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

XTM/2

Deposition Monitor

IPN 074-186

INFICON

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

XTM/2
Deposition Monitor

IPN 074-186S

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INFICON

DECLARATION OF CONFORMITY

This is to certify that this equipment, designed and manufactured by:

INFICON Inc.
2 Technology Place
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:	XTM/2 Deposition Monitor, 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.

ANY QUESTIONS RELATIVE TO THIS DECLARATION OR TO THE SAFETY OF INFICON'S PRODUCTS SHOULD BE DIRECTED, IN WRITING, TO THE QUALITY ASSURANCE DEPARTMENT AT THE ABOVE ADDRESS.

11/14/01

Registration Card

INFICON

Thank you for selecting INFICON® instrumentation.
Please fill out and return this postage paid card as soon as possible.

Model ______________________ Serial # ______________________

Name ____

Title ____

Company ______________________ Bldg./MS ______________

Address ______________________ Phone # ______________

City ______________ State ________ Zip ______________

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Your help is very important in our continuing efforts to improve our manuals.
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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East Syracuse, New York 13057-9714

Warranty

WARRANTY AND LIABILITY - LIMITATION: Seller warrants the products manufactured by it, or by an affiliated company and sold by it, and described on the reverse hereof, to be, for the period of warranty coverage specified below, free from defects of materials or workmanship under normal proper use and service. The period of warranty coverage is specified for the respective products in the respective Seller instruction manuals for those products but shall in no event exceed one (1) year from the date of shipment thereof by Seller. Seller's liability under this warranty is limited to such of the above products or parts thereof as are returned, transportation prepaid, to Seller's plant, not later than thirty (30) days after the expiration of the period of warranty coverage in respect thereof and are found by Seller's examination to have failed to function properly because of defective workmanship or materials and not because of improper installation or misuse and is limited to, at Seller's election, either (a) repairing and returning the product or part thereof, or (b) furnishing a replacement product or part thereof, transportation prepaid by Seller in either case. In the event Buyer discovers or learns that a product does not conform to warranty, Buyer shall immediately notify Seller in writing of such non-conformity, specifying in reasonable detail the nature of such non-conformity. If Seller is not provided with such written notification, Seller shall not be liable for any further damages which could have been avoided if Seller had been provided with immediate written notification.

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No warranty is made by Seller of any Seller product which has been installed, used or operated contrary to Seller's written instruction manual or which has been subjected to misuse, negligence or accident or has been repaired or altered by anyone other than Seller or which has been used in a manner or for a purpose for which the Seller product was not designed nor against any defects due to plans or instructions supplied to Seller by or for Buyer.

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

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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 or the loss of data.

WARNING

Failure to heed these messages could result in personal injury.

WARNING

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

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1.1.2 General Safety Information

WARNING

There are no user serviceable components within the instrument case.

Potentially lethal voltages are present when the line cord or system 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.

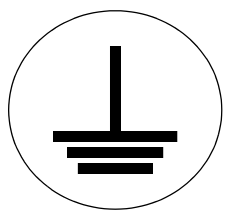
1.1.3 Earth Ground

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.

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1.1.4 Main Power Connection

WARNING

This instrument has a 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 is no operator serviceable items within this instrument.

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

In order to comply with accepted safety standards, this instrument must be 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.

1.2 Introduction to the Instrument

The XTM/2 is an economical quartz crystal transducer type deposition/etch process monitor that incorporates 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 Liquid Crystal Display of the XTM/2 is easily read and keeps the operator continuously informed with pertinent deposition data including rate, thickness and elapsed time. Special messages such as Crystal Fail, achievement of setpoints, measurement units or etch mode are clearly presented to reduce operator uncertainty and eliminate the possibility of costly mistakes. Basic instrument operation is easily verified with a built-in test mode and preprogrammed parameters.The set up and storage of nine different process variable sets is provided.The RATE and THICKNESS displays as well as the limit parameters may be read and programmed in the traditional kÅ units or directly in mass (mg, µgm,ngm).

All units come with RS232 (and support Data Rates to 9,600 Baud).The SECSII protocol is supported.The optional computer interface is IEEE-488. Four relays are used to manipulate various external devices such as source and sensor shutters, heaters or valves.There are five input lines to provide the ability to sense and react to discrete external signals.These instruments are fully compatible with the complete family of INFICON transducers, excluding 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 XTM/2

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 +/- 0.1 Hz (per 250 msec sample)

Thickness & Rate Resolution* . . . . 0.123Å (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%

Measurements/second . . . . 4 max., user selectable multiple measurement averaging to 16 seconds in four ranges.

1.3.1.3 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)

1.3.1.4 Input/Output

Inputs . . . . 5 TTL inputs

Outputs. . . . . 4 SPST 2.5 amp relays rated
@ 30 V(dc) / 30 V(ac) / 42 V(peak) max.

Scan/Change Rate . . . . 4 Hz

1.3.1.5 Display

Type . . . . 2x multiplexed custom LCD

Thickness Resolution* . . . . 1 Å

Rate Resolution* . . . . .1 Å for 1 to 99.9 Å/sec
1 Å for 100 to 999 Å/sec

* Other units appropriately scaled. Enhanced resolution is achieved when multiple measurement averaging is employed.

Update Rate . . . . 1 Hz

1.3.1.6 Process Variable Storage

Quantity . . . . 9 sets

Variables per set. 6

1.3.1.7 Hardware Interface

Sensors . . . . 1, 15 pin D-Sub type

I/O
Standard (inputs/outputs) 5/4
Optional . . . . None

Communications
Standard . . . . RS232C, 9 Pin D-Sub type
Optional IEEE-488

Chart Recorder . . . . BNC

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1.3.1.8 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)

1.3.1.9 Mechanical

Size . . . . .3.5" H x 8" W x 12" D (89 mm H x 203 mm W x 305 D 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
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 3.1 mm high)	12" (305 mm) 20" (508 mm) 30" (762 mm)	304 SS	750-012-G1 750-012-G2 750-012-G3
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.

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1.3.3 XIU (Crystal Interface Unit) Specifications

The XTM/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 2-7.

WARNING

There are no user serviceable components within the instrument case.

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

Refer all maintenance to qualified personnel.

1.5 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.

1.5.1 Application Support

Austin, TX . . . . . . ph. 512-448-0488. . . . . .fax 512-448-0398
San Jose, CA. . . . ph. 408-361-1200 ext. 125 . . .fax 408-362-1556
Syracuse, NY. . . . ph. 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.

1.5.2 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.

1.5.3 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

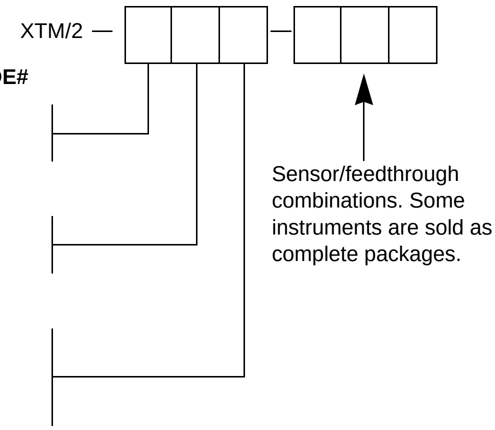
1. If you haven't removed the instrument from its shipping containers, do so now.
2. Carefully examine the unit for damage that may have occurred during shipping. This is especially important if you notice signs of obvious rough handling on the outside of the cartons. *Report any damage to the carrier 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 2-3 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 XTM/2 System Configuration

BASIC CONFIGURATION	IPN #	CODE#
115V 50/60 Hz	758-500-G1	1
230V 50/60 Hz	758-500-G2	2
Optional Computer Communications Module		
None	757-211-G1	1
IEEE-488 Parallel	760-122-G1	2
Rack Mounting		
None		0
1 Unit Mounting Kit	757-212-G1	1
2 Unit Mounting Kit	757-212-G2	2



2.1.2.2 Ship Kit - XTM/2

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.

Item	Qty G2 (230V)	Qty G1 (115V)	IPN Number	Part # and/or Description
01	-	X	758-203-G1	Ship Kit - XTM/2 115V
02	X	-	758-203-G2	Ship Kit - XTM/2 230V
03	-	1	068-0385	North America 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	1	1	051-483	Conn 25 Pin Female D/Sub Sod. Cup
08	1	1	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 074-186.

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.

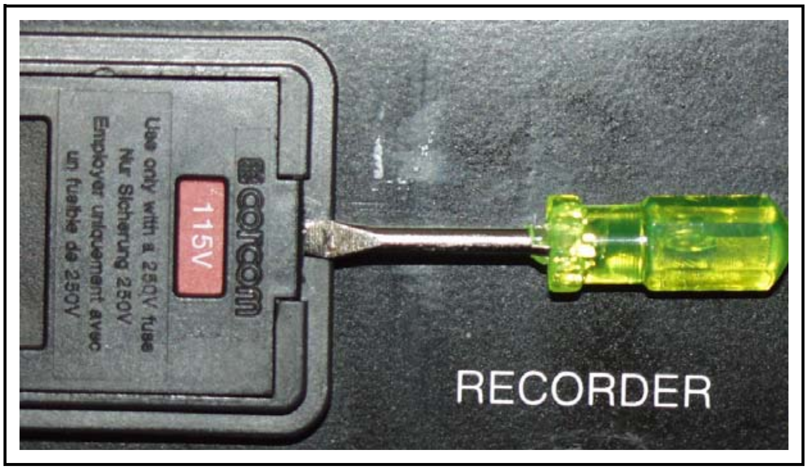
Potentially lethal voltages are present when the line cord, system I/O or aux I/O are connected.

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

To inspect the fuse, proceed as follows.

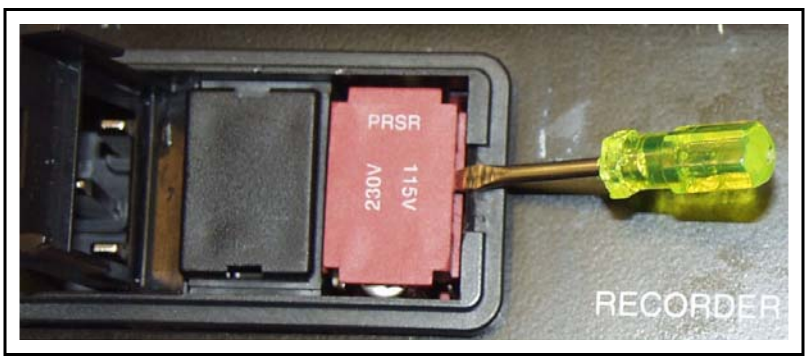
1 Pry open the power entry module cover. See Figure 2-1.

Figure 2-1 Opening the Power Entry Module Cover



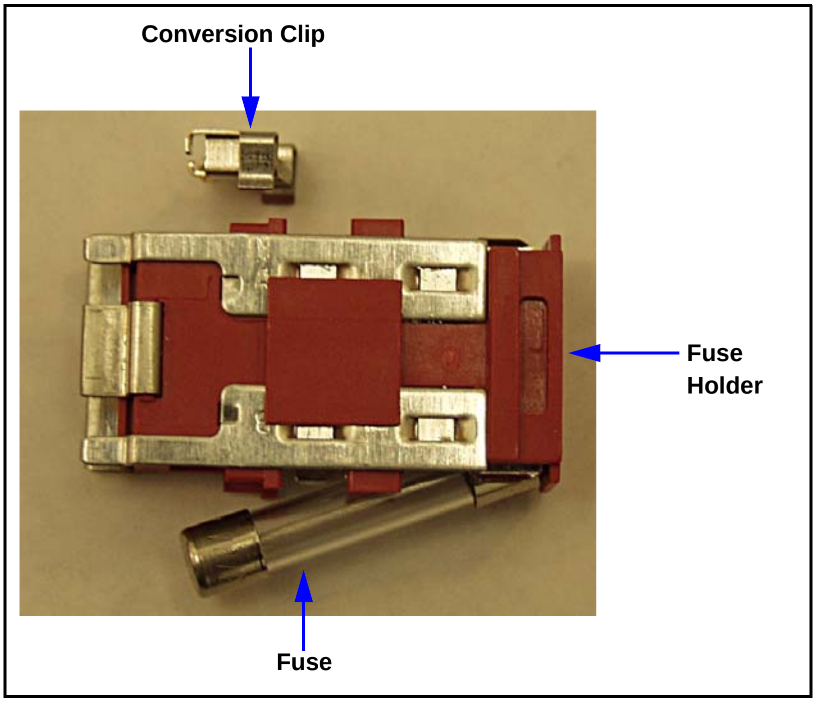
2 Pry the fuse holder out of the housing. See Figure 2-2.

Figure 2-2 Removing the Fuse Holder



3 Inspect the fuse. See Figure 2-3.

Figure 2-3 Clip, Fuse Holder, Fuse



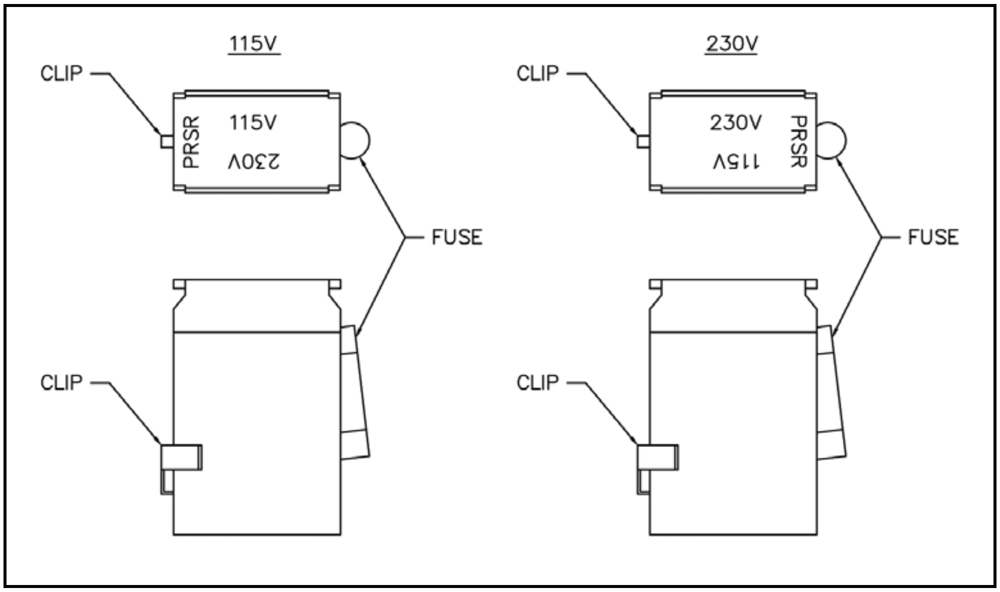
The Corcom fuse holder has chambers for two 1/4" x 1 1/4" (5 mm x 20 mm) fuses. Since only one fuse is used, that fuse must be on the live (hot) side and a conversion clip is inserted to bridge the unused fuse chamber in the neutral side.

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 Diagram, Figure 4-2 on page 4-2.

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 equipment.

1. Check for correct line voltage, section 2.2 on page 2-3.
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 2.5 on page 2-13. Be especially attentive of the special features available on the configuration switches, section 2.5.2 on page 2-15
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 2-9.
6. Program the desired film parameter values per section 4.1 on page 4-1 and section 4.2 on page 4-3.
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.

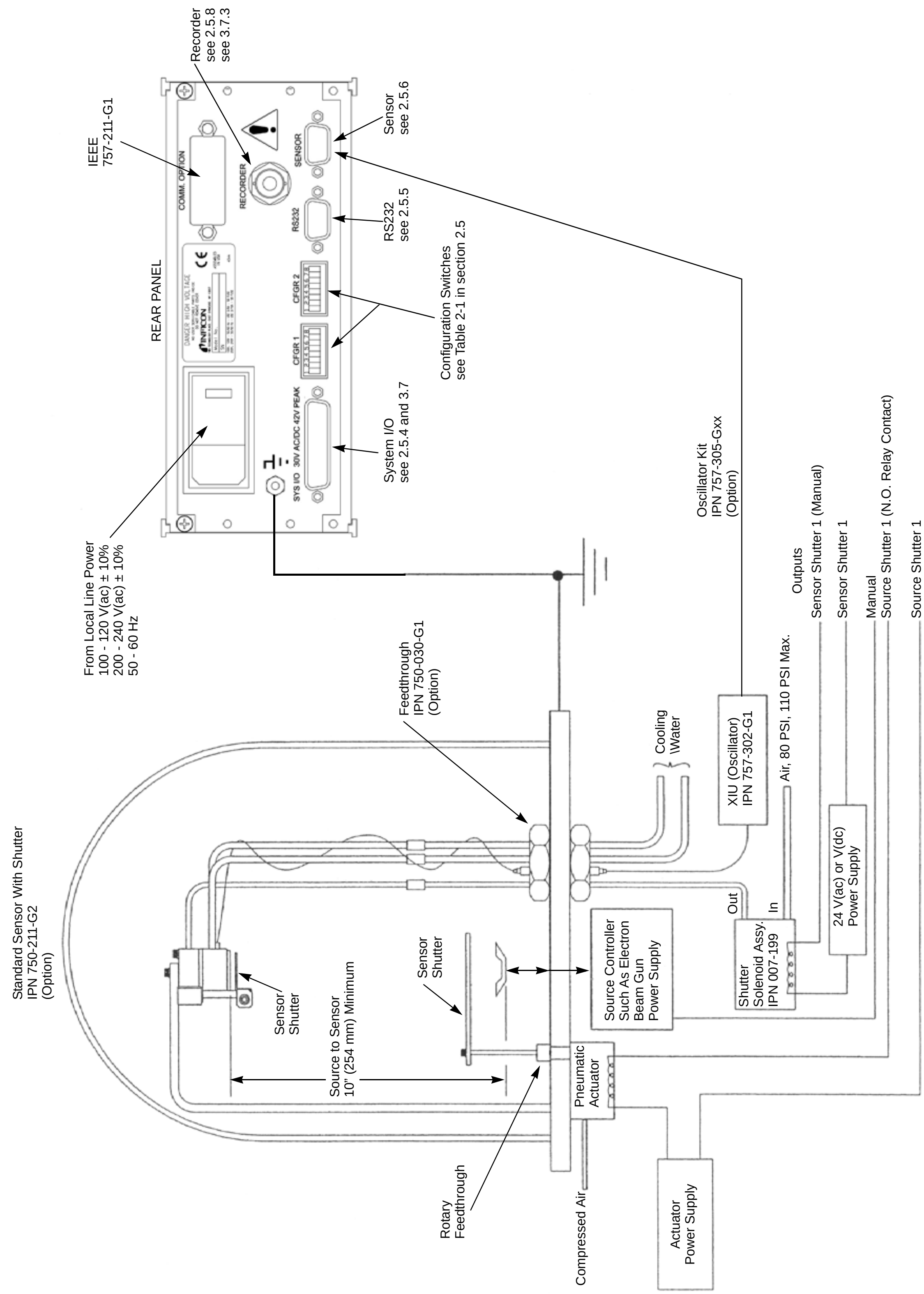


Figure 2-5 Installation Guide Schematic

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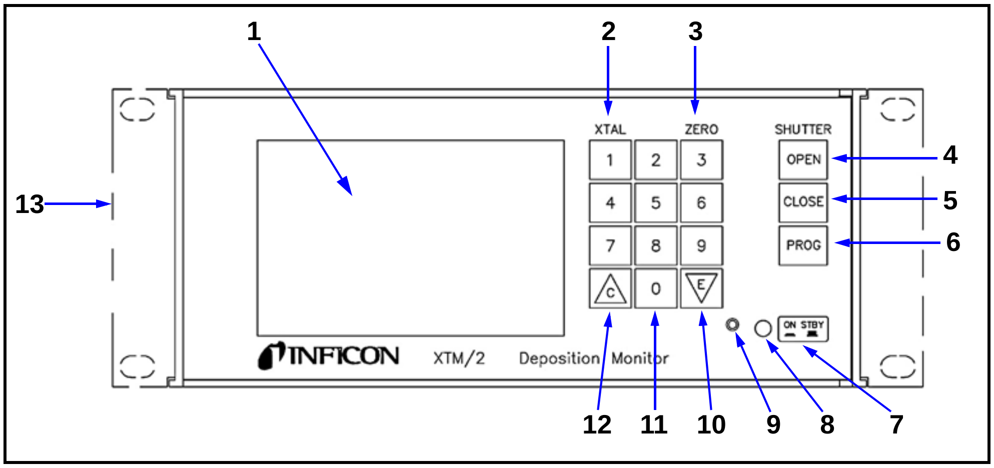
2.4 XTM/2 Front Panel Description

Figure 2-6 Front Panel XTM/2



2.4.1 XTM/2 Front Control Panel Description

1— LCD DISPLAY
Display of current information and parameters. See section 2.4.2 on page 2-11 for details.

2— XTAL
Pressing this key momentarily switches the display to percent of crystal life used, software version, and crystal frequency, when the display is in operate mode. If the Frequency display mode is chosen (see section 2.5.2 on page 2-15), pressing this key provides temporary added display resolution to 0.01 Hz.

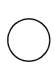
3— ZERO
Zeros the displayed thickness and elapsed time when the display is in the operate mode.

4— OPEN
Closes the "shutter" relay's contacts and "zeros" the accumulated thickness (mass) and elapsed time.

5— CLOSE
Opens the "shutter" relay's contacts and initiates a data log when the instrument is properly configured. See section 3.8.4 on page 3-21.

6— PROG
Program. Toggles the display between the program and operate modes.

7— ON/STBY
Switches secondary power of the instrument between **ON** and **STANDBY**.

8— 
Green LED illuminates to indicate that the unit is connected to an active line power source and the **ON/STBY** switch is set to ON.

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9— 

Access to adjust LCD contrast, see section 6.1 on page 6-1.

10— 

Enter and cursor down. Two function switch used when the display is in the program mode.

11— DIGITS (0-9)

Decimal based key pad for data entry.

a. If the zero key is held down during power-up, the communications interface may be configured (see section 3.8.1 on page 3-16)

b. 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 2-11.

12— 

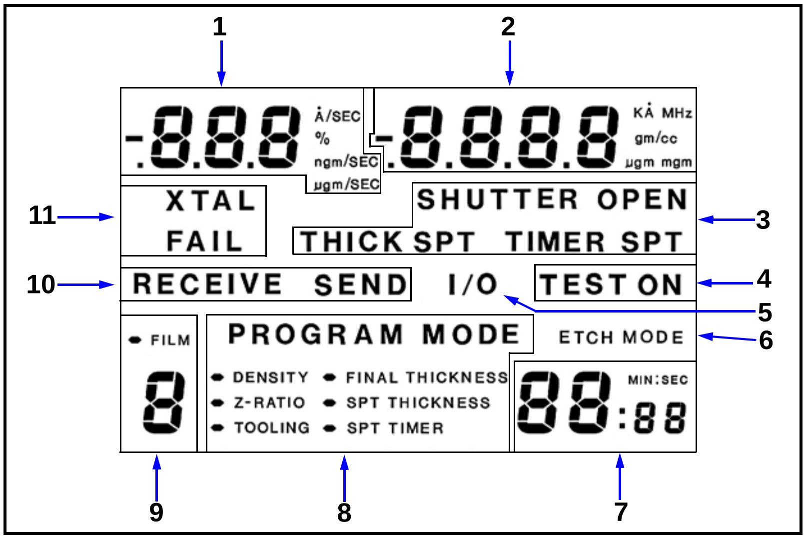
Clear and cursor up. Two function switch that is used when the display is in the program mode.

13—

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 XTM/2 Display Description

Figure 2-7 XTM/2 Display



1— RATE DISPLAY GROUP
Indicates the deposition or etching rate in the displayed units, or used to display the tooling value when the display is in the Program mode. Also used to briefly display %of Xtal life (based on 5 MHz = 100%) when **xtal** is pressed and the display is in the operate mode. Displays the most significant frequency information in the frequency monitor mode.

2— THICKNESS/MASS GROUP
Indicates the deposited or etched thickness (mass) in the displayed units. Also used for briefly displaying the monitor crystal's frequency when the **xtal** key is pressed in the operate mode. This group is also used for displaying **density** (gm/cc) when in the program mode. Displays the least significant frequency information in the frequency monitor mode.

3— STATUS MESSAGE GROUP
When illuminated, indicates that the shutter is open and if the specified limit was exceeded.

4— TEST MODE INDICATOR
When illuminated, indicates that the test mode configuration switch has been set.

5— COMPUTER I/O OVERRIDE
Illuminates when control of one or more relays have been reconfigured through computer communications.

6— ETCH MODE ON INDICATOR
When illuminated, indicates that the etch mode configuration switch has been set. The thickness display now indicates the amount removed.

7— TIMER GROUP
Elapsed time indicator and unit annunciator. Displays the software version number when **XTAL** key is pressed while display is in operate mode.

8— PROGRAM MODE GROUP
Indicator annunciator and cursor array for the definition of parameters.

9— FILM GROUP
Indicates which stored film's parameters are being used in the operate mode, or being changed/programmed in the program mode. The active film may be changed when the cursor is blinking.

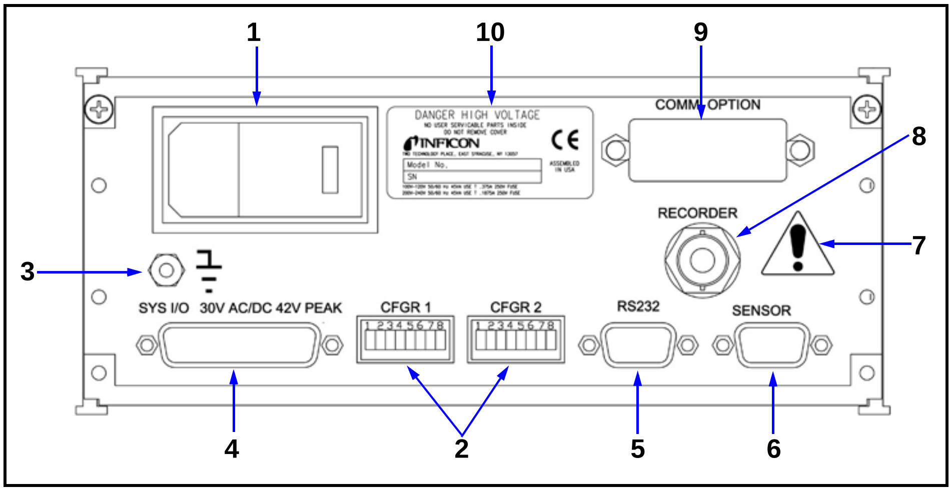
10— COMMUNICATIONS ACTIVITY GROUP
Illuminates whenever computer communications are being sent or received, respectively.

11— CRYSTAL FAIL INDICATOR
Illuminates whenever the ModeLock system cannot drive a crystal, or a crystal has been shifted by loading beyond 5 MHz. May also illuminate when there is a cable or sensor failure.

2.5 XTM/2 Rear Panel Description

The rear panel provides the interface for all external connections to the instrument. Each ballooned item is covered in the following respectively numbered sub-paragraphs.

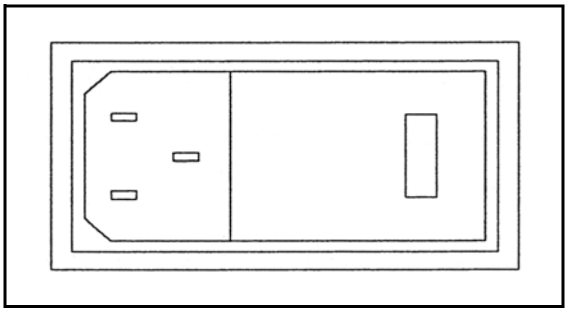
Figure 2-8 XTM/2 Rear Panel



2.5.1 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 2-3.

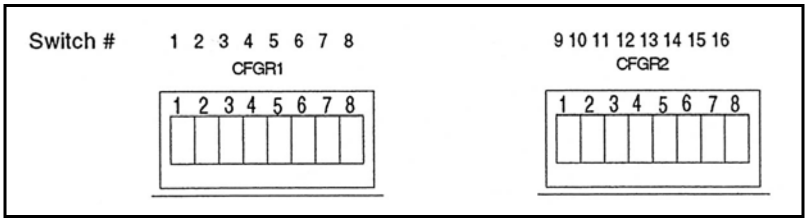
Figure 2-9 Power Module



2.5.2 Configuration Switches 1 & 2

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

Figure 2-10 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 to effect the change.

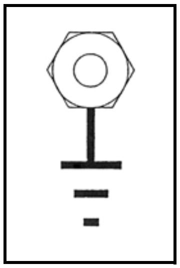
Table 2-1 Configuration Switch Settings

Switch 1	Test Mode	(0 = off, 1 = on)
Switch 2	Parameter Lock	(0 = off, 1 = on)
Switch 3	Beep On/Off	(0 = on, 1 = off)
Switch 4	Close Shutter on Crystal Fail	(0 = yes, 1 = no)
Switch 5	Continue Thickness/Timer Accumulation Option	(0 = off, 1 = on)
	With Switch 5 in the On position, pressing the OPEN button adds to the Thickness and Time counters and does not zero previously accumulated Thickness or Time. Pressing CLOSE freezes the Thickness and Time displayed at the current value. The displayed Rate will not be frozen. The Zero function works normally and can be used to zero accumulated Thickness or Time at any time.	
Switch 6	Unused	
Switch 7	Unused	
Switch 8	Etch Mode	(0 = off, 1 = on)
Switch 9	Displayed units MSB	00 = kÅ, 01 = µgm
Switch 10	Displayed units LSB	10 = mgm, 11 = MHz Note: recorder function remains as Å/sec or Å in the MHz setting.
Switch 11	Recorder function MSB	00 = Rate, ±2000Å/sec, 1000ng/sec or 200µgm/sec 01 = Rate, ±200Å/sec, 100ng/sec or 20 µgm/sec 10 = Rate, ±20Å/sec, 10ng/sec or 2 µgm/sec
Switch 12	Recorder function LSB	11 = Thickness, Modulus ±2000Å, 2000ng or 2000µgm
Switch 13	Recorder Output & Display Averaging MSB	00 = 1/4 sec 01 = 1 sec
Switch 14	Recorder Output & Display Averaging LSB	10 = 4 sec 11 = 16 sec
		Note: Display average is always 1 second or greater.
Switch 15	Unused	
Switch 16	Unused (Reserved)	

2.5.3 Grounding Stud

Recommended point for connecting the system ground strap. For specific recommendations see section 3.2, Electrical Grounding and Shielding Requirements, on page 3-1.

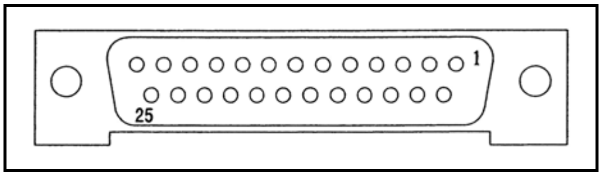
Figure 2-11 Grounding Stud



2.5.4 System I/O

A 25-pin male "D" type connector for interface connection. (See section 3.7 on page 3-14 for details.) The outputs are normally open type relays.

Figure 2-12 25-Pin Male "D" Connector



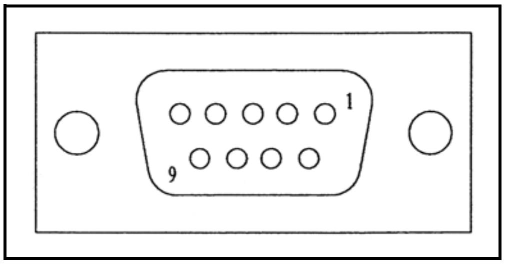
Pin #	Function*
Outputs	
1,2	Source Shutter
3,4	Thickness Setpoint
5,6	Timer Setpoint
7,8	Sensor Fail
Inputs	
9	Crystal Fail Inhibit
14,15,16,17	INPUT Common (GND)
18	OPEN shutter
19	CLOSE shutter
20	Zero thickness
21	Zero timer

*The function of the relay outputs may be altered to be controlled remotely through the computer communications, see section 3.8.5.6 on page 3-26 for more information on the Remote Command.

2.5.5 RS232

A 9-pin female "D" type connector which enables the instrument to be controlled by a host computer. See section 3.8 on page 3-16 for details.

Figure 2-13 9-Pin Type "D" Female Connector

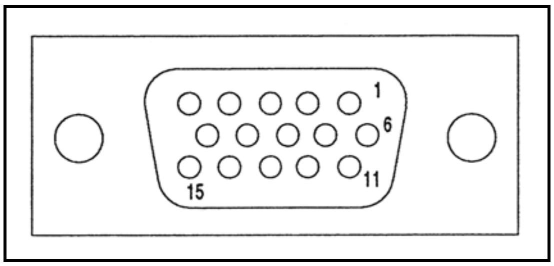


Pin #		Description	IBM Compatible Host Computer DB9-Pin	DB 25-Pin
1		Not used	1	-
2	TXD	Data transmitted from XTM2	2	3
3	RXD	Data received by XTM/2	3	2
4		Not used	4	-
5	GND	Signal ground	5	7
6	DTR	Output from XTM/2 indicating ready to transmit	6	6
7	CTS	Input to XTM/2 indicating stop transmitting	7	4
8		Not used	8	-
9	GND	Shield ground	9	-

2.5.6 Sensor

High density 15-Pin female "D" type input connectors for intelligent oscillators (IPN757-302-G1). These oscillators are normally supplied with 15' (4.572 m) cables as IPN 757-305-G15. These are specifiable as 30' (9.144 m) and 100' (30.28 m) by changing the group (G-xx) designation to 30 or 100, respectively.

Figure 2-14 15-Pin Type "D" Female Connector



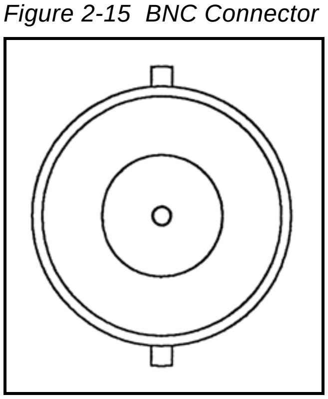
2.5.7 International Warning Symbol for Users and Technicians

This symbol is intended to alert the user to the presence of important operating and maintenance (servicing) instructions in the literature accompanying the instrument.

2.5.8 Recorder

A BNC type connector that supplies analog voltage proportional to rate or thickness (mass). The specific function is determined by configuration switches 9-14, refer to section 2.5.2 on page 2-15.

Figure 2-15 BNC Connector



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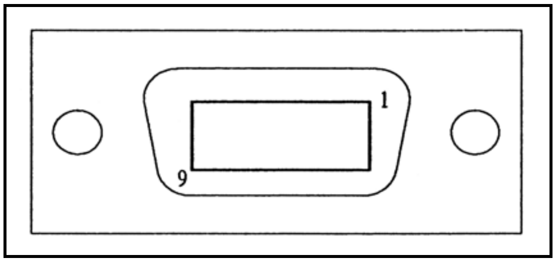
2.5.9 Comm. Option

Location of optional computer interface, see section 3.8 on page 3-16 for setup details.

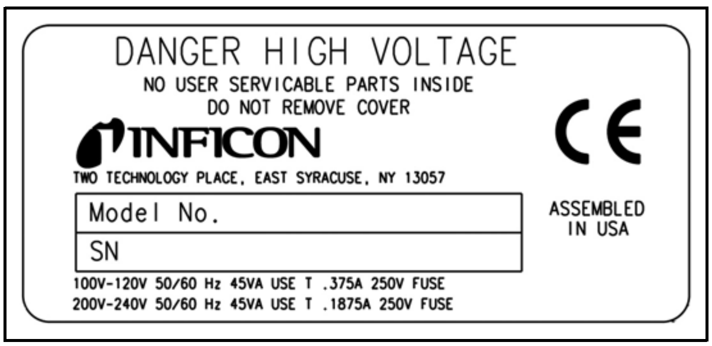
Figure 2-16 IEEE-488 Option



2.5.10 Manufacturer's Identification and Serial Number Plate

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

Figure 2-17 Serial Number Plate



2.6 Operation as a Deposition Monitor

Although this instrument is designed as a vacuum deposition/etch monitor, it is also easily used for many other types of mass measurement applications. It is easily installed by reviewing section 2.3 on page 2-7 for a schematic view of the installation requirements and section section 4.1 on page 4-1 for an overview of instrument function.

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. The units may be programmed in Å/KÅ or µgm/mgm/ngm depending on the setting of configuration switches 9 and 10, refer to section 2.5.2 on page 2-15. If these switches are subsequently changed, the two thickness parameter values of the active film are appropriately recomputed.

2.6.1 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 switch the display in the program mode and enter the appropriate values. The values entered for these parameters are independent of which units are chosen for display (thickness or mass).

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 . . . . Corrects for the geometrical differences between the sensor and the substrate, see section 5.3 on page 5-2.

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

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

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

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2.6.2 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 section 2.6.1 on page 2-22) must also be programmed.

FINAL THICKNESS . . . . Program to the desired film thickness (or mass).

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 **OPEN** 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.

2.6.3 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 (1, 2) of the **SYSTEM I/O** connector.
2. Program the **FINAL THICKNESS** 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 **OPEN**. 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 increase the **FINAL THICKNESS** value.

NOTE: This arrangement does not allow automatic substrate final thickness termination.

2.7 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 +/- 1.23 nanograms/cm^2 in a single 250 ms measurement (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 cm^2. 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.

2.7.1 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 2.5.2 on page 2-15) 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 THICKNESS** parameter may be programmed to terminate the process.

2.7.2 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. Special transducers may be required as many liquids can electrically short the crystal's drive voltage and induce a crystal failure.

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

2.7.3 Biological

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

2.7.4 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.

2.7.5 Use as a Frequency Counter

The ability to measure a crystal’s frequency between 6.000000 and 5.000000 MHz may be accessed by setting the "displayed units" configuration switches 9 and 10 (refer to section 2.5.2 on page 2-15). The displayed frequency is averaged according to the setting of the recorder and display averaging configuration switches. In addition, by pressing the **LIFE** key, even finer frequency resolution is displayed (x.xx or x.x Hz), suppressing the most significant data. Data to 0.1 Hz is always available through the computer interface for the latest 0.25 sec. measurement.

The recorder output and programmed limits of this instrument behave as if the "displayed units" configuration switches were set to 00 or "kÅ".

2.7.6 Contamination Detection

The measurement of a crystal’s mass loss or gain is enhanced by utilizing the averaging and displayed units configuration switches, refer to section 2.5.2 on page 2-15. These may be used to directly display the mass change in micrograms (µgm) or milligrams (mg). In addition, the displayed resolution may be enhanced by increasing the measurement time averaging to as long as 16 seconds. This technique reduces the relative noise in the ratio of the square root of the sample time.

The limiting problem will most probably be either temperature changes of the monitor crystal or the instrument’s reference crystal. Careful temperature control can minimize these effects.

Chapter 3
Installation

3.1 Installing the Instrument - Details

A general schematic of instrument installation is given in section 2.3 on page 2-7, 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 15’ (4.572 m). Longer cables are specifiable as 30’ (9.144 m) or 100’ (30.28 m), refer to section 2.5.6 on page 2-20 for ordering details.

The monitor 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.

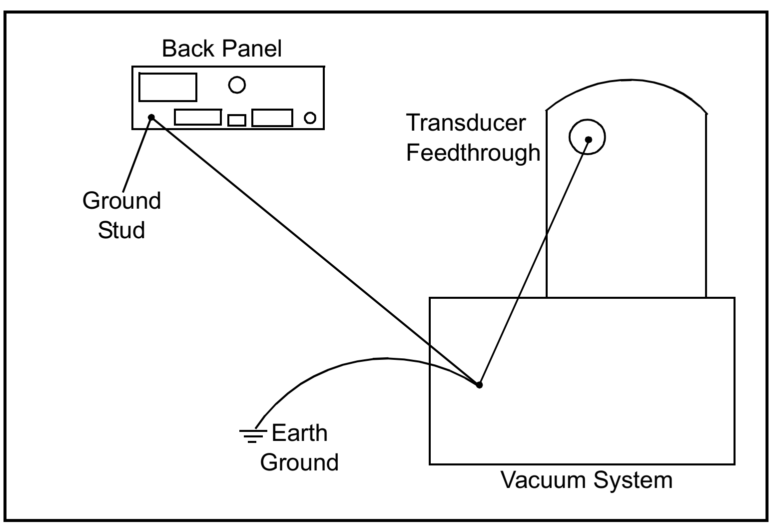
Where soil conditions allow, drive two ten foot copper clad steel rods into the ground six feet apart. Pour a copper sulfate or other salt solution around the rods to improve the soil's conduction. A near zero resistance measurement between the two rods indicates that a desirable earth ground has been 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" (0.762 mm) thick X 1" (25.4 mm) wide) is more suitable because of its lower RF impedance.

Figure 3-1 System Grounding Diagram



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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 1 foot (305 mm) 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 of 1/4" (6.4 mm). 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.

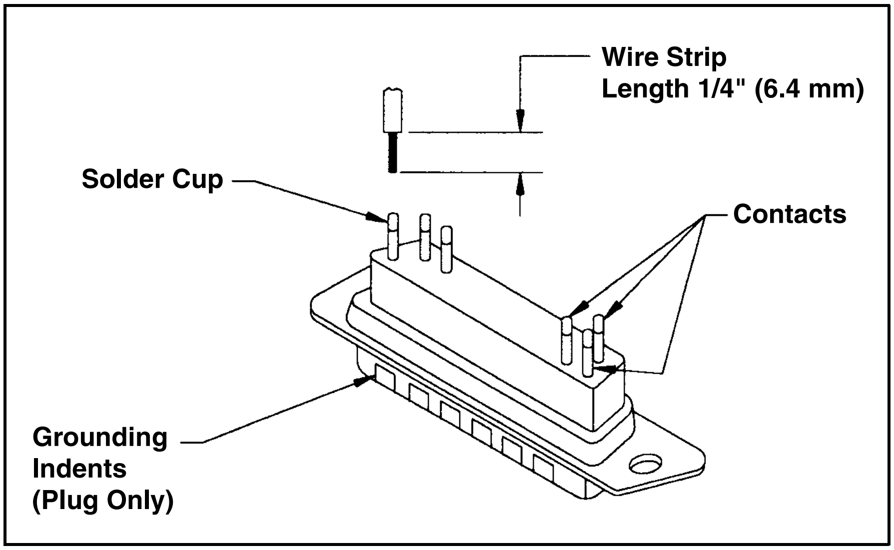
5 Coat the stripped portion of the wire(s) with the flux and insert into the solder cup of the contact until the conductor is bottomed in the cavity.

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) 20" (508 mm) 30" (762 mm)	007-219 007-220 007-221	450°	Front	Side	Must remove water cooling and open the tubes prior to bakeout
Bakeable w/Shutter					
12" (304.8 mm) 20" (508 mm) 30" (762 mm)	750-012-G1 750-012-G2 750-012-G3	450°	Front	Side	Must remove water cooling and open the tubes prior to bakeout
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

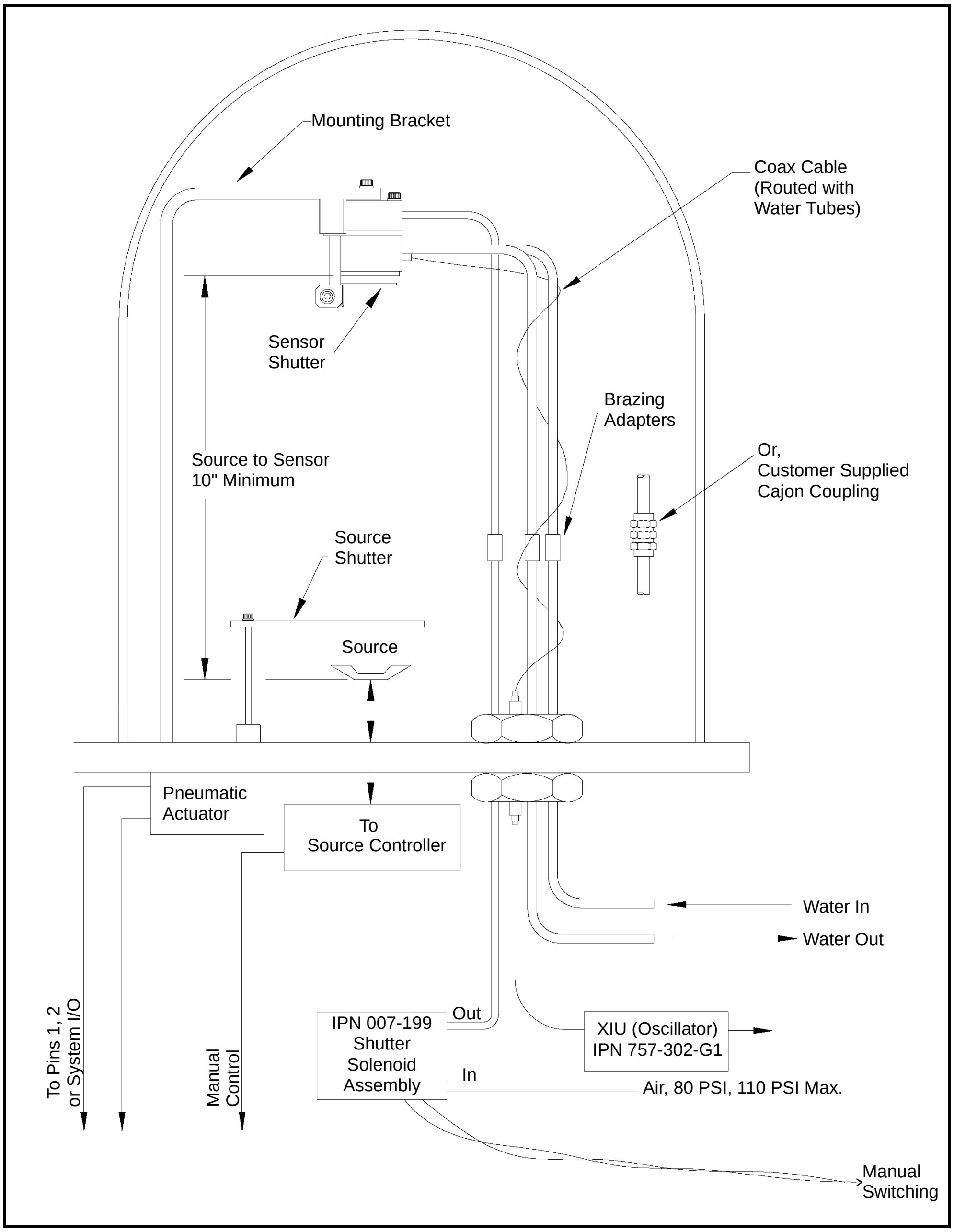
WARNING

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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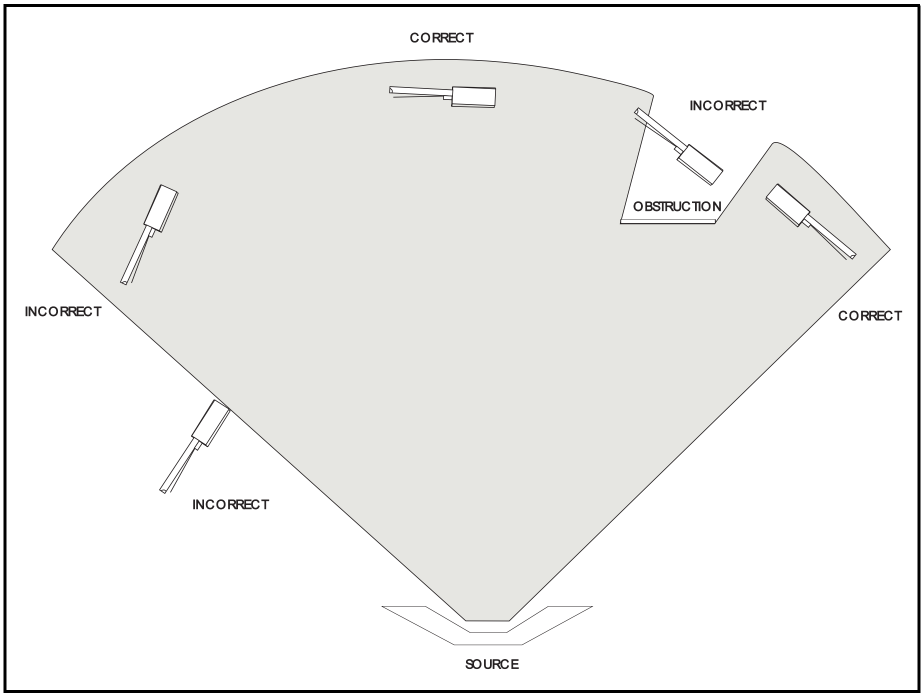
Generally, install the sensor as far as possible from the evaporation source (a minimum of 10" or 254 mm) while still being in a position to accumulate thickness at a rate proportional to accumulation on the substrate. Figure 3-4 shows proper and improper methods of installing sensors.

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.

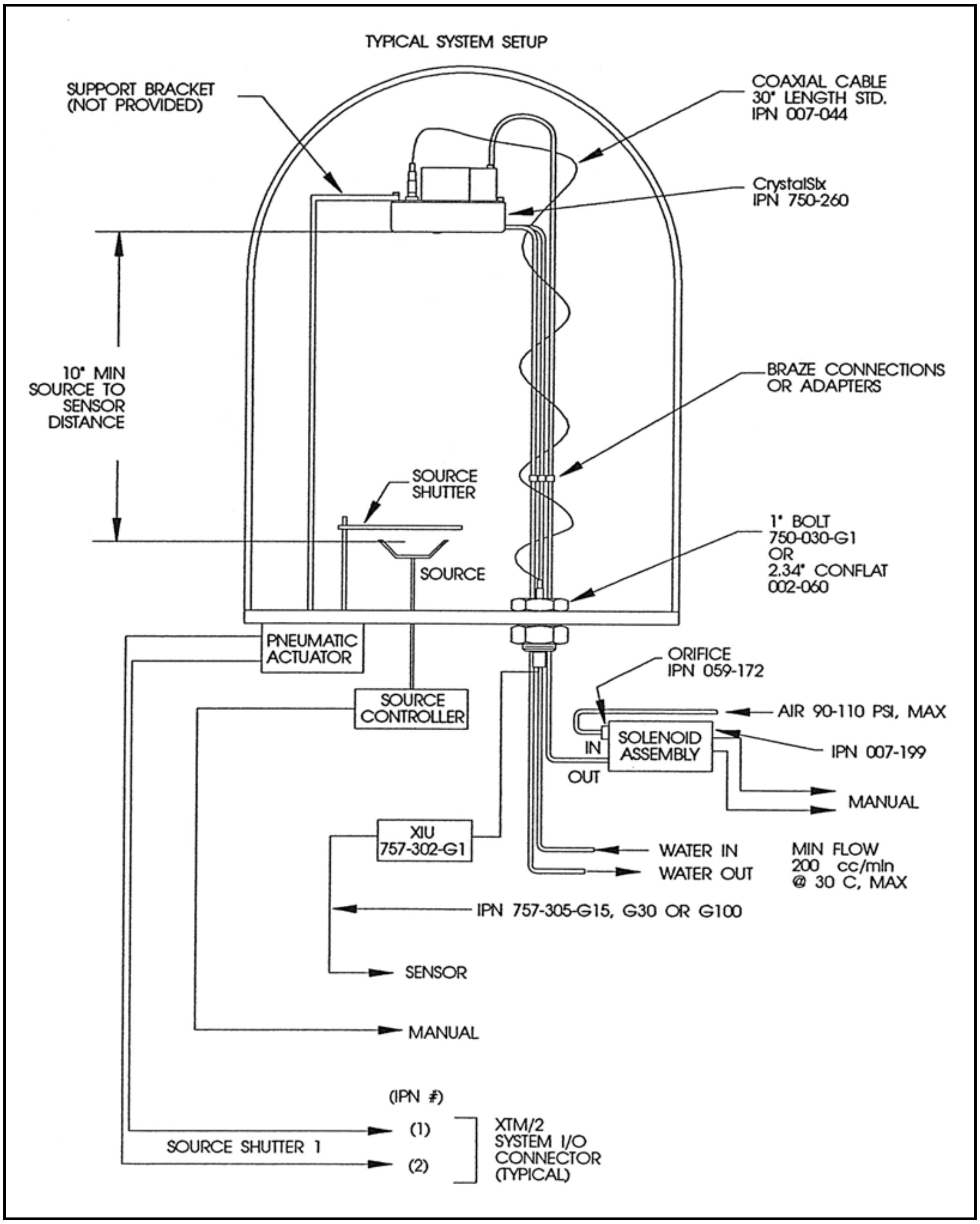
Figure 3-4 Sensor Installation Guidelines



3.5.2 CrystalSix

Installing the CrystalSix transducer requires that the crystals be manually advanced. Follow the guidelines in the CrystalSix Operating Manual (IPN 074-155) and Figure 3-5.

Figure 3-5 CrystalSix Installation for XTM/2



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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

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:

$$\text{Displayed Rate} = \frac{40}{\textbf{DENSITY}\ (\text{gm/cc})} \times \frac{\textbf{TOOLING}\ (\%)}{100\%}\ \text{Å/sec} \qquad [1]$$

All relays and inputs operate normally during Test Mode operation.

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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 illuminate. If **Err** is displayed on the LCD, see section 6.2 on page 6-1.

4 The following LCD displays will appear:

TEST
XX:XX PHASE MIN:SEC
XTAL FAIL

5 Press the **PROG** key. The program display will appear and the cursor will be located beside **DENSITY.**

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

DENSITY	02.73	gm/cc
Z-RATIO	1.000	
TOOLING	110	%
FINAL THICKNESS	2.000	KÅ
SPT THICKNESS	1.000	KÅ
SPT TIMER	1:00	min:sec

NOTE: There is a built-in "TEST FILM" with all of the parameters preprogrammed, as shown in Table 3-2. It is accessed by moving the cursor to the **FILM** parameter and entering zero. The two thickness values will be modified if the mgm or µgm display mode has been selected. Press the **PROG** key to exit the display mode and continue with step 9.

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 **OPEN** to begin the programmed sequence.

10 The **SHUTTER OPEN** annunciator is displayed.

11 The time begins to increment from 00:00 and the deposition rate will be 16.1 Å/s. The **THICK SPT** annunciator is lit at 1.000 kÅ and the **TIMER SPT** lights at 1:00 min:sec. Reaching the **FINAL THICKNESS** parameter of 2.000 kÅ takes and elapsed time of 02:05, then after reaching **FINAL THICKNESS** limit the **SHUTTER OPEN** annunciator disappears. The clock immediately begins counting up from 00:00 again.

12 The instrument will remain in this mode until **OPEN** is pressed.

13 When **OPEN** is pressed, the process will repeat steps 11 through 13.

14 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

WARNING

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

Pin #	Function*	Closed Contacts	Open Contacts	Relay #
1,2	**Source Shutter**	During "Shutter Open" State.	Balance	1
3,4	**Thickness Setpoint**	When SPT THICKNESS is exceeded.	Balance	2
5,6	**Timer Setpoint**	When SPT TIMER is exceeded.	Balance	3
7,8	**Crystal Fail**	When crystal fails to oscillate.	Balance	4

Function may be overwritten by Remote Communications Commands "**R**6 - **R**9", see section 3.8.5 on page 3-22.

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 3-4 System I/O Connector

Pin #	Function	Description	Input #
14,15,16,17	Input Common (GND)	Used as reference for activating any of the inputs	
18	**OPEN**	Detection of a falling edge duplicates front panel OPEN	1
19	**CLOSE**	Detection of a falling edge duplicates front panel CLOSE	2
9	**CRYSTAL FAIL INHIBIT**	Presence of a closure to ground reference prohibits the closure of the Crystal Fail Relay.	3
20	**ZERO** thickness	Detection of a falling edge duplicates the front panel ZERO, for thickness only.	4
21	**ZERO** timer	Detection of a falling edge duplicates the front panel ZERO for the timer only.	5

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 configuration switches; see section 2.5.2 on page 2-15. 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.

3.8 Computer Communications

This instrument supports a number of standard and optional computer communications protocol formats. RS232 is standard, operating in either INFICON checksum or non-checksum as well as SECS II formats. The unit may also be configured to automatically output process data (data logging) upon reaching **FINAL THICKNESS**. Pressing the shutter **CLOSE** switch on the front panel will also initiate a data dump.

3.8.1 Communications Setup

The XTM/2 has serial communications as a standard feature. Rates from 1200 to 9600 baud are accommodated. Refer to section 2.5.5 on page 2-19 for RS232 connector details.

To configure the remote communication interface, hold down the 0 key during power up. The following set of parameters can then 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 RECEIVE 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.

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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
Board: XTM2	Access: GPIB0	SELECT (use right/left arrow keys):
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 XTM/2:	STX 00 NN message_string CS	
From XTM/2:	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 XTM/2:	message_string ACK	
From XTM/2:	message_string ACK	(if success)
	- or -	
	error_code NAK	(if failure)

IEEE488 FORMAT (Message Protocol)

To XTM/2: message_string LF d10 (CHR$10)

From XTM/2: message_string LF (if success)

- or -

error_code LF (if failure)

SECS FORMAT (Message Protocol)

To XTM/2: NN SECS_10_BYTE_HEADER message CS CS

From XTM/2: NN SECS_10_BYTE_HEADER ACK message CS CS (if success)

- or -

NN SECS_10_BYTE_HEADER NAK error_code CS CS (if not)

If there is a problem, the unit will return a **NAK** preceded by one of the following Error Codes:

A. . . . . . . Illegal command

B. . . . . . . Illegal Value

C . . . . . . Illegal ID

D . . . . . . Illegal command format

E. . . . . . . No data to retrieve

F. . . . . . . Cannot change value now

G . . . . . . Bad checksum

NOTE: When transmitting commands directly by typing on a keyboard, the entire command, including the "ACK", must be entered quickly. Otherwise, the instrument will fail to recognize the transmission as a valid command.

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:

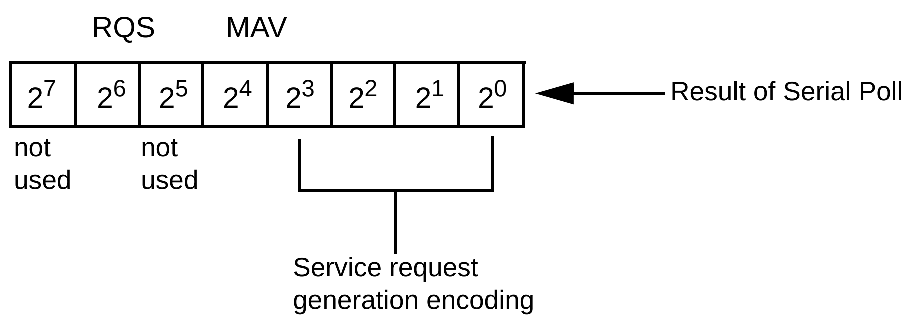

Table 3-5 Service Request Encoding

Generator Event	Code	Value
FINAL THICKNESS	0001	1
STBY/ON sequence	0100	4
Crystal Fail	0110	6
250ms **DATA READY**. Available only after **R**23 is issued, see page 3-26. This is automatically cleared on crystal failure.	0111	7
TIMER SPT exceeded	1000	8
THICKNESS SPT exceeded	1001	9

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.

3.8.4 Datalogging

Data logging may be configured to be automatic, see section 3.8.1 on page 3-16. The RS232 port is then 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 Datalog data output represents the information concerning the latest **SHUTTER OPEN** to **SHUTTER CLOSE** sequence. The data is a series of ASCII strings, each separated by a carriage return (CR) and line feed (LF), in the order below:

1 Film #

2 Rate = _ _ _.__Å/s [or ngm/sec or µgm/sec] [Last good rate if crystal failed]

3 Thickness = _ _ _ _._ _ _ _ kÅ [or µgm or mgm] [Last good thickness if crystal failed]

4 Deposit Time = _ _:_ _ Min:Sec.

5 Begin Frequency = _ _ _ _ _ _ ._ Hz

6 End Frequency = _ _ _ _ _ _ ._ Hz [negative of last good frequency if crystal fail]

7 Crystal Life = _ _%

In addition to automatic datalogging, the datalog information string is available via execution of the **S**12 communications command, or may be manually initiated by pressing the **CLOSE** (shutter) key on the front panel.

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 "XTM/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 P F - Query parameter **P** of film **F**. A space is used as a delimiter between **P** and **F**, where **F** is a digit between 1 and 9, inclusive,

or

Q 6 - Query the current film number.

Table 3-6 Parameter Definition Table (for Query and Update Commands)

PP	XTC/2 Parameter	Range
0	Tooling	10 to 500.9 (%)
1	Final Thickness	0 to 999.9999 (kÅ/µgm/mgm)
2	SPT Thickness	0 to 999.9999 (kÅ/µgm/mgm)
3	Density	0.5 to 99.999 (gm/cc)
4	Z-ratio	0.1 to 9.999
5	SPT Time	00:00 to 99:59 (min:sec)
6	Film Number	1-9
99	All	See note below
	Note: **Q 99 F** returns parameters 0 to 5 for film **F** in the order and ranges as specified above; each parameter is separated by a space.	

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3.8.5.4 Update Command

The format of the update command is:

U P F vvv.

Update parameter **P** of film **F**, with value vvv. A space is used as a delimiter between the **P** and **F** values as well as the **F** and vvv values, where **F** is a digit between 1 and 9;inclusive. Refer to Table 4-2 on page 4-4 for a numbered list of parameters and their limits.

or

U 6 F

Set the current film number to film **F**

See Query Command Parameter Definition Table for numbered list of parameters.

NOTE: The command "**U 99 F** Tooling Final Thickness SPT Thickness Density Z-ratio SPT Time" will update all parameters for film F. All parameter values must be separated by spaces and must use allowed values per those shown in the Parameter Definition Table.

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:

S 0 . . . . . Rate, Thickness, Time, Xtal-Life

S 1 . . . . . Rate

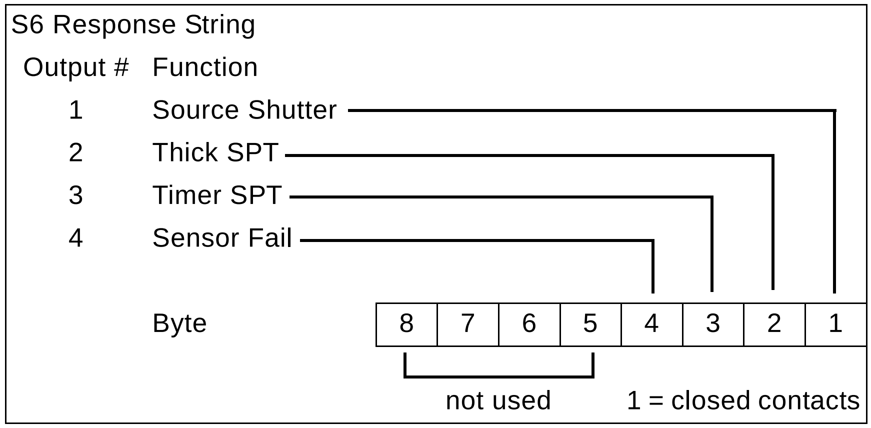
S 2 . . . . . Thickness

S 3 . . . . . Time

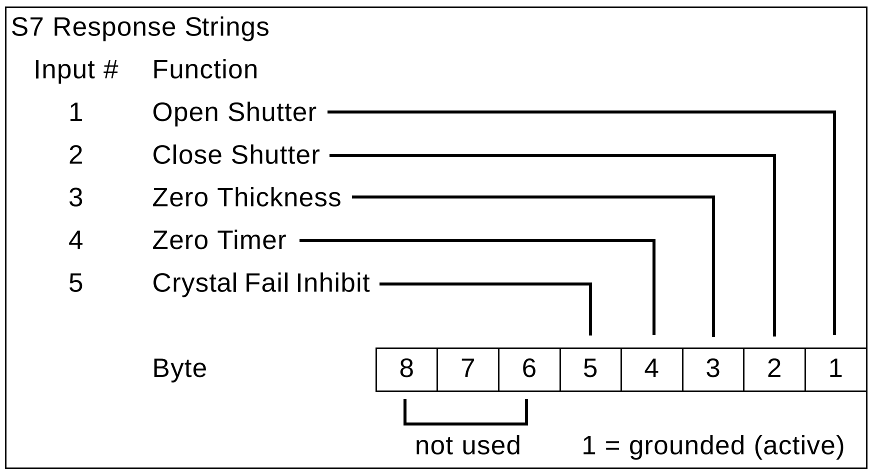
S 4 . . . . . Film

S 5 . . . . . Crystal life (%)

S 6. . . . . Output status - returns 8 ASCII bytes each with a value of 0 or 1.



S 7. . . . . Input status - returns 8 ASCII bytes each with a value of 0 or 1.



S 8. . . . . Present frequency of Crystal

Sxxxxxx.xD

where

x is any digit 0 to 9

S character is a space when good readings are available or a negative sign for failed crystals

D character is:
0 when there is 0.25 second averaging
0 or 5 when there is 1 second averaging
Even Digit when there is 4 second averaging
x when there is 16 second averaging

S 9. . . . . Crystal fail, 1 = Fail, 0 = Good

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S 10 . . . . Present configuration switch settings—returns 16 ASCII bytes with a value of 0 or 1, corresponding to the position of switches 1-16. Byte 1 corresponds to switch 1. See **S**13 also.

S10 Response Strings

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

[1 = switch on, refer to section 2.5.2 on page 2-15]

S 11 . . . . Power-up errors

S11 Response Codes

0. . . . Parameter data checksum error—indicates a loss of stored parameter data.

1. . . . STBY/ON sequence since last query—the front panel power switch has been used since the last inquiry.

2. . . . Line power failure.

9. . . . Process data checksum error—indicates a loss of process data.

10. . . No errors.

NOTE: If more than 1 error condition exists, the response string will list them all, each separated by a single space.

NOTE: STBY/ON status is cleared automatically by issuing an **S**11 command. All others require intentional clearing (available via remote command).

S 12 . . . . Datalog output, see section 3.8.4 on page 3-21. The data is separated by a space instead of CR LF.

S 13 . . . . Instrument Configuration, the position of the configuration switches at the last **STBY/ON** sequence. Use this command to determine the instrument's current operating configuration. See **S**10 also.

3.8.5.6 Remote Command

The format of the remote command is:

R xx # . . A space is used as a delimiter between xx and #

where:

R . . . . . . Is the literal **R**

xx . . . . . Is the remote code per list below.

. . . . . . Is the associated value needed for some remote commands.

R 0. . . . . Open Shutter

R 1. . . . . Close Shutter

R 2. . . . . Locks out parameters via the front panel

R 3. . . . . Unlocks parameter changes via the front panel

R 4. . . . . Zeros Thickness accumulation

R 5. . . . . Zeros Timer

R 6. . . . . Output override on. [Allows external control of relays.]

R 7. . . . . Output override off.

R 8 # . . . Set output # (if output override on). [Closes Relay #, see section 3.7.1 on page 3-14.]

R 9 # . . . Clears output # (if output override on). [See **R**8.]

R 10. . . . Clear power up error messages. [See **S**11 commands.]

R 23. . . . Set "250ms Data Ready" Service request (IEEE only).

R 24. . . . Clear "250ms Data Ready" Service request (IEEE only).

3.8.6 Examples of RS232 Programs

```
10 '----XTM/2 RS232 COMMUNICATIONS PROGRAM WITHOUT CHECKSUM----
20 '
30 '------THIS PROGRAM IS DESIGNED TO TRANSMIT INDIVIDUAL COMMANDS TO THE XTM/2
AND ACCEPT THE APPROPRIATE RESPONSE FROM THE XTM/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 XTM/2
90 GOSUB 130                                       :'--GOTO TRANSMIT COMMAND SUBROUTINE.
100 PRINT RESPONSE$                                :'--PRINT XTM/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 XTM/2----
160 PRINT #1, CMD$ + ACK$;
170 '
180 '----RECEIVE RESPONSE MESSAGE FROM THE XTM/2----
190 RESPONSE$ = ""                                 :'--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 SERIALLY 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.
```

```
10 ’--XTM/2 RS232 COMMUNICATIONS PROGRAM WITH CHECKSUM USING THE INFICON FORMAT--
20 ’
30 ’------THIS PROGRAM IS DESIGNED TO TRANSMIT INDIVIDUAL COMMANDS TO THE XTM/2
           AND ACCEPT THE APPROPRIATE RESPONSE FROM THE XTM/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 XTM/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 XTM/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 XTM/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 XTM/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                                    :’--RECIEVE HIGH ORDER BYTE
350 SIZE = 256 * ASC(I$)                                   :’ OF TWO BYTE RESPONSE SIZE.
360 TOUT = 3: GOSUB 510                                    :’--RECIEVE LOW ORDER BYTE
370 SIZE = SIZE + ASC(I$)                                  :’ 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$)                          :’ CHARACTER BY CHARACTER.
440 NEXT I
450 TOUT = 3: GOSUB 510                                    :’--RECIEVE THE CHECKSUM
460 N = ASC(I$)                                            :’ 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 SERIALLY 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.
```

3.8.6.1 Example of SEMI II Program

```
10 ’XTM/2 RS232 COMMUNICATIONS PROGRAM USING THE SECS FORMAT
20 ’———THIS PROGRAM IS DESIGNED TO TRANSMIT———
30 ’————INDIVIDUAL COMMANDS TO THE XTM/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$)                              : ’ CALUCULATE THE COMMAND LENGTH
130 ’
140 ’——ADD THE TWO BYTE PREAMBLE TO THE COMMAND——
150 PRE$ = 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$(128)                               : ’RESPONSE FROM XTM/2 REQUIRED
320 STREAM$ = 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 XTM/2——
700 ’
710 ’
720 HEADER$ = BYTE1$ + BYTE2$ + STREAM$ + FUNCTION$ + BYTE5$ + BYTE6$ + BYTE7$ + BYTE8$ + BYTE9$ +
              BYTE10$
730 PRINT #1, LTHBYT$; HEADER$; CMD$; CHEKSUMM$; CHEKSUML$;
740 GOTO 580
750 ’
760 ’
770 ’———WAIT FOR DATA FROM XTM/2———
780 ’
790 ’———FIND SIZE OF RESPONSE——
800 ’
810 PRINT #1, EOT$;
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 '----------------------XTM/2 GPIB COMMUNICATIONS PROGRAM--------------------
20 '------THIS PROGRAM IS DESIGNED TO TRANSMIT INDIVIDUAL COMMANDS TO THE XTM/2
AND ACCEPT THE APPROPRIATE RESPONSE FROM THE XTM/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 XTM2$="XTM2" : CALL IBFIND(XTM2$,XTM2%)          '--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(XTM2%,V%)                      '--ASSERT EOI ON WRITE
170 V%=12 : CALL IBTMO(XTM2%,V%)                     '--SET THREE SEC TIMEOUT
180 INPUT "ENTER COMMAND";COMMAND$                   '--ENTER COMMAND TO XTM/2
190 CALL IBCLR(XTM2%)                                '--CLEAR THE XTM/2 COMM
200 GOSUB 240                                        '--GOTO TRANSMIT COMMAND SUBROUTINE.
210 PRINT I$                                         '--PRINT XTM/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 XTM/2----
270 COMMAND$ = COMMAND$ + CHR$(&HA)
280 CALL IBWRT(XTM2%,COMMAND$)
290 '
300 '----RECEIVE RESPONSE MESSAGE FROM THE XTM/2----
310 '
320 I$=SPACE$(40) : CALL IBRD(XTM2%,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 (XTM2%,SPR%)
287 B = SPR% / 16: B = INT(B)
289 IF B = 1 THEN 290 ELSE 285
```

After sending a command to the XTM/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 (XTM2%,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 (2^0 through 2^3) to determine which event generated the service request. Once this is determined the appropriate action may be taken.

Chapter 4
Programming System Operation Details

4.1 State and Measurement System Sequencing

The following pages give an overview of the XTM/2's operational flow. There are two basic loops: the Measurement Loop and the Display Loop. These two loops operate independently of each other. The following symbols are used in these flow charts:

Figure 4-1 Symbols Used in Flow Charts

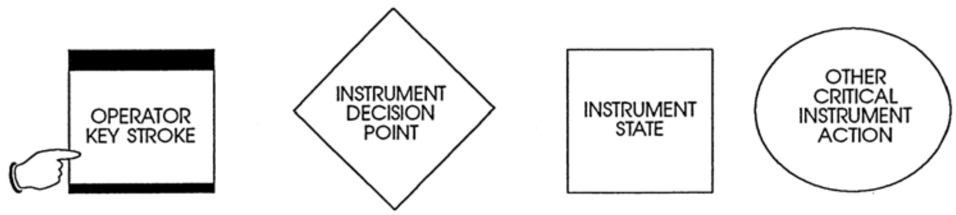

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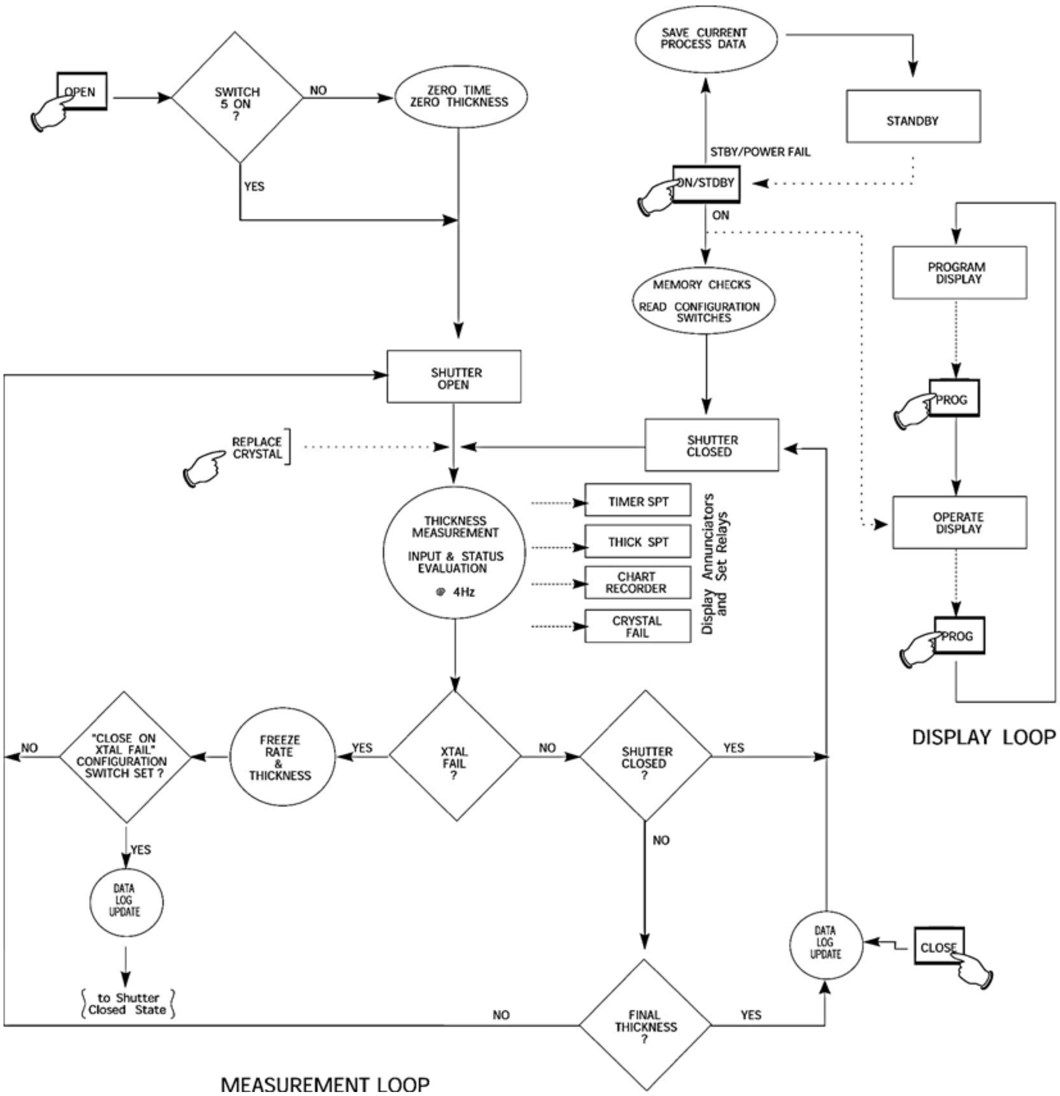
Figure 4-2 State Diagram for a Film



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

4.2 State Descriptions

Operating the XTM/2 as a film thickness/rate monitor requires programing the film parameters, refer to section 2.6 on page 2-22. A film sequence begins with a **OPEN** command and ends when the film in process reaches the **FINAL THICKNESS** or the **CLOSE** switch is pressed. The **RATE** and **THICKNESS** displayed is modified by the values programmed in the possible parameters and the units used are set by the configuration switches, refer to section 2.5.2 on page 2-15.

In reviewing the state diagram of Figure 4-2 on page 4-2, note that there are only two basic machine states, **SHUTTER OPEN** or **SHUTTER CLOSED**. On power-up, the machine proceeds to the **SHUTTER CLOSED** state after performing a series of memory checks. Various abnormal conditions are indicated by ERR# messages, see section 6.2.1 on page 6-1 and section 6.2.2 on page 6-2. The operations indicated by a pointing finger are manual key strokes or the equivalent system hardware input or computer communications command.

Table 4-1 State Descriptions

State	Condition	Source Shutter
1. **SHUTTER CLOSED**	Will accept an OPEN command.	Open
2. **SHUTTER OPEN**	Will accept a CLOSE command.	Closed

In addition, there are two basic display modes: Operate and Program. Pressing the **PROG** switch at any time alternates between these modes.

Information may be stored and recalled for nine setups. The particular setup is chosen by moving the cursor to the **FILM** parameter and selecting 1-9. In addition, Film 0 is preprogrammed for Test Mode use, refer to section 3.6 on page 3-11.

4.3 Parameter Limits

The variable parameters and their limits are listed below. The two thickness (mass) parameters may be set over a wider range of values through the computer communications interface. If a value outside the stated limits is attempted, the message “ERR1” is displayed, see section 6.2.2 on page 6-2. When the “Displayed Units” configuration switches are changed (refer to section 2.5.2 on page 2-15) the **FINAL THICKNESS** and **SPT THICKNESS** values are automatically scaled to preserve the settings. If a value rescales out of limits, “ERR 3” is displayed.

Table 4-2 Parameters and Limits

Parameter	Limits	Units
FILM	1 - 9, 0 in Test Mode	--
DENSITY	0.500 - 99.99	gm/cc
Z-RATIO	0.1 - 9.999	--
TOOLING	10.0 - 500	%
FINAL THICKNESS	0.000 - 999.9*	kÅ/µgm/mgm
SPT THICKNESS	0.000 - 999.9*	kÅ/µgm/mgm
SPT TIMER	00:00 - 99:59	MIN:SEC

*Although the full value range of the parameter may be entered, the maximum mass loading on a 6 MHz crystal is about 16 mgm.

4.4 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. If the measurement system is unable to recover, the message XTAL FAIL is displayed and the last "good" rate and thickness values are preserved on the operate screen until the monitor crystal is replaced or recovers.

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 5-12.

4.5 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 2.5.4 on page 2-18. When this input is activated the crystal fail relay will not close on crystal fail. 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.

4.6 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 oroptical 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 (%), 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 in Material Set-Up) 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 Appendix A, Table of Densities and Z-ratios, 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).
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:

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

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.

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5.4 Laboratory Determination of Z-ratio

A list of Z-values for materials commonly used is available in Appendix A, Table of Densities and Z-ratios. 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/cm^3) of deposited film

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

d_q = density of quartz (crystal) (2.649 gm/cm^3)

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

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

Laboratory results indicate that Z-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 - 5000Å).
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 Lostis[3] that the change in frequency, DF = 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:

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

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)

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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, DF, 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 gm/cm^3) is the density of single crystal quartz and N_{at} (=166100 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

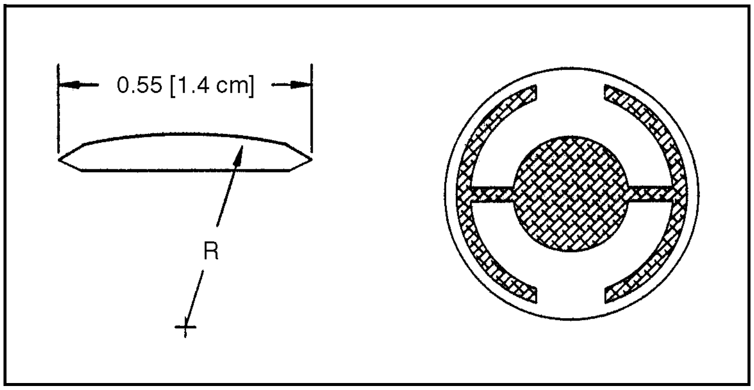
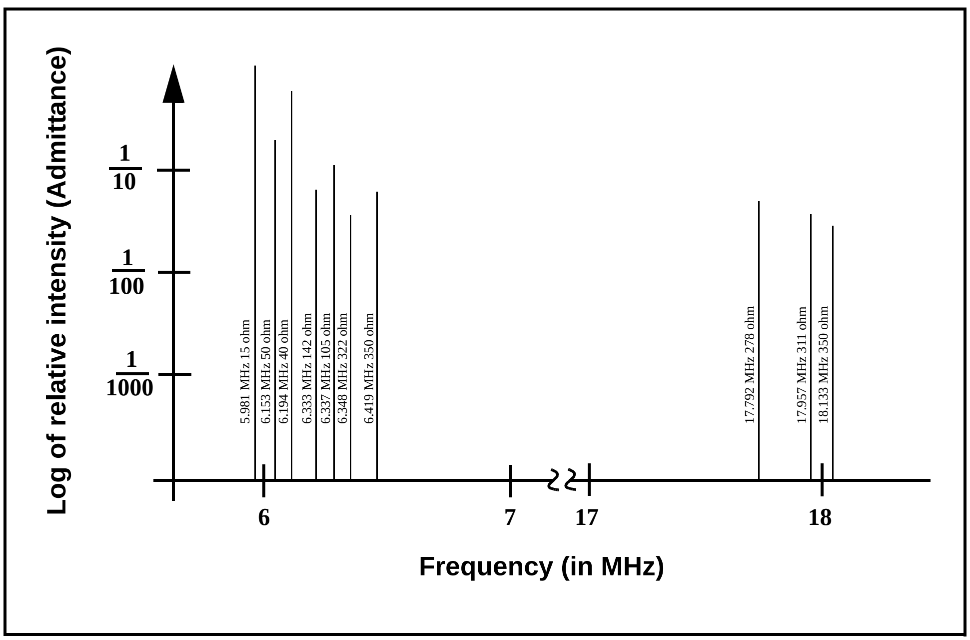


Figure 5-2 Frequency Response Spectrum



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

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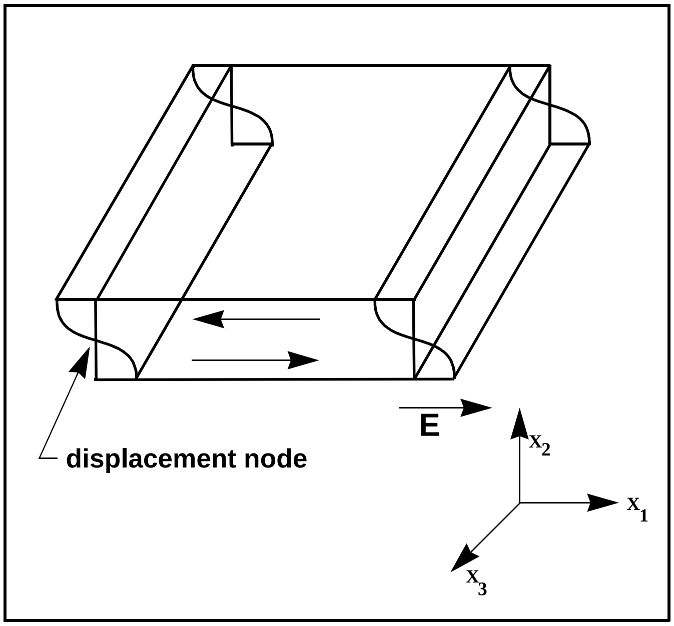
response at about three times the frequency of the fundamental is called the third quasiharmonic. There are also a series of anharmonics slightly higher in frequency associated with the quasiharmonic.

Figure 5-3 Thickness Shear Displacement



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.

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.

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 Behrndt[4] that:

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

where T_c and Tq 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 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

4.K. H. Behrndt, J. Vac. Sci. Technol. 8, 622 (1961) 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 Bolef [5], which rigorously treated the resonating quartz and deposited film system as a one-dimensional continuous acoustic resonator, Lu and Lewis[6] 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].

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

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 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 $\sim 0.05F_q$.

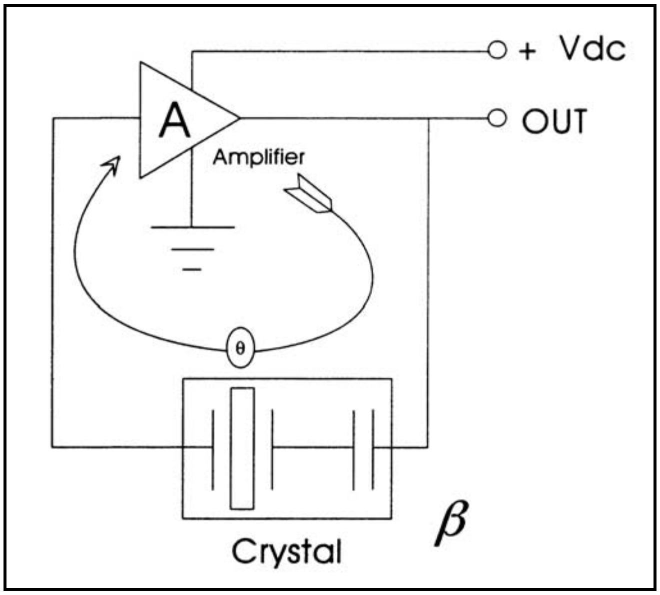
5.5.5 Active Oscillator

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

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)

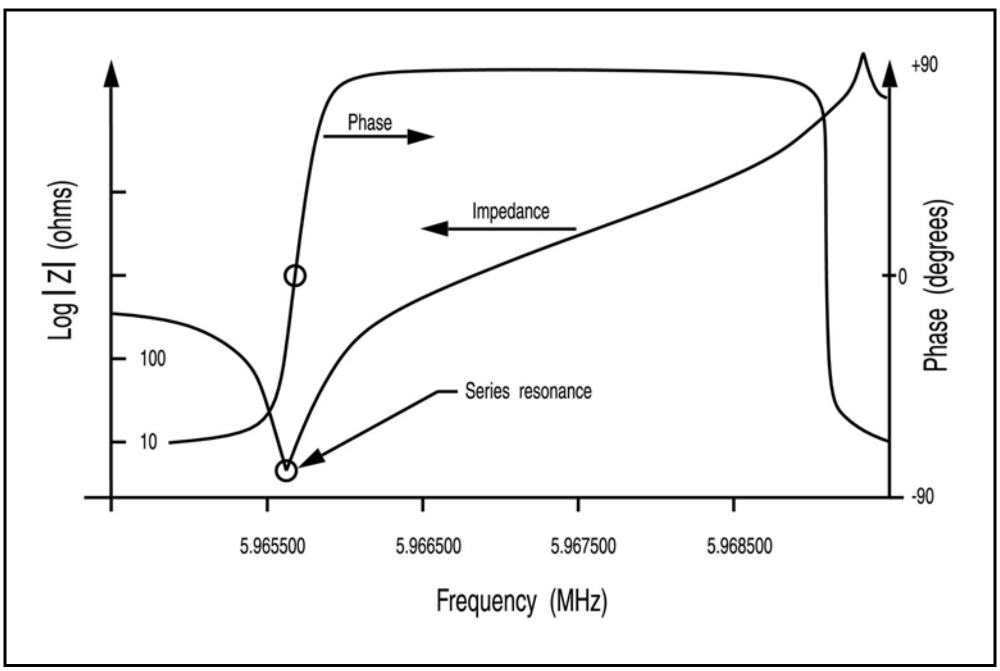
sustained as long as the gain provided by the amplifiers is sufficient to offset losses in the crystal and circuit and the crystal can provide the required phase shift.

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

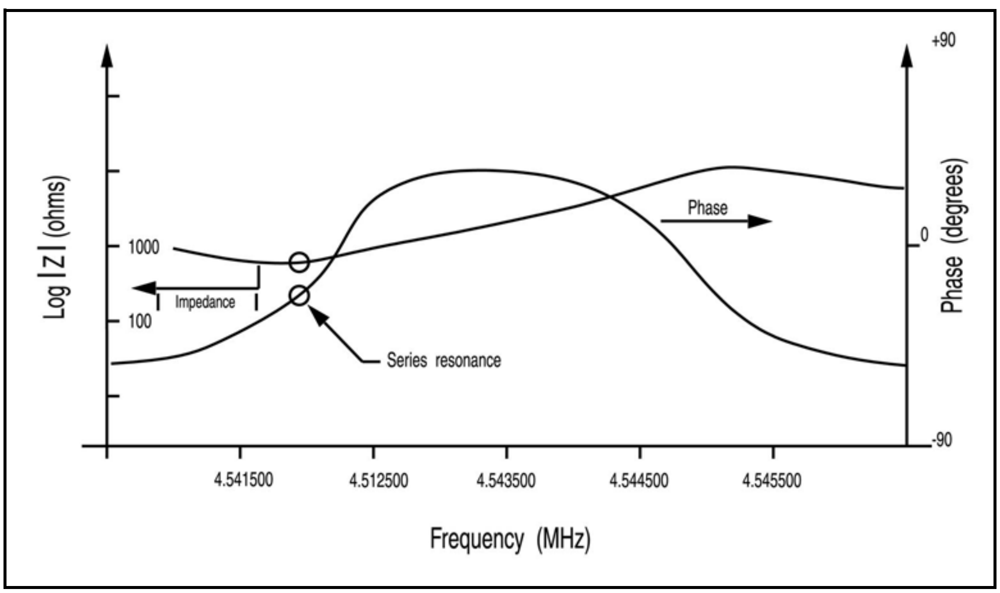


The active oscillator circuit is designed so the crystal is required to produce a phase shift, θ, of 0 degrees, which allows it to operate at the series resonance point. Long- and short-term frequency stabilities are a property of crystal oscillators because very small frequency changes are needed to 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 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 technology[7] 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 0.05 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 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.

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

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.

WARNING

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

6.1 LCD Contrast Adjustment

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 2-9, 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 XTM/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 2. . . . . . Line power loss. This message is cleared by pressing any key.

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 4-4 for parameter ranges.

ERR 3 . . . . . Parameter out of range as the result of a change in the displayed units. This is cleared with any key.

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 Symptom/Cause chart in section 6.3.2 on page 6-4 may be helpful.

WARNING

There are no user serviceable components within the instrument case.

Potentially lethal voltages are present when the line cord, or 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.

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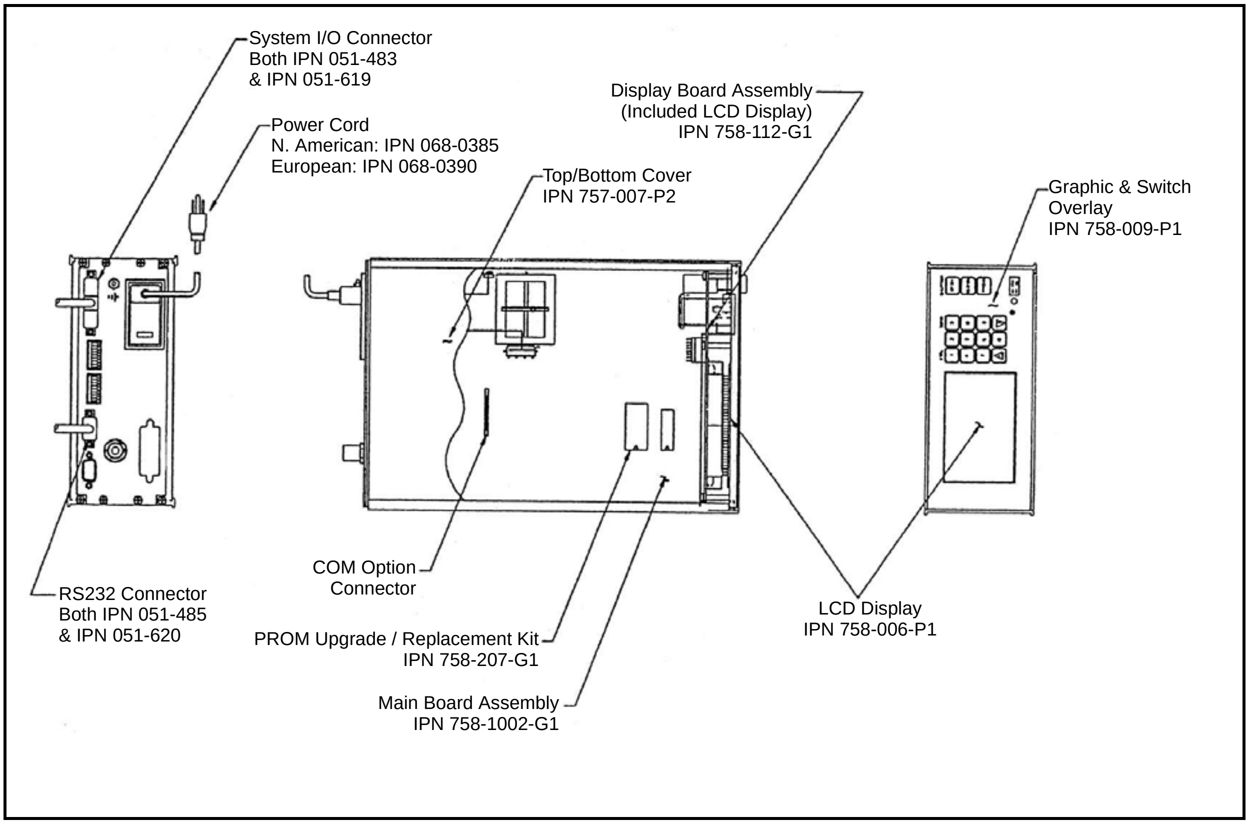
6.3.1 Major Instrument Components, Assemblies and Mating Connectors

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' (305 mm) 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.verfify 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

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Table 6-1 Troubleshooting the Instrument (continued)

SYMPTOM	CAUSE	REMEDY
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
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. CRT or LCD display dull or blank	a. brightness/contrast adjustment required	a. refer to manual for location of adjustment potentiometer, adjust as required
	b. LCD or CRT/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

Table 6-1 Troubleshooting the Instrument (continued)

SYMPTOM	CAUSE	REMEDY
9. crystal fail always on	a. XIU/oscillator not connected	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

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 megohms, 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 6-20 for a discussion of its use and diagnostic capabilities.

NOTE: A more detailed troubleshooting guide is shipped with the sensor. Refer to the sensor's 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 use high performance buffered 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

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 senor 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 leafs to approximately 60°. See section 6.3.5 on page 6-14
	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

Table 6-2 Troubleshooting Transducers/Sensors (continued)

SYMPTOM	CAUSE	REMEDY
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
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)	a. inadequate cooling water/cooling water temperature too high	a. check cooling water flow rate, be certain that cooling water temperature is less than 30 °C; refer to appropriate sensor manual
	b. excessive heat input to the crystal	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
	c. crystal not seated properly in holder	c. clean or polish the crystal seating surface on the crystal holder
	d. crystal heating caused by high energy electron flux (often found in RF sputtering)	d. use a sputtering sensor head
	e. poor thermal transfer from water line to body (CrystalSix sensor)	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
	f. poor thermal transfer (Bakeable)	f. use Al or Au foil washer between crystal holder and sensor body

Table 6-2 Troubleshooting Transducers/Sensors (continued)

SYMPTOM	CAUSE	REMEDY
6. poor thickness reproducibility	a. variable source flux distribution	a. move sensor to a more central location to reliably sample evaporant, ensure constant relative pool height of melt, avoid tunneling into the melt
	b. sweep, dither, or position where the electron beam strikes the melt has been changed since the last deposition	b. maintain consistent source distribution by maintaining consistent sweep frequencies, sweep amplitude and electron beam position settings
	c. material does not adhere to crystal	c. make certain the crystal's surface is clean; avoid touching crystal with fingers, make use of an intermediate adhesion layer
	d. cyclic change in rate	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)]
7. large drift in thickness (greater than 200 Å for a density of 5.00 g/cc) after termination of sputtering	a. crystal heating due to poor thermal contact	a. clean or polish the crystal seating surface on the crystal holder
	b. external magnetic field interfering with the sensors magnetic field (sputtering sensor)	b. rotate sensor magnet to proper orientation with external magnetic field, refer to sputtering sensor manual IPN 074-157
	c. sensor magnet cracked or demagnetized (sputtering sensor)	c. check sensor magnetic field strength, the maximum field at the center of the aperture should be 700 gauss or greater

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Table 6-2 Troubleshooting Transducers/Sensors (continued)

SYMPTOM	CAUSE	REMEDY
8. CrystalSix, crystal switch problem (does not advance or not centered in aperture)	a. loss of pneumatic supply, or pressure is insufficient for proper operation	a. ensure air supply is regulated at 80-90 PSI
	b. operation has been impaired as a result of material accumulation on cover	b. clean material accumulation as needed, refer to CrystalSix manual IPN 074-155 for maintenance
	c. improper alignment	c. realign as per instructions in CrystalSix manual IPN 074-155
	d. 0.0225" diameter orifice not installed on the supply side of solenoid valve assembly	d. install orifice as shown in the CrystalSix manual IPN 074-155

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	a. improper cable connection	a. verify for correct cable wiring as described in the manual
	b. BAUD rate in host computer not the same as the instrument	b. verify BAUD rate in the host's applications program, verify BAUD rate in the instrument
	c. incompatible protocols being used	c. verify the instrument protocol: RS232, SECS, GPIB, DATALOG, CHECKSUM, matches host
	d. incorrect device address (GPIB or SECS protocol)	d. verify device address in host's applications program, (or in IBCONF file for National Instrs. GPIB) and verify instrument address

Table 6-3 Troubleshooting Computer Communications (continued)

SYMPTOM	CAUSE	REMEDY
2. error code returned	a. A = illegal command	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. B = illegal value	b. the parameter's value sent is outside the range for the given parameter, verify parameter's range
	c. C = illegal ID	c. the command sent was for a parameter which doesn't exist; verify the correct parameter number
	d. D = illegal command format	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. E = no data to retrieve	e. some parameters may not be in use, depending on the value of other parameters

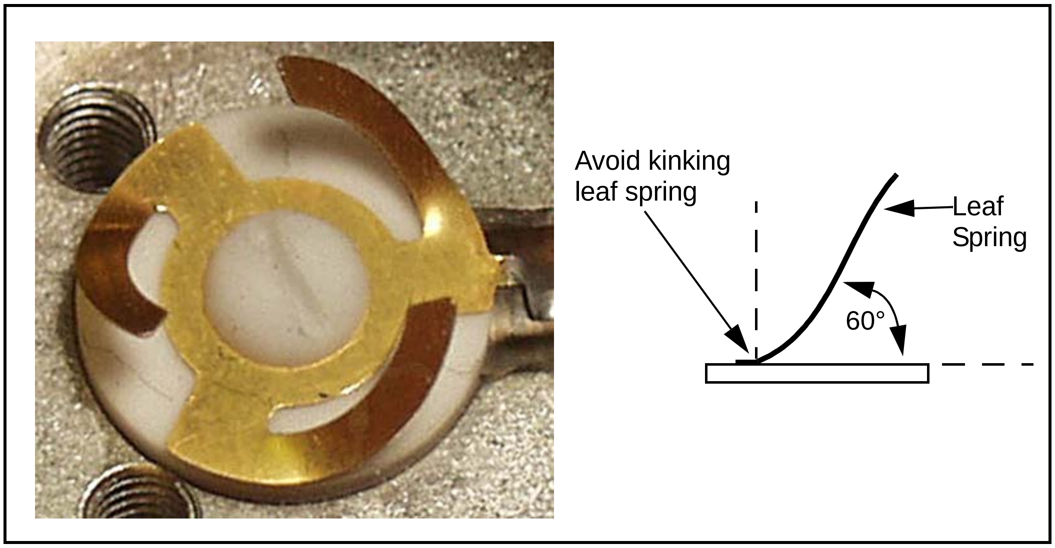
Table 6-3 Troubleshooting Computer Communications (continued)

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, stream lining 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.

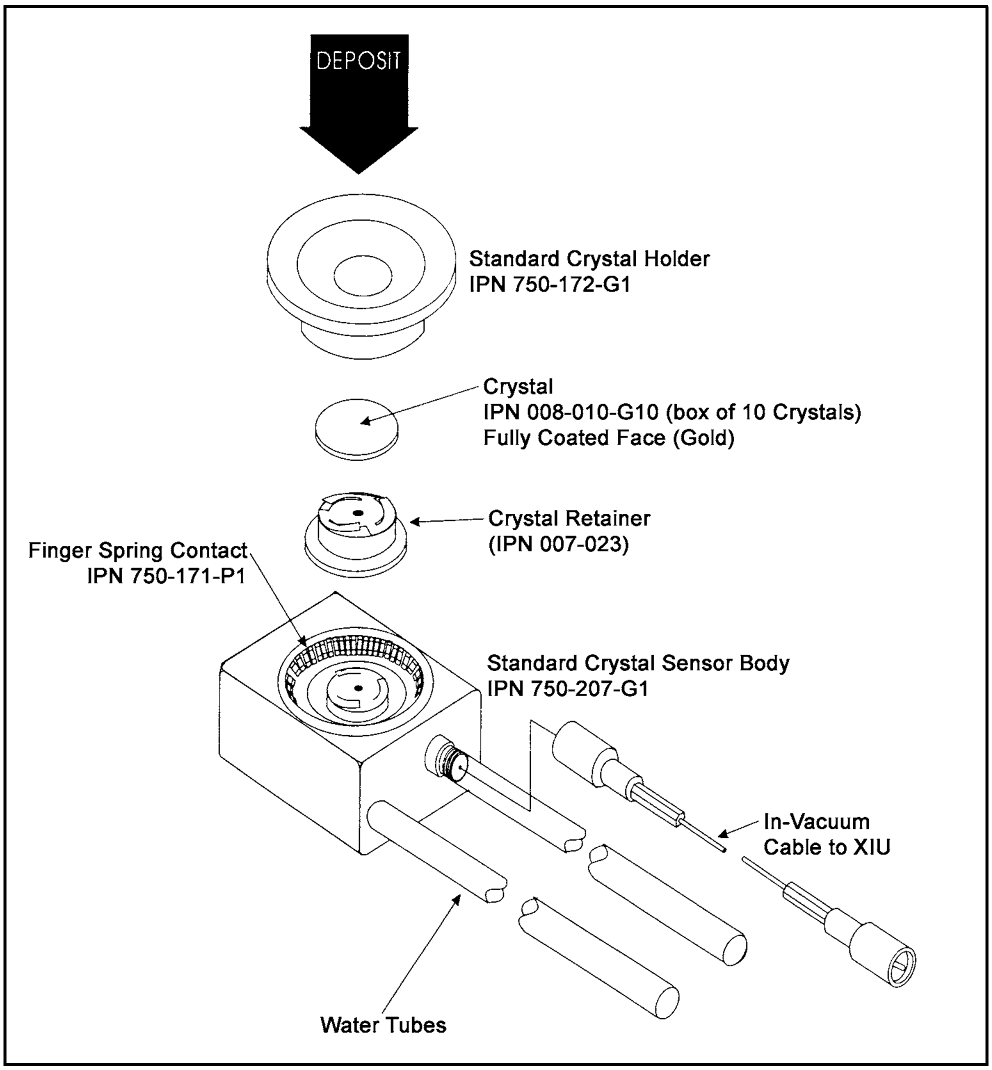
Thick deposits of some materials, such as SiO, Si, and Ni will normally peel off the crystal when it is exposed to air, as a result of changes in film stress caused by gas absorption. When you observe peeling, change the crystals.

6.4.1 Standard and Compact

Follow the procedure below to replace the crystal in the Standard and Compact sensor: (see Figure 6-3)

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 6-19).
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) (750-030/S&D HEAD)



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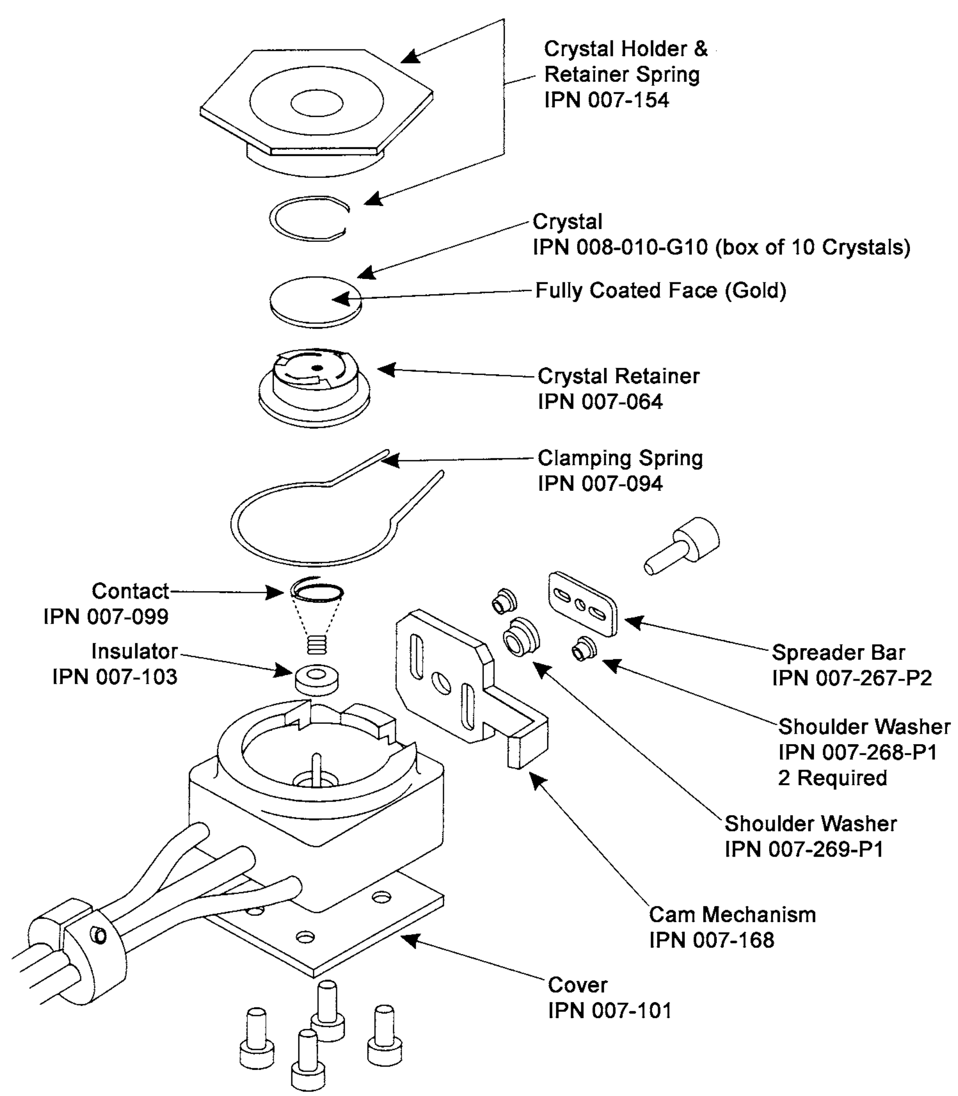
6.4.2 Shuttered and Dual Sensors

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) (750-030/BAKEABLE)

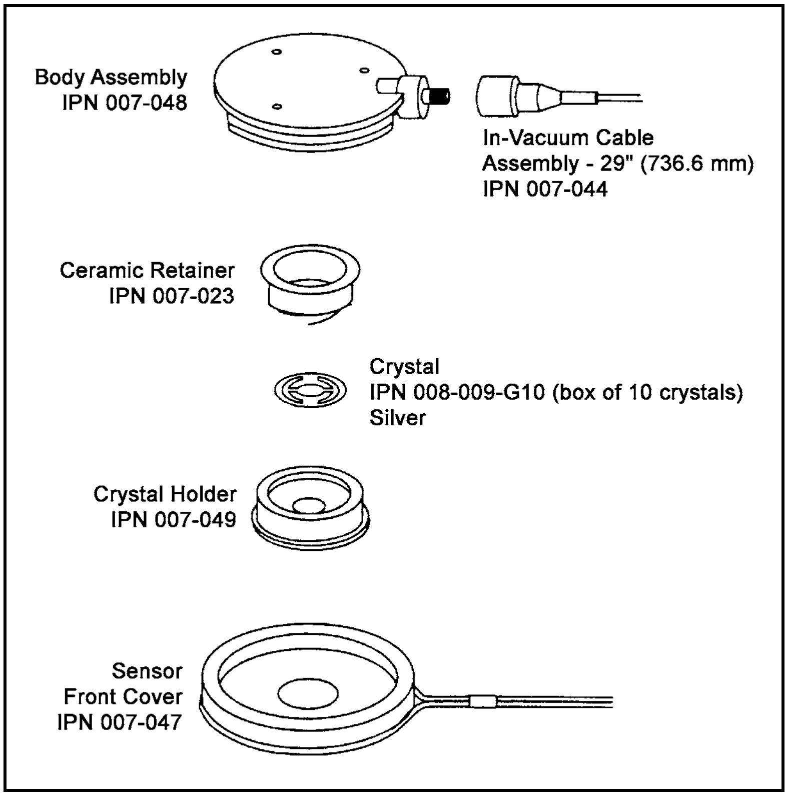


6.4.4 Sputtering Sensor

Observe the general precautions (section 6.4 on page 6-15) 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 6-19).
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)



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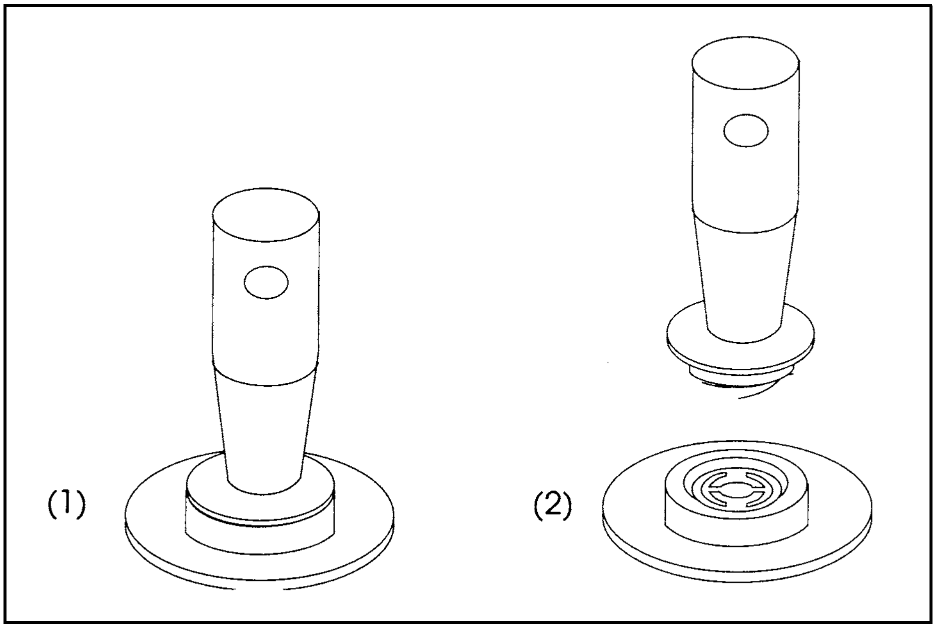
6.4.5 Crystal Snatcher

To use the crystal snatcher supplied with the sensor follow the instructions below (see Figure 6-6):

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

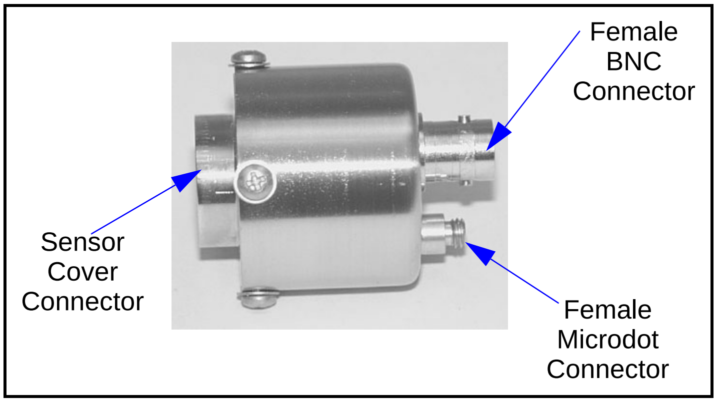


6.5 Crystal Sensor Emulator IPN 760-601-G1 or 760-601-G2

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.

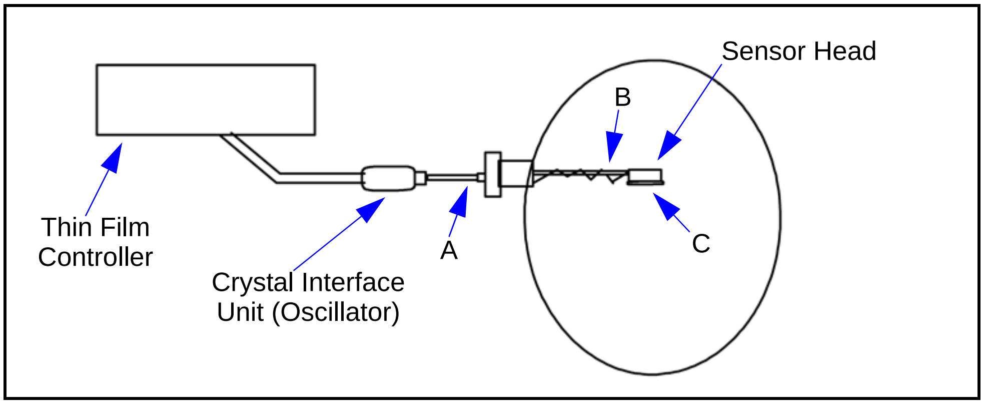
The Crystal Sensor Emulator option is used in conjunction with the Thin Film Deposition Controller to rapidly diagnose problems with the Deposition Controller's measurement system. See Figure 6-7.

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 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.

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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 6-20. 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 6-20. 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 6-23.
   - 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 6-20. 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.
- 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 deposition controllers which allow a 1 MHz frequency shift.
- approximately 38% for deposition controllers which allow a 1.25 MHz frequency shift
- approximately 30% for deposition controllers which allow a 1.5 MHz frequency

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.
(40.13 mm diameter x 45.47 mm)

Temperature Range

0 to 50 ^{o}C

Frequency

760-601-G1: 5.5 MHz ± 30 ppm at room temperature
760-601-G2: 5.5 MHz ± 1 ppm at room temperature

Materials

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

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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_2O_3	3.970	0.336	Aluminum Oxide
Al_4C_3	2.360	*1.000	Aluminum Carbide
AlF_3	3.070	*1.000	Aluminum Fluoride
AlN	3.260	*1.000	Aluminum Nitride
AlSb	4.360	0.743	Aluminum Antimonide
As	5.730	0.966	Arsenic
As_2Se_3	4.750	*1.000	Arsenic Selenide
Au	19.300	0.381	Gold
B	2.370	0.389	Boron
B_2O_3	1.820	*1.000	Boron Oxide
B_4C	2.370	*1.000	Boron Carbide
Ba	3.500	2.100	Barium
BaF_2	4.886	0.793	Barium Fluoride
BaN_2O_6	3.244	1.261	Barium Nitrate
BaO	5.720	*1.000	Barium Oxide

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_2O_3	8.900	*1.000	Bismuth Oxide
Bi_2S_3	7.390	*1.000	Bismuth Trisulphide
Bi_2Se_3	6.820	*1.000	Bismuth Selenide
Bi_2Te_3	7.700	*1.000	Bismuth Telluride
BiF_3	5.320	*1.000	Bismuth Fluoride
BN	1.860	*1.000	Boron Nitride
C	2.250	3.260	Carbon (Graphite)
C	3.520	0.220	Carbon (Diamond)
C_8H_8	1.100	*1.000	Parlyene (Union Carbide)
Ca	1.550	2.620	Calcium
CaF_2	3.180	0.775	Calcium Fluoride
CaO	3.350	*1.000	Calcium Oxide
$CaO-SiO_2$	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

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Table A-1 Material Table (continued)

Formula	Density	Z-ratio	Material Name
Cr	7.200	0.305	Chromium
Cr_2O_3	5.210	*1.000	Chromium (111) Oxide
Cr_3C_2	6.680	*1.000	Chromium Carbide
CrB	6.170	*1.000	Chromium Boride
Cs	1.870	*1.000	Cesium
Cs_2SO_4	4.243	1.212	Cesium Sulfate
CsBr	4.456	1.410	Cesium Bromide
CsCI	3.988	1.399	Cesium Chloride
CsI	4.516	1.542	Cesium Iodide
Cu	8.930	0.437	Copper
Cu_2O	6.000	*1.000	Copper Oxide
Cu_2S	5.600	0.690	Copper (I) Sulfide (Alpha)
Cu_2S	5.800	0.670	Copper (I) Sulfide (Beta)
CuS	4.600	0.820	Copper (11) Sulfide
Dy	8.550	0.600	Dysprosium
Dy_2O_3	7.810	*1.000	Dysprosium Oxide
Er	9.050	0.740	Erbium
Er_2O_3	8.640	*1.000	Erbium Oxide
Eu	5.260	*1.000	Europium
EuF_2	6.500	*1.000	Europium Fluoride
Fe	7.860	0.349	Iron
Fe_2O_3	5.240	*1.000	Iron Oxide
FeO	5.700	*1.000	Iron Oxide
FeS	4.840	*1.000	Iron Sulphide
Ga.	5.930	0.593	Gallium
Ga_2O_3	5.880	*1.000	Gallium Oxide (B)
GaAs	5.310	1.590	Gallium Arsenide
GaN	6.100	*1.000	Gallium Nitride
GaP	4.100	*1.000	Gallium Phosphide
GaSb	5.600	*1.000	Gallium Antimonide
Gd	7.890	0.670	Gadolinium
Gd_2O_3	7.410	*1.000	Gadolinium Oxide
Ge	5.350	0.516	Germanium

Table A-1 Material Table (continued)

Formula	Density	Z-ratio	Material Name
Ge_3N_2	5.200	*1.000	Germanium Nitride
GeO_2	6.240	*1.000	Germanium Oxide
GeTe	6.200	*1.000	Germanium Telluride
Hf	13.090	0.360	Hafnium
HfB_2	10.500	*1.000	Hafnium Boride,
HfC	12.200	*1.000	Hafnium Carbide
HfN	13.800	*1.000	Hafnium Nitride
HfO_2	9.680	*1.000	Hafnium Oxide
$HfSi_2$	7.200	*1.000	Hafnium Silicide,
Hg	13.460	0.740	Mercury
Ho	8.800	0.580	Holminum
Ho_2O_3	8.410	*1.000	Holminum Oxide
In	7.300	0.841	Indium
In_2O_3	7.180	*1.000	Indiurn Sesquioxide,
In_2Se_3	5.700	*1.000	Indium Selenide
In_2Te_3	5.800	*1.000	Indium Telluride
InAs	5.700	*1.000	Indium Arsenide
InP	4.800	*1.000	Indium Phosphide
InSb	5.760	0.769	Indium Antimonide
Ir	22.400	0.129	Iridium
K	0.860	10.189	Potassium
KBr	2.750	1.893	Potassium Bromide
KCl	1.980	2.050	Potassium Chloride
KF	2.480	*1.000	Potassium Fluoride
KI	3.128	2.077	Potassium Iodide
La	6.170	0.920	Lanthanum
La_2O_3	6.510	*1.000	Lanthanum Oxide
LaB_6	2.610	*1.000	Lanthanurn 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
$MgAl_2O_4$	3.600	*1.000	Magnesium Aluminate
$MgAl_2O_6$	8.000	*1.000	Spinel
MgF_2	3.180	0.637	Magnesium Fluoride
MgO	3.580	0.411	Magnesium Oxide
$MgO_3Al_2O_3$	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_2C	9.180	*1.000	Molybdenum Carbide
MoB_2	7.120	*1.000	Molybdenum Boride
MoO_3	4.700	*1.000	Molybdenum Trioxdide
MoS_2	4.800	*1.000	Molybdenum Disulfide
Na	0.970	4.800	Sodium
Na_3AlF_6	2.900	*1.000	Cryolite
$Na_5Al_3F_{14}$	2.900	*1.000	Chiolite
NaBr	3.200	*1.000	Sodium Bromide
NaCl	2.170	1.570	Sodium Chloride
$NaClO_3$	2.164	1.565	Sodium Chlorate
NaF	2.558	0.949	Sodium Fluoride
$NaNO_3$	2.270	1.194	Sodium Nitrate
Nb	8.578	0.492	Niobium (Columbium)
Nb_2O_3	7.500	*1.000	Niobium Trioxide
Nb_2O_5	4.470	*1.000	Niobium (V) Oxide
NbB_2	6.970	*1.000	Niobium Boride
NbC	7.820	*1.000	Niobium Carbide
NbN	8.400	*1.000	Niobiunn Nitride
Nd	7.000	*1.000	Neodynium
Nd_2O_3	7.240	*1.000	Neodynium Oxide
NdF_3	6.506	*1.000	Neodynium Fluoride
Ni	8.910	0.331	Nickel

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_3N_5	2.510	*1.000	Phosphorus Nitride
Pb	11.300	1.130	Lead
$PbCl_2$	5.850	*1.000	Lead Chloride
PbF_2	8.240	0.661	Lead Fluoride
PbO	9.530	*1.000	Lead Oxide
PbS	7.500	0.566	Lead Sulfide
PbSe	8.100	*1.000	Lead Selenide,
$PbSnO_3$	8.100	*1.000	Lead Stannate
PbTe	8.160	0.651	Lead Telluride
$PbTiO_3$	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_2O_3	6.880	*1.000	Praseodymium Oxide
Pt	21.400	0.245	Platinum
PtO_2	10.200	*1.000	Platinum Oxide
Ra	5.000	*1.000	Radium
Rb	1.530	2.540	Rubidium
RbI	3.550	*1.000	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_2O_3	5.200	*1.000	Antimony Trioxide
Sb_2S_3	4.640	*1.000	Antimony Trisulfide
Sc	3.000	0.910	Scandiurn

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Table A-1 Material Table (continued)

Formula	Density	Z-ratio	Material Name
Sc_2O_3	3.860	*1.000	Scandiurn Oxide
Se	4.810	0.864	Selenium
Si	2.320	0.712	Silicon
Si_3N_4	3.440	*1.000	Silicon Nitride
SiC	3.220	*1.000	Silicon Carbide
SiO	2.130	0.870	Silicon (II) Oxide
SiO_2	2.648	1.000	Silicon Dioxide
Sm	7.540	0.890	Samarium
Sm_2O_3	7.430	*1.000	Samariurn 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 Fluroide
$SrTiO_3$	5.123	0.31	Strontium Titanate
SrO	4.990	0.517	Strontium Oxide
Ta	16.600	0.262	Tantalum
Ta_2O_5	8.200	0.300	Tantalum (V) Oxide
TaB_2	11.150	*1.000	Tantalum Boride
TaC	13.900	*1.000	Tantalum Carbide
TaN	16.300	*1.000	Tantalum Nitride
Tb	8.270	0.660	Terbium
Tc	11.500	*1.000	Technetium
Te	6.250	0.900	Tellurium
TeO_2	5.990	0.862	Tellurium Oxide
Th	11.694	0.484	Thorium
ThF_4	6.320	*1.000	Thorium.(IV) Fluoride
ThO_2	9.860	0.284	Thorium Dioxide
$ThOF_2$	9.100	*1.000	Thorium Oxyfluoricle
Ti	4.500	0.628	Titanium
Ti_2O_3	4.600	*1.000	Titanium Sesquioxide

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
TI	11.850	1.550	Thallium
TIBr	7.560	*1.000	Thallium Bromide
TICI	7.000	*1.000	Thallium Chloride
TII	7.090	*1.000	Thalliurn Iodide (B)
U	19.050	0.238	Uranium
U_3O_8	8.300	*1.000	Tri Uranium Octoxide
U_4O_9	10.969	0.348	Uranium Oxide
UO_2	10.970	0.286	Uranium Dioxide
V	5.960	0.530	Vanadium
V_2O_5	3.360	*1.000	Vanadium Pentoxide
VB_2	5.100	*1.000	Vanadium Boride
VC	5.770	*1.000	Vanadium Carbide
VN	6.130	*1.000	Vanadium Nitride
VO_2	4.340	*1.000	Vanadium Dioxide
W	19.300	0.163	Tungsten
WB_2	10.770	*1.000	Tungsten Boride
WC	15.600	0.151	Tungsten Carbide
WO_3	7.160	*1.000	Tungsten Trioxide
WS_2	7.500	*1.000	Tungsten Disulphicle
WSi_2	9.400	*1.000	Tungsten Silicide
Y	4.340	0.835	Yttrium
Y_2O_3	5.010	*1.000	Yttrium Oxide
Yb	6.980	1.130	Ytterbium
Yb_2O_3	9.170	*1.000	Ytterbium Oxide
Zn	7.040	0.514	Zinc
Zn_3Sb_2	6.300	*1.000	Zinc Antimonide
ZnF_2	4.950	*1.000	Zinc Fluoride
ZnO	5.610	0.556	Zinc Oxide

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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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