Materials

304 Stainless Steel, Nylon, Teflon, brass. Some internal components contain zinc, tin, and lead.

Appendix A

Table of Densities and Z-ratios

The following table represents the content of the instrument's material library. The list is alphabetical by chemical formula.

 **CAUTION**

Some of these materials are toxic. Please consult the material safety data sheet and safety instructions before use.

Remote Communications Responses and Commands use the code value to represent a specific material. 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.

Table A-1 Material Table

Formula	Density	Z-ratio	Material Name
Ag	10.5000	0.529	Silver
AgBr	6.470	1.180	Silver Bromide
AgCl	5.560	1.320	Silver Chloride
Al	2.700	1.080	Aluminum
Al ₂ O ₃	3.970	0.336	Aluminum Oxide
Al ₄ C 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 ₂ Se ₃	4.750	*1.000	Arsenic Selenide
Au	19.300	0.381	Gold
B	2.370	0.389	Boron
B ₂ O ₃	1.820	*1.000	Boron Oxide
B ₄ C	2.370	*1.000	Boron Carbide
Ba	3.500	2.100	Barium
BaF ₂	4.886	0.793	Barium Fluoride
BaN ₂ O ₆	3.244	1.261	Barium Nitrate
BaO	5.720	*1.000	Barium Oxide

Table A-1 Material Table (continued)

Formula	Density	Z-ratio	Material Name
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 ₂ O ₃	8.900	*1.000	Bismuth Oxide
Bi ₂ S ₃	7.390	*1.000	Bismuth Trisulphide
Bi ₂ Se ₃	6.820	*1.000	Bismuth Selenide
Bi ₂ Te ₃	7.700	*1.000	Bismuth Telluride
BiF ₃	5.320	*1.000	Bismuth Fluoride
BN	1.860	*1.000	Boron Nitride
C	2.250	3.260	Carbon (Graphite)
C	3.520	0.220	Carbon (Diamond)
C ₈ H 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-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 (111) Fluoride
CeO ₂	7.130	*1.000	Cerium (IV) Dioxide
Co	8.900	0.343	Cobalt
CoO	6.440	0.412	Cobalt Oxide

Table A-1 Material Table (continued)

Formula	Density	Z-ratio	Material Name
Cr	7.200	0.305	Chromium
Cr ₂ O ₃	5.210	*1.000	Chromium (111) Oxide
Cr ₃ C ₂	6.680	*1.000	Chromium Carbide
CrB	6.170	*1.000	Chromium Boride
Cs	1.870	*1.000	Cesium
Cs ₂ SO 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 ₂ O	6.000	*1.000	Copper Oxide
Cu ₂ S	5.600	0.690	Copper (I) Sulfide (Alpha)
Cu ₂ S	5.800	0.670	Copper (I) Sulfide (Beta)
CuS	4.600	0.820	Copper (II) Sulfide
Dy	8.550	0.600	Dysprosium
Dy ₂ O ₃	7.810	*1.000	Dysprosium Oxide
Er	9.050	0.740	Erbium
Er ₂ O 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 ₂ O 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 ₂ O 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
Gd	7.890	0.670	Gadolinium
Gd ₂ O ₃	7.410	*1.000	Gadolinium Oxide
Ge	5.350	0.516	Germanium

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Table A-1 Material Table (continued)

Formula	Density	Z-ratio	Material Name
Ge ₃ N 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	Holmium
Ho ₂ O ₃	8.410	*1.000	Holmium Oxide
In	7.300	0.841	Indium
In ₂ O ₃	7.180	*1.000	Indium Sesquioxide,
In ₂ Se ₃	5.700	*1.000	Indium Selenide
In ₂ Te 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 ₂ O 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
LiBr	3.470	1.230	Lithium Bromide
LiF	2.638	0.778	Lithium Fluoride
LiNbO ₃	4.700	0.463	Lithium Niobate

Table A-1 Material Table (continued)

Formula	Density	Z-ratio	Material Name
Lu	9.840	*1.000	Lutetium
Mg	1.740	1.610	Magnesium
MgAl ₂ O ₄	3.600	*1.000	Magnesium Aluminate
MgAl ₂ O ₆	8.000	*1.000	Spinel
MgF ₂	3.180	0.637	Magnesium Fluoride
MgO	3.580	0.411	Magnesium Oxide
MgO ₃ Al ₂ O ₃	8.000	*1.000	Spinel
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 ₂ C	9.180	*1.000	Molybdenum Carbide
MoB ₂	7.120	*1.000	Molybdenum Boride
MoO ₃	4.700	*1.000	Molybdenum Trioxide
MoS ₂	4.800	*1.000	Molybdenum Disulfide
Na	0.970	4.800	Sodium
Na ₃ AlF ₆	2.900	*1.000	Cryolite
Na ₅ Al ₃ F 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	0.949	Sodium Fluoride
NaNO ₃	2.270	1.194	Sodium Nitrate
Nb	8.578	0.492	Niobium (Columbium)
Nb ₂ O ₃	7.500	*1.000	Niobium Trioxide
Nb ₂ O 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	Neodymium
Nd ₂ O ₃	7.240	*1.000	Neodymium Oxide
NdF ₃	6.506	*1.000	Neodymium Fluoride
Ni	8.910	0.331	Nickel

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Table A-1 Material Table (continued)

Formula	Density	Z-ratio	Material Name
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 ₃ N 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
PbTiO ₃	7.50	1.16	Lead Titanate
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 ₂ O 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	Rubidiurn 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 ₂ O ₃	5.200	*1.000	Antimony Trioxide
Sb ₂ S ₃	4.640	*1.000	Antimony Trisulfide
Sc	3.000	0.910	Scandiurn

Table A-1 Material Table (continued)

Formula	Density	Z-ratio	Material Name
Sc ₂ O ₃	3.860	*1.000	Scandium Oxide
Se	4.810	0.864	Selenium
Si	2.320	0.712	Silicon
Si ₃ N 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 ₂ O 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
SrTiO ₃	5.123	0.31	Strontium Titanate
SrO	4.990	0.517	Strontium Oxide
Ta	16.600	0.262	Tantalum
Ta ₂ O 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 ₂ O ₃	4.600	*1.000	Titanium Sesquioxide

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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 ₃ O ₈	8.300	*1.000	Tri Uranium Octoxide
U ₄ O ₉	10.969	0.348	Uranium Oxide
UO ₂	10.970	0.286	Uranium Dioxide
V	5.960	0.530	Vanadium
V ₂ O 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 ₂ O ₃	5.010	*1.000	Yttrium Oxide
Yb	6.980	1.130	Ytterbium
Yb ₂ O ₃	9.170	*1.000	Ytterbium Oxide
Zn	7.040	0.514	Zinc
Zn ₃ Sb ₂	6.300	*1.000	Zinc Antimonide
ZnF ₂	4.950	*1.000	Zinc Fluoride
ZnO	5.610	0.556	Zinc Oxide

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
	10.000	*1.000	USER

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