



IC/5

Thin Film Deposition Controller

IPN 074-237AE



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

IC/5

Thin Film Deposition Controller

IPN 074-237AE



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**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: IC/5 Thin Film Deposition Controllers, including
Oscillators and Crystal Sensors 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
EN 55011, Group 1, Class A : 1991
EN 50082-1 : 1992

CE Implementation Date: January 2, 1996

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

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Appendix A

Material Table

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Chapter 1

Introduction and Specifications

1.1 Introduction

The IC/5 is a closed loop process controller designed for use primarily in physical vapor deposition. The unit monitors and/or controls the rate and thickness of the deposition of thin films. Deposition rate and thickness are inferred from the frequency change induced by mass added to a quartz crystal. This technique positions sensors in the path between or to the side of the source of the vaporized material and the target substrate. The sensor incorporates an exposed oscillating quartz crystal whose frequency decreases as material accumulates. The change in frequency provides information to determine rate and thickness and to continually control the evaporation power source. With user supplied time, thickness and power limits and with desired rates and material characteristics, the unit is capable of automatically controlling the process in a precise and repeatable manner. User interaction is accomplished via the unit's front panel and consists of selection or entry of parameters to define the process.

The complete system consists of a main electronics unit, the IC/5, sensor heads and a crystal interface unit (XIU) for each attached sensor. These items are generally bundled at the factory and are also sold separately.

The IC/5 Manual provides user information for installing, programming, calibrating and operating the main electronics unit.

When reading the IC/5 Manual, please pay particular attention to the NOTES, CAUTIONS, and WARNINGS found throughout the text. The Notes, Cautions, and Warnings are defined in [section 1.2.1 on page 1-2](#).

You are invited to comment on the usefulness and accuracy of this manual by filling out the registration card and returning it.

1.1.1 Related Manuals

Sensors are covered in separate manuals.

- ◆ 074-154 - Bakeable
- ◆ 074-155 - CrystalSix
- ◆ 074-156 - Single/Dual
- ◆ 074-157 - Sputtering

1.2 Instrument Safety

1.2.1 Definition of Notes, Cautions and Warnings

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

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



CAUTION

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



WARNING

Failure to heed these messages could result in personal injury.



WARNING - Risk Of Electric Shock

Dangerous voltages are present which could result in personal injury.

1.2.2 General Safety Information



WARNING - Risk Of Electric Shock

Do not open the instrument case! There are no user-serviceable components within the instrument case.

Dangerous voltages may be present whenever the power cord or external input/relay connectors are present.

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.

1.2.3 Earth Ground

The IC/5 is connected to earth ground through 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 terminal.



WARNING - Risk Of Electric Shock

Never interrupt the protective earth circuit.

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



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

1.2.4 Main Power Connection



WARNING - Risk Of Electric Shock

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

Never remove the covers from the instrument during normal operation.

There are no operator-serviceable items within this instrument.

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

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.

1.3 How To Contact Customer Support

Worldwide support information regarding:

- ◆ Technical Support, to contact an applications engineer with questions regarding INFICON products and applications, or
- ◆ Sales and Customer Service, to contact the INFICON Sales office nearest you, or
- ◆ Repair Service, to contact the INFICON Service Center nearest you,

is available at www.inficon.com.

If you are experiencing a problem with your instrument, please have the following information readily available:

- ◆ the serial number for your instrument,
- ◆ a description of your problem,
- ◆ an explanation of any corrective action that you may have already attempted,
- ◆ and the exact wording of any error messages that you may have received.

To contact Customer Support, see Support at www.inficon.com.

1.3.1 Returning Your Instrument

Do not return any component of your instrument to INFICON without first speaking with a Customer Support Representative. You must obtain a Return Material Authorization (RMA) number from the Customer Support Representative.

If you deliver a package to INFICON without an RMA number, your package will be held and you will be contacted. This will result in delays in servicing your instrument.

Prior to being given an RMA number, you may be required to complete a Declaration Of Contamination (DOC) form if your instrument has been exposed to process materials. DOC forms must be approved by INFICON before an RMA number is issued. INFICON may require that the instrument be sent to a designated decontamination facility, not to the factory. Failure to follow these procedures will delay the repair of your instrument.

1.4 IC/5 Specifications

1.4.1 Measurement

Crystal Frequency	6.0 MHz (new crystal) to 4.5 MHz
Internal Precision	± 0.004657 Hz over 100 ms sample for fundamental and anharmonic frequencies
Thickness & Rate Resolution	0.00577 Å (new crystal); 0.01016 Å (crystal @ 4.5 MHz) over 100 ms sample for material density = 1.0, Z-ratio = 1.0
Thickness Accuracy	0.5% typical, (dependent on process conditions, especially sensor location, material stress, temperature and density)
Frequency Accuracy	± 2 ppm 0-50 °C
Measurement Frequency	10 Hz
Measurement Technique	ModeLock with Auto-Z
User Interface	CRT and limited membrane keypad. All parameters accessible through computer communications. Multiple message areas for indication of states and detailed indication of abnormal and stop conditions.

1.4.2 Screens and Hierarchy

Navigation	
1) Traditional	Six soft keys
2) "Windows" influence	X-tree like function with 4 levels of hide/show.
Structure	Separate screens dedicated to 1) Materials, 2) Layers, 3) Logic, 4) Sensors, 5) Sources, 6) Utility, 7) Maintenance, 8) Communications, 9) Operation

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1.4.3 Set-Up Parameters

# of Processes	50
# of Layers	250 (total)
# of Materials	24
Density	0.100 to 99.99 gm/cc
Z-ratio	0.100 to 15.000 or Automatic
# of Sources	Any of 6 channels
Co-deposition	2 sources may operate concurrently
Control Loop types	(0,1,2) Non-PID, PI, PID
PID Control Mode	Fast or Slow Source
Process Gain	0.01 to 100 Å/sec/%Power
Primary Time Constant	0.010 to 200.0 seconds
System Dead Time	0.010 to 50.000 seconds
Master Tooling Factor	10.0 to 400.0%
Sensor Tooling Factor	10.0 to 400.0%
Sensor Weight	1.0 to 400.0%
Sensors	2 standard, 6 additional w/optional hardware
CrystalSix Position Select	Material designation of position(s)
Sensor Option	Enter 0 for "not used" Enter 1 for "stop if last to fail" Enter 2 for "time power if last to fail" Enter 3 for "stop if failed" Enter 4 for "time power if failed"
Maximum Source Power	0.0 to 99.9%
Power Ramps	2 per material
Power Level	0.0 to 99.9%
Rise Time	00:00 to 99:59 min:sec
Soak Time	00:00 to 99:59 min:sec
Auto Soak 2 Power	Yes/No
Delay Option	(0,1,2,3) None, Shutter Delay, Control Delay, Both
Control Delay Time	00:00 to 99:59

Feed Ramps	1 per material
Feed Power	0.0 to 99.9%
Feed Ramp Time	00:00 to 99:59 min:sec
Feed Time.	00:00 to 99:59 min:sec
Idle Ramps	1 per material
Idle Power.	0.0 to 99.9%
Idle Ramp Time	00:00 to 99:59 min:sec
Aggregate Rate	0.0 to 999.9 Å/sec
Aggregate Multiplier	Yes/No
Final Thickness	0.0 to 999.9 kÅ
Thickness Limit.	0.0 to 999.9 kÅ
Time Limit.	00:00 to 99:59 min:sec
Co-deposition	
Cal Thick.	uncal, 0.000 to 99.99kÅ
Ratio Control.	0 to 99%
RateWatcher®	Sample and Hold Feature
RateWatch Time	00:00 to 99:59 min:sec
RateWatch	Accuracy 1 to 99%
Rate Ramps	2 per layer
New Rate	0 to 999 Å/sec
Start Ramp	0 to 999.9 kÅ
Ramp Time	00:00 to 99:59 min:sec
Crucible Selection	1 to 64, each source

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1.4.4 Display

Type/Color/Size	CRT/ Amber/ 5" H x 9" W
Format	23 kHz Horizontal Scan Rate
Resolution	750 W x 350 H Monochrome
Vertical Scan Rate	50/60 Hz automatically detected
Thickness Display Range.	0.000 to 999.9 kÅ
Thickness Display Resolution	1 Å
Rate Display Range	0.0 to 99.9 Å/sec; 100 to 999 Å/sec
Rate Display Resolution.	0.1 Å for 0 to 99.9 Å/sec 1 Å for 100 to 999 Å/sec
Power Display Range.	0.0 to 99.9%
Graphic Display Functions	Rate Deviation at ± 10 or ± 20 Å/sec or Power at 0 to 100%
Display Data Update Rate	1 Hz

1.4.5 Source / Recorder Outputs

Quantity	6 BNC
Configuration	User programmable for recorder or source control.
Function Ranges	
Source Control	0 to 10 V, 0 to -10 V, 0 to 5 V, 0 to -5 V, 0 to 2.5 V, 0 to -2.5 V
Recorder Output	0 to 10 V
Current rating	20 mA per channel
Resolution	15 bits over full range (10 V)
Update Rate	10 Hz, maximum, (dependent on source characteristics).
Recorder Output Functions	Aggregate Rate or Thickness or Rate Deviation; Individual Sensor Rate, Thickness or Rate Deviation; or Source Power.
Recorder Output Ranges	
Rate	0 to 100 Å/sec, 0 to 1000 Å/sec
Thickness	0 to 100 Å, 0 to 1000 Å
Rate Deviation	Desired rate \pm 50 Å/sec
Accuracy	\pm 3% full scale
Zero Adjust	Individual potentiometer

1.4.6 Logic Processing

Type	If/Then statements
Logical Functions	And; Or; Not; Parentheses; ON
Depth	5 "If" conditions and 5 "Then" results/actions per statement
# of Statements	100 If/Then
Selectable events	Deposition monitor events, states, external inputs, relays, timers, and counters.
Hierarchy	Statements evaluated in numerical order at 10 Hz any time the unit is on.
Partitioning	None
Initialization	All outputs transition to their normal states as early as possible during power-on initialization sequence.

1.4.7 Relays / Inputs

Relays	SPST 2.5 A relays rated @ 30 V(dc) or 30 V(ac) RMS or 42 V(peak) maximum; (8 standard, up to 16 optional with 2 additional I/O cards); D sub connector; relays are normally open in the power off state, but may be programmed to normally open or normally closed during operation.
Relay Ratings	100 VA inductive; 2.5A maximum.
# of TTL Compatible Outputs	14 with optional I/O card. Internally pulled up to 5 V(dc). May be pulled up externally to 24 V(dc) through 2.4k resistor. minimum high level 0.5mA load @3.75 V maximum low level 10mA load @1.1 V
Inputs (TTL Compatible).	(14 standard, 14 additional optional)
Input Levels	
maximum high	24 V
minimum high	2.5 V
maximum low	1.1 V
Scan/Update Rate	10 Hz

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1.4.8 Remote Communications

RS232C Serial Port	Standard; INFICON protocol
Baud Rates	19,200; 9,600; 4,800; 2,400
IEEE488 Parallel Port	Optional
IEEE Service Requests	Supported with RQS and MAV status bits

1.4.9 Accessories

Manual Power	Front panel
Control Connection	
Function	Handheld, increase/decrease/stop
Floppy (Optional)	3.5", 1.44 MByte for process and datalog storage
Connector Kit	Connectors for inputs and relays
Operating Manual	3-ring binder type

1.4.10 Power

Power	100 +10%, -15% V(ac) 50/60 Hz
	120 +10%, -10% V(ac) 50/60 Hz
	230 +10%, -10% V(ac) 50/60 Hz
	240 +10%, -15% V(ac) 50/60 Hz
Maximum apparent power	300 VA
Fuse	100 V(ac), 120 V(ac) use 4 Amp IEC 127 approved type T
	230 V(ac), 240 V(ac) use 2 Amp IEC 127 approved type T

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1.4.11 Operating Environment

- Usage Indoor only
- Temperature 0 to 50 °C (32-122 °F)
- Humidity Up to 85%RH, non-condensing
- Altitude Up to 2000 meters
- Installation (Overvoltage) Category II per IEC 664
- Pollution Degree 1 per IEC 664

1.4.12 Storage Temperature

- Storage Temperature -10 to 60 °C (14 to 140 °F)

1.4.13 Warm Up Period

- Warm Up Period None required;
For maximum stability allow 5 minutes.

1.4.14 Size

- Not including mounts or user connectors
 - 5.25" H x 17.625" W x 18.5" D
(133.4 mm H x 447.7 mm W x 470 mm D)
- Including mounts, but no user connectors
 - 5.25" H x 18.85" W x 18.5" D
(133.4 mm H x 478.8 mm W x 470 mm D)

1.4.15 Connector Clearance Requirements

- Front Less than 1.0" (25.4 mm)
- Rear Less than 4.0" (101.6 mm)

1.4.16 Weight

- With all options 13.2 kg / 29 lb

1.4.17 Cleaning

Use a mild, nonabrasive cleaner or detergent taking care to prevent cleaner from entering the unit.

1.5 Unpacking and Inspection

- 1 If the IC/5 control unit has not been removed from its shipping container, do so now.
- 2 Carefully examine the unit for damage that may have occurred during shipping. This is especially important if you notice obvious rough handling on the outside of the container. *Immediately report any damage to the carrier and to INFICON.*
- 3 Do not discard the packing materials until you have taken inventory and have at least performed a power on verification.
- 4 Take an inventory of your order by referring to your order invoice and the information contained in [section 1.6 on page 1-15](#).
- 5 To perform a power-on verification, see [section 1.7 on page 1-18](#).
- 6 For additional information or technical assistance, contact your nearest INFICON Inc. sales office.

1.6 Parts and Options Overview

1.6.1 Base Configurations

IC/5 Control Unit	760-500-G1 (100 V(ac) 50/60 Hz) 760-500-G2 (120 V(ac) 50/60 Hz) 760-500-G3 (230 V(ac) 50/60 Hz) 760-500-G4 (240 V(ac) 50/60 Hz)
Technical Manual	074-237
Hand Controller	755-262-G1
I/O Relay Ship Kit	760-024-G1
Input/Relay Interface Connectors. . .	(8 relay outputs, 14 TTL inputs)
Power Cord	068-0433 (shielded power cord - North America) 068-0434 (shielded power cord - European)
Ship Kit	760-020-G1 (100 V(ac), 120 V(ac)) 760-020-G2 (230 V(ac), 240 V(ac))

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1.6.2 Pre-installed Options or Spares

Additional Sensor Module	760-1132-G1 (up to 3 extra)
Relay Card	760-162-G1 (8 relay outputs, 14 TTL inputs)
Relay Card	760-162-G2 (8 relay outputs, 14 TTL outputs)
I/O Relay Ship Kit	760-024-G1 (8 relay outputs, 14 TTL inputs) 760-024-G2 (8 relay outputs, 14 TTL outputs)
IEEE488 Parallel	760-142-G1 Communications
Floppy disk	760-023-G1

1.6.3 Optional Accessories

IC/5 15' Oscillator Kit	760-025-G15
IC/5 30' Oscillator Kit	760-025-G30
IC/5 50' Oscillator Kit	760-025-G50
IC/5 100' Oscillator Kit	760-025-6100
Oscillator to vacuum	755-257-G6 feedthrough cable, 6"
IC/5 Unit to Oscillator Cable 15'	600-1039-G15
IC/5 Unit to Oscillator Cable, 30'	600-1039-G30
IC/5 Unit to Oscillator Cable, 50'	600-1039-G50
IC/5 Unit to Oscillator Cable, 100' . . .	600-1039-6100
Pneumatic Shutter Actuator	750-420-G1 Control Valve
Sensor Emulator Kit	760-601-G2
IC/5 Offline Editor Software	760-030-G1

Adapter Cables

IC/5 to IC/4 Kit	600-1084-P1 (Relays and Inputs - for IC/4 or IC/4 PLUS)
DAC, IC/5 to IC/4 Kit.	600-1049-P1 (IC/5 to IC/4 Analog Outputs - for IC/4 or IC/4 PLUS)
IC/5 to IC6000 Kit	600-1083-P1 (Relays and Inputs)

1.6.4 Oscillator Packages and Sensors

IC/5 Oscillator, 15' and 6" cable pkg.	760-025-G15
IC/5 Oscillator, 30' and 6" cable pkg.	760-025-G30
IC/5 Oscillator, 50' and 6" cable pkg.	760-025-G50
IC/5 Oscillator, 100' and 6" cable pkg.	760-025-G100
4 Meter Oscillator Kit	4XI5-nnn
for operation with 3 to 4 m long in-vacuum cable, contact factory for part number	
Standard Sensor.	750-211-G1
Standard Sensor with Shutter.	750-211-G2
Compact Sensor.	750-213-G1
Compact Sensor with Shutter.	750-213-G2
Sputtering Sensor.	750-618-G1
UHV Bakeable Sensor, 12"	007-219
UHV Bakeable Sensor, 20"	007-220
UHV Bakeable Sensor, 30"	007-221
UHV Bakeable Sensor with Shutter, 12"	750-012-G1
UHV Bakeable Sensor with Shutter, 20"	750-012-G2
UHV Bakeable Sensor with Shutter, 30"	750-012-G3
Dual Sensor	750-212-G2
CrystalSix Multiple Sensor	750-446-G1

NOTE: Contact INFICON for a complete listing of oscillators and sensors.

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1.7 Initial Power-On Verification

A preliminary functional check of the instrument can be made before formal installation. It is not necessary to have sensors, source controls, inputs or relays connected to do this. For more complete installation information, refer to [Chapter 11, Installation and Interfaces](#) and to [Chapter 12, Calibration Procedures](#).



WARNING - Risk Of Electric Shock

There are no user-serviceable components within the instrument case.

Dangerous voltages may be present whenever the power cord or external input/relay connectors are present.

Refer all maintenance to qualified personnel.



WARNING - Risk Of Electric Shock

Never interrupt the protective earth circuit.

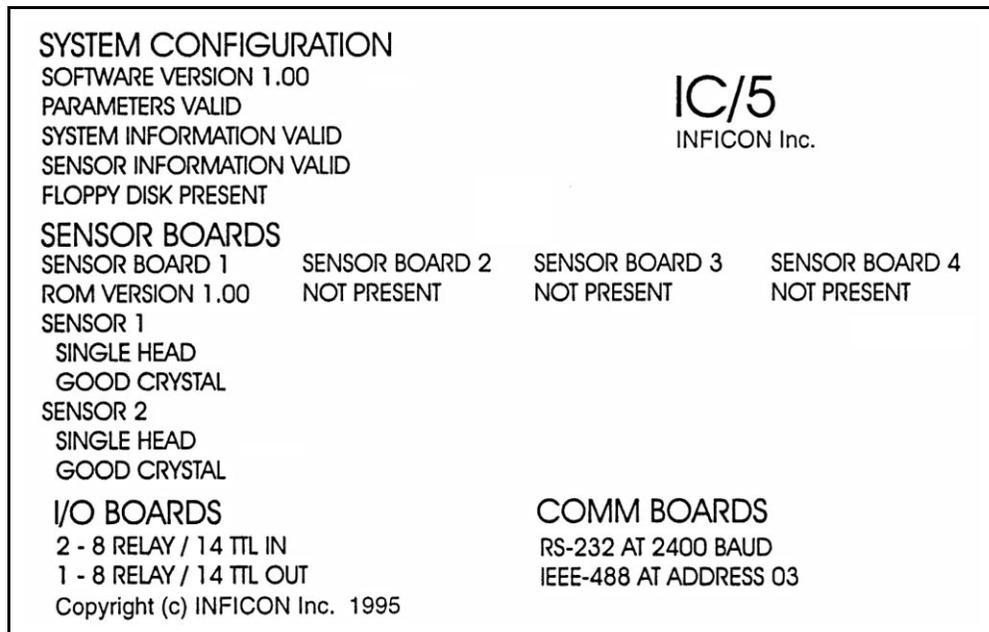
Any interruption of the protective earth circuit inside or outside the instrument, or disconnection of the protective earth terminal is likely to make the instrument dangerous.



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

- 1 Confirm that AC line voltage is supplied and proper for the instrument. Line voltage should be indicated on the instrument back label.
- 2 Press the power button on the front panel. A green pilot light should be seen next to the power switch.
- 3 The fan at the back of the instrument should be exhausting air.
- 4 Video monitor will display an image similar to the one shown in [Figure 1-1](#).
- 5 Compare the configuration information on the screen against the unit configuration ordered.
- 6 Status of parameter information will be displayed. If information was valid prior to this power up, it should stay valid.
- 7 After a delay, the instrument will enter the OPERATE display.
- 8 In the OPERATE display, confirm that the display is centered vertically. Lines between the function keys (F1...F6) should align with the lines between the panels on the right side of the display.
- 9 Using a non-conducting alignment tool, verify that the brightness pot is operative. Adjust for the desired brightness. Access to the brightness pot is at the bottom-center of the face panel, see [Figure 3-1 on page 3-1](#).

Figure 1-1 IC/5 System Status Screen (Display will vary depending on options present)



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Chapter 2

Measurement and Control Theory

2.1 Basics

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

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

$$\frac{M_f}{M_q} = \frac{(\Delta F)}{F_q} \quad [1]$$

where M_q is the mass of the uncoated quartz crystal. Simple substitutions lead to the equation that was used with the first "frequency measurement" instruments:

$$T_f = \frac{K(\Delta F)}{d_f} \quad [2]$$

where the film thickness, T_f , is proportional (through K) to the frequency change, ΔF , and inversely proportional to the density of the film, d_f . The constant, $K = N_{at}d_q/F_q^2$; where $d_q (= 2.649 \text{ gm/cm}^3)$ is the density of single crystal quartz and $N_{at} (= 166100 \text{ Hz cm})$ is the frequency constant of AT cut quartz. A crystal with a starting frequency of 6.0 MHz will display a reduction of its frequency by 2.27 Hz when 1 angstrom of Aluminum (density of 2.77 gm/cm^3) is added to its surface. In this manner the thickness of a rigid adlayer is inferred from the precise

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

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

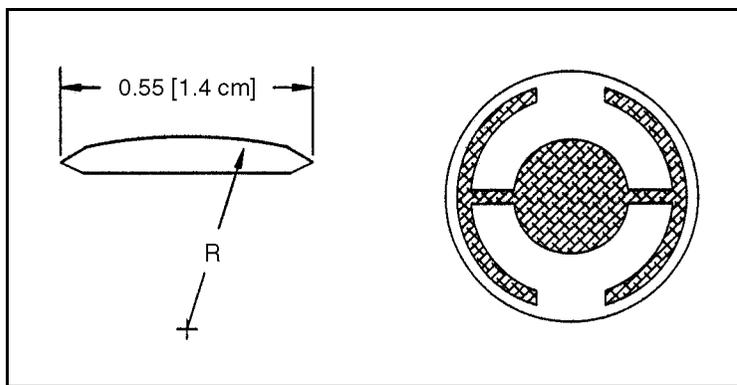
3.P. Lostis, Rev. Opt. 38,1 (1959)

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.

2.1.1 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 2-1](#) has a frequency response spectrum that is schematically shown in [Figure 2-2](#). The ordinate represents the magnitude of response, or current flow of the crystal, at the specified frequency.

Figure 2-1 Quartz Resonator

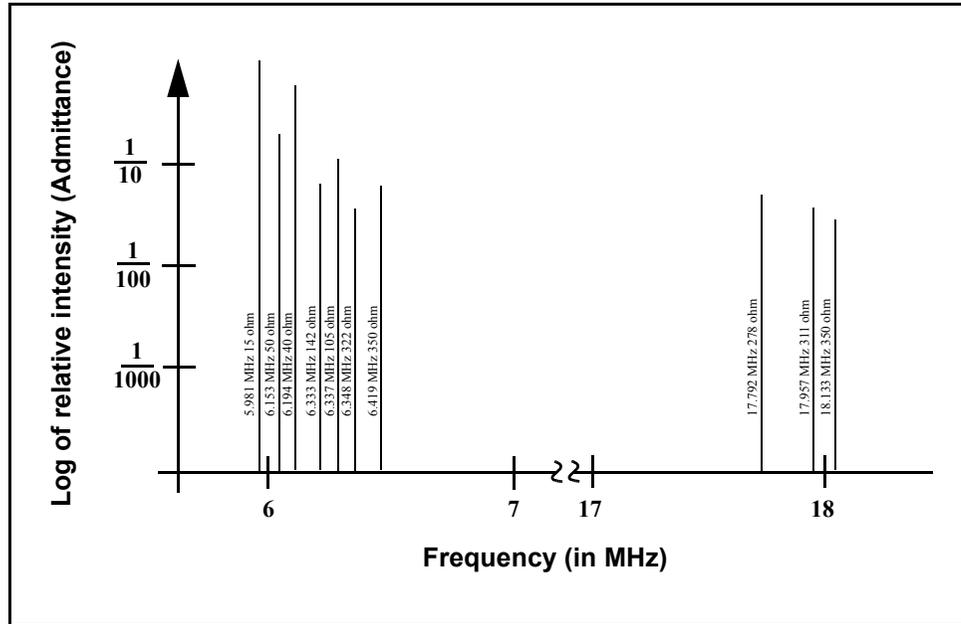


The lowest frequency response is primarily a “thickness shear” mode that is called the fundamental. The characteristic movement of the thickness shear mode is for displacement to take place parallel to the major monitor crystal faces. In other words, the faces are displacement antinodes as shown in [Figure 2-3](#). The responses located slightly higher in frequency are called anharmonics; they are a combination of the thickness shear and thickness twist modes. The response at about three times the frequency of the fundamental is called the third quasiharmonic. There are also a series of anharmonics slightly higher in frequency associated with the quasiharmonic.

The monitor crystal design depicted in [Figure 2-1](#) 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.

Figure 2-2 Frequency Response Spectrum

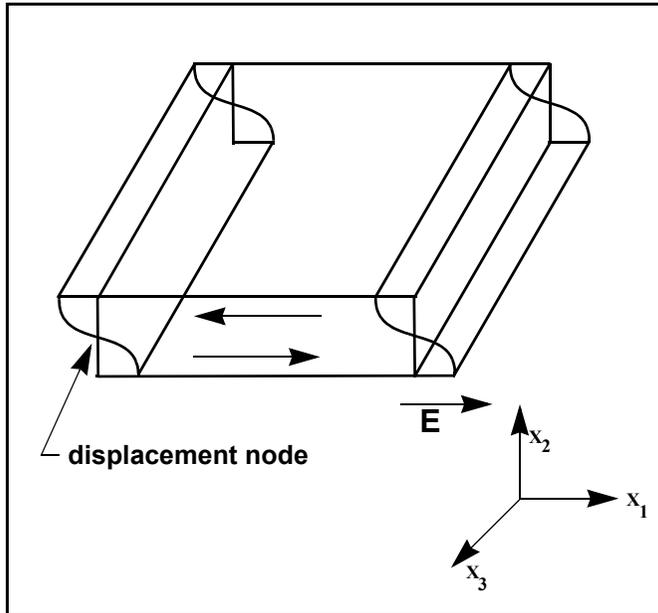


The use of an adhesion layer has improved the electrode-to-quartz bonding, reducing “rate spikes” caused by micro-tears between the electrode and the quartz as film stress rises. These micro-tears leave portions of the deposited film unattached and therefore unable to participate in the oscillation. 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.

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Figure 2-3 Thickness Shear Displacement



2.1.2 Period Measurement Technique

Although instruments using equation [2] were very useful, it was soon noted they had a very limited range of accuracy, typically holding accuracy for DF less than $0.02 F_q$. In 1961 it was recognized by Behrndt⁴ that:

$$\frac{M_f}{M_q} = \frac{(T_c - T_q)}{T_q} = \frac{(\Delta F)}{F_c} \quad [3]$$

where T_c and T_q are the periods of oscillation of the crystal with film (composite) 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

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

monitor crystal's period is $(n/F_r)/m$ where n is the number of counts in the second accumulator. The precision of the measurement is determined by the speed of the reference clock and the length of the gate time (which is set by the size of m). Increasing one or both of these leads to improved measurement precision.

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

2.1.3 Z-match Technique

After learning of fundamental work by Miller and Bolef⁵, which rigorously treated the resonating quartz and deposited film system as a one-dimensional continuous acoustic resonator, Lu and Lewis⁶ developed the simplifying Z-match™ equation in 1972. Advances in electronics taking place at the same time, namely the micro-processor, made it practical to solve the Z-match equation in “real-time”. Most deposition process controllers sold today use this sophisticated equation that takes into account the acoustic properties of the resonating quartz and film system as shown in [equation \[4\]](#).

$$T_f = \left(\frac{N_{at}d_q}{\pi d_f F_c Z} \right) \arctan \left(Z \tan \left[\frac{\pi(F_q - F_c)}{F_q} \right] \right) \quad [4]$$

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

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

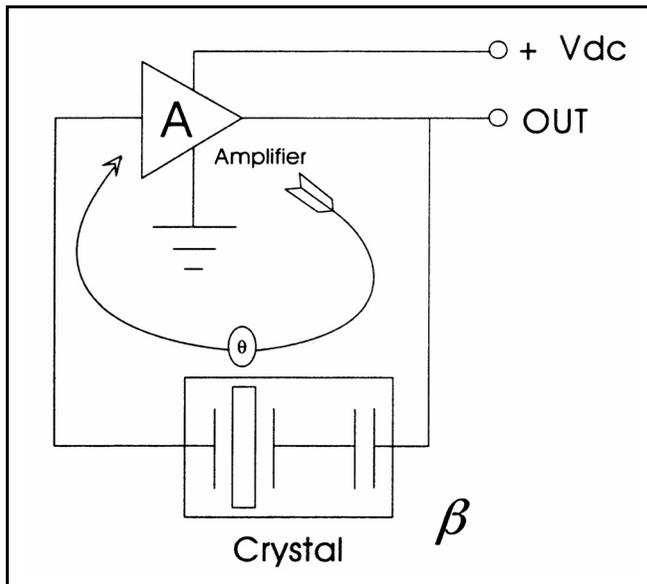
6.C. Lu and O. Lewis, J Appl. Phys. 43, 4385 (1972)

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 \[2\]](#) was valid to only $0.02F_q$ and [equation \[3\]](#) was valid only to $\sim 0.05F_q$.

2.1.4 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 2-4](#). This circuit actively keeps the crystal in resonance, so that any type of period or frequency measurement may be made. In this type of circuit, oscillation is sustained as long as the gain provided by the amplifiers is sufficient to offset losses in the crystal and circuit and the crystal can provide the required phase shift. 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 2-5 on page 2-7](#).

Figure 2-4 Active Oscillator Circuit



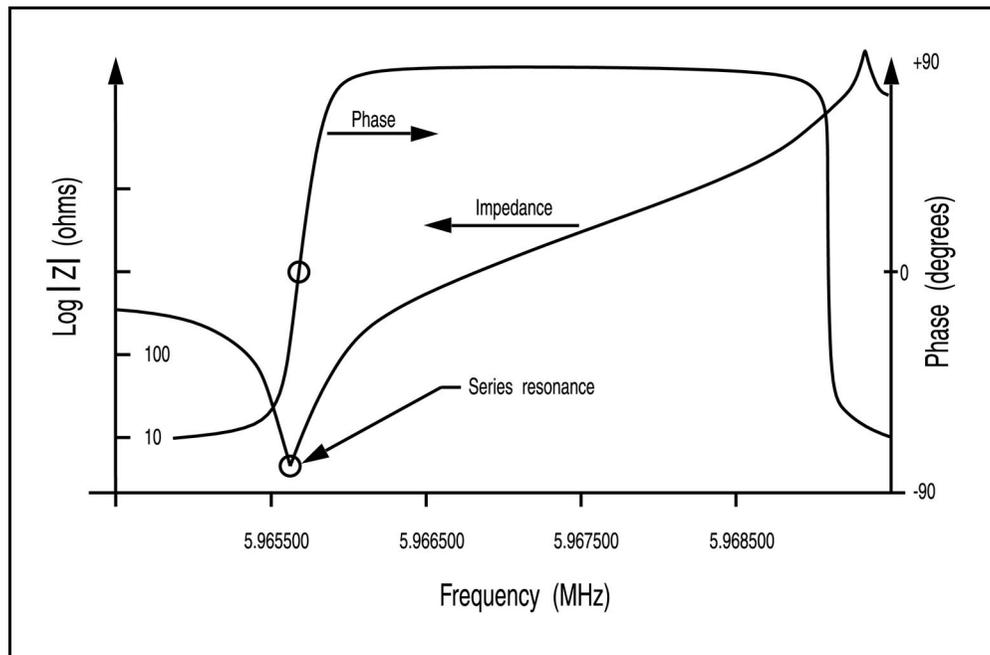
The active oscillator circuit is designed so the crystal is required to produce a phase shift of 0 degrees, which allows it to operate at the series resonance point. Long- and short-term frequency stabilities are a property of crystal oscillators because very small frequency changes are needed to sustain 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 2-6 on page 2-8](#) is the same plot as [Figure 2-5](#) overlaid with the response of a heavily loaded crystal. The crystal has lost the steep slope displayed in [Figure 2-5](#). 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 2-5 Crystal Frequency Near Series Resonance Point

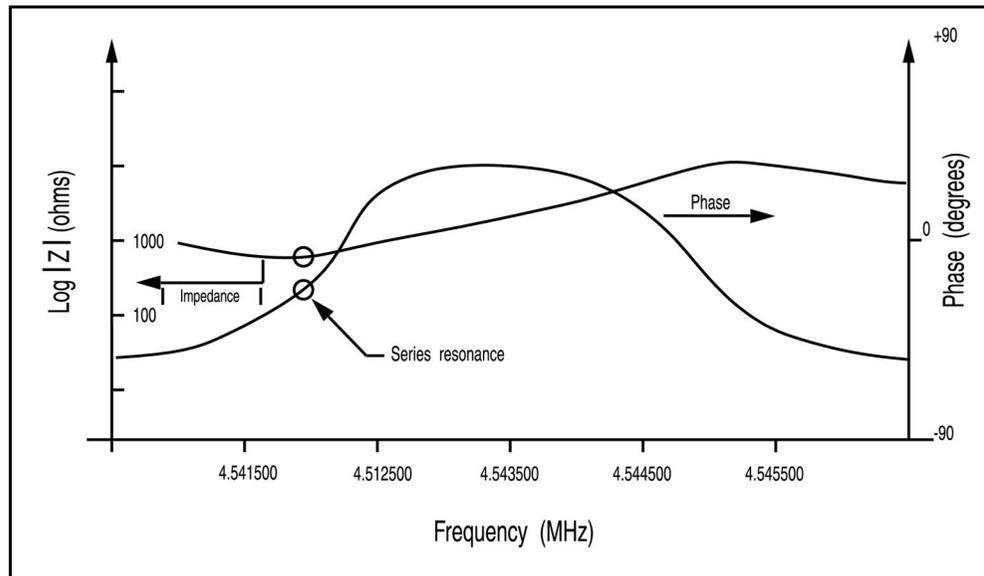


2.1.5 ModeLock Oscillator

INFICON has created a new technology 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 .005 Hz at a rate of 10 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 new "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.

Figure 2-6 Heavily Loaded Crystal



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 and precision of measurement. The technique also allows the implementation of a sophisticated feature that cannot even be contemplated using the active oscillator approach. The same capability that allows the new technology to sweep and identify the fundamental can be used to identify other oscillation modes, such as the anharmonics and the quasiharmonic. Not only can the instrument track the

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fundamental mode continuously, but also it can be implemented to alternate between one or more other modes. This interrogation of multiple modes can be performed as fast as 10 Hz for two modes of the same crystal.

2.1.6 Auto Z-match Theory

The one drawback in using [equation \[4\] on page 2-5](#) is that the acoustic impedance must be known. There are several cases where accuracy has to be compromised because of incomplete or limited knowledge of the material constants of the deposited materials.

- ♦ Often the Z-ratio for the bulk material is different from that of the deposited thin film. Thin films are especially sensitive to process parameters, particularly in a sputtering environment. Consequently, the values available for bulk materials may not be pertinent.
- ♦ For many exotic materials, including alloys, the Z-ratio is not known nor easily available.
- ♦ There has always been a need to accurately measure layer thickness of multiple material films using the same crystal sensor. This is particularly true for multi-layer optical coatings and high-temperature superconductor fabrication. The effective Z-ratio of the composite of multi-material layers is not known.

In such cases, the only recourse is to assume the Z-ratio to be unity (that is, ignoring the reality of wave propagation in composite media). This false premise introduces error in the thickness and rate predictions. The magnitude of this error depends upon the film thickness and the amount of departure of the true Z-ratio from unity.

In 1989, A. Wajid became aware of the ModeLock oscillator⁷. He speculated there might be a relationship between the fundamental and one of the anharmonics similar to the relationship noted by Benes⁸ between the fundamental and the third quasiharmonic. The frequencies of the fundamental and the anharmonics are very similar, solving the problem of capacitance of long cables. He found the ideas needed for establishing the required connections in papers published by Wilson⁹ in 1974 and Tiersten and Smythe¹⁰ in 1979.

Contouring a crystal, that is, giving one face a spherical shape, has the effect of separating the various modes further apart and preventing the transfer of energy from one mode to another. For the sake of identification it is common to assign mode [100] to the fundamental, [102] to the lowest frequency anharmonic and [120] to the next lowest frequency anharmonic. The three indices of the mode

7.U.S. Patent No. 5,117,192 (May 26, 1992) International Patents Pending.

8.E. Benes, J. Appl. Phys. 56(3), 608-626 (1984)

9.C. J. Wilson, J. Phys. d7,2449 (1974)

10.H. F. Tiersten and R.C. Smythe, J. Acoust. Soc. Am., 65(6), 1455 (1979).

assignment refer to the number of phase reversals in the wave motion along the three axes of the crystal. The above-referenced papers by Wilson and Tiersten & Smythe are examinations of modal properties, relating the various properties of the radius of curvature to the placement of the anharmonics relative to the fundamental.

As material is deposited upon one face of a crystal, the entire spectrum of resonances shifts to lower frequencies. The three above mentioned modes are observed to have slightly different mass sensitivity and hence undergo slightly different frequency shifts. It is this difference that is used to estimate the Z-ratio of the material. Using the modal equations and the observed frequencies of the modes [100] and [102], one can calculate the ratio of two elastic constants C_{66} and C_{55} . Both of these elastic constants relate to shear motion. The essential element of Wajid's theory is the following equation:

$$\frac{(C_{55}/C_{66})_{\text{coated}}}{(C_{55}/C_{66})_{\text{uncoated}}} \sim \frac{1}{(1 + MZ)} \quad [5]$$

where M is the aerial mass density (film mass to quartz mass ratio per unit area) and Z is the Z-ratio. It is a fortunate coincidence that the combination MZ also appears in the Lu-Lewis [equation \[4\]](#), which can be used to extract an estimate of the effective Z-ratio from the equations below:

$$\tan\left(MZ\pi\frac{F_c}{F_q}\right) + Z \tan\left(\pi\frac{F_c}{F_q}\right) = 0 \quad [6]$$

or

$$Z = -\frac{\tan\left(MZ\pi\frac{F_c}{F_q}\right)}{\tan\left(\pi\frac{F_c}{F_q}\right)} \quad [7]$$

Where, F_q and F_c denote uncoated and coated crystal frequencies in the fundamental mode (mode [100]). Due to the multi-valued nature of the mathematical functions involved, the value of Z-ratio extracted in this manner is not always a positive definite quantity. This is hardly of any consequence however, because M is uniquely determined with the estimated Z and the measured frequency shift. Thus, thickness and rate of deposition are subsequently calculated from the knowledge of M.¹¹

One must be aware of the limitations of this technique. Since the estimate for Z-ratio is dependent on the frequency shifts of the two modes, any spurious shift due to excessive mechanical or thermal stress on the crystal will lead to errors.

11.U.S. Patent No. 5,112,642 (May 12, 1992) International Patents Pending.

Needless to say, similar errors occur with the Z-match™ technique under similar circumstances. However, the automatic Z-ratio estimate is somewhat more prone to error, because the amplitude distribution of the mode [102] is asymmetric, whereas that of the mode [100] is symmetric over the active area of the crystal.

In our experience, film-induced stress on the crystal has the most deleterious effect. This effect is most pronounced whenever there is a presence of gas in the environment, for example, in reactive evaporation or sputtering processes. In such cases, if the bulk Z-ratio is already well known, it is better to use the bulk value instead of the automatically determined Auto Z-ratio. In cases of co-deposition and sequential layers, automatic Z-ratio estimation is significantly superior.

2.1.7 Control Loop Theory

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

The controller model most commonly chosen, for converting error into action is called PID. In the PID, P stands for proportional, I stands for integral and D stands for derivative action. Certain aspects of this model will be examined in detail a little further on. The responsiveness of an evaporation source can be found by repetitively observing the system response to a disturbance under a particular set of controller settings. After observing the response, improved controller parameters are estimated and then tried again until satisfactory control is obtained. Control, when it is finally optimized, essentially matches the parameters of the controller model to the characteristics of the evaporation source.

It is quite laborious and frustrating to tune a controller for an evaporation source that takes several minutes to stabilize. It may take several hours to obtain satisfactory results. Often the parameters chosen for a specific rate will not be satisfactory for another. Ideally, it would be nice if a machine could optimize itself. INFICON's IC/5 can do this. In an operator initiated mode that is used during initial setup the instrument will measure the source characteristics. Slow sources are characterized by having significant dead time, whereas fast sources have no dead time.

For a slow source, the IC/5 will use a PID model to calculate optimum source control parameters. For a fast source, the IC/5 will use an integrating control loop model to calculate optimum source control parameters

Techniques for calculating optimum source control parameters can be classified by the type of data used for tuning. They fall into basically three categories:

- ◆ Closed Loop Methods
- ◆ Open Loop Methods
- ◆ Frequency Response Methods

Of these categories, the open loop methods are considered superior. They are considered superior because of the ease with which the necessary experimental data can be obtained and because of the elimination (to a large extent) of trial and error when the technique is applied.

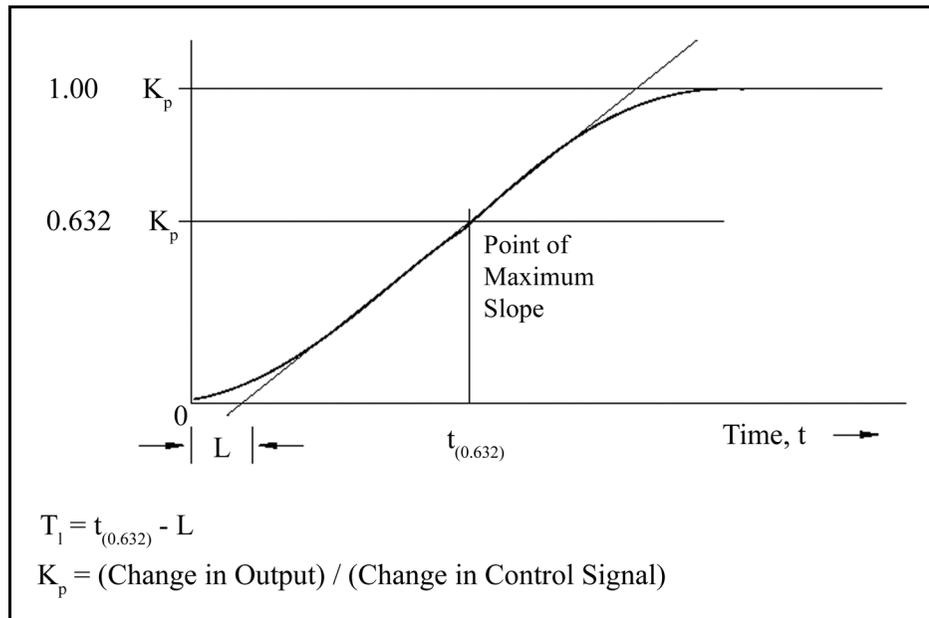
INFICON's Auto-Control-Tune characterizes a process from its step response attributes. After Auto-Control-Tune executes a step change of power, the resulting rate changes are smoothed and stored. The important response characteristics are determined as shown in [Figure 2-7](#).

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

$$\frac{\text{Output}}{\text{Input}} = \frac{K_p \exp(-Ls)}{T_1 s + 1} \quad [8]$$

Three parameters are determined from the process reaction curve. They are the steady state gain, K_p , the dead time, L , and the time constant, T_1 . Several methods have been proposed to extract the required parameters from the system response as graphed in [Figure 2-7](#). These are: a one point fit at 63.2% of the transition (one time constant); a two point exponential fit; and a weighted least-square-exponential fit. From the above information a process is sufficiently characterized so that a controller algorithm may be customized.

Figure 2-7 Response of Process To An Open Loop Step Change
(At $t=0$ Control Signal is Increased)



A controller model used extensively is the PID type, shown in Laplace form in [equation \[9\]](#).

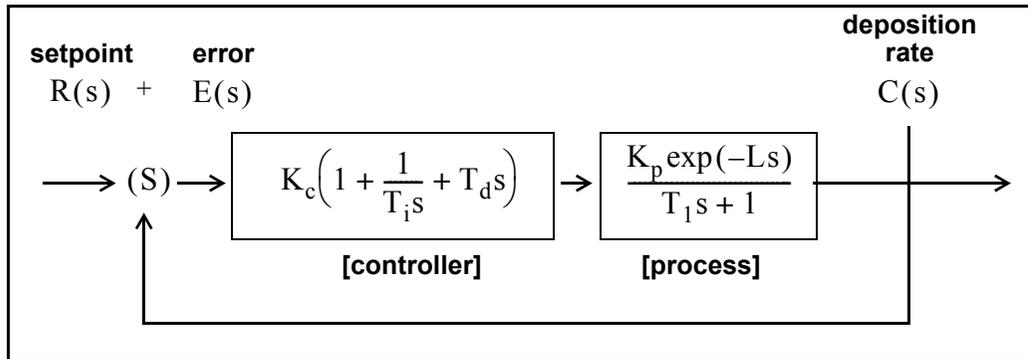
$$M(s) = K_c \left(1 + \frac{1}{T_i s} + T_d s \right) E s \quad [9]$$

Where

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

[Figure 2-8](#) represents the controller algorithm and a process with first order lag plus a dead time. The process block implicitly includes the dynamics of the measuring devices and the final control elements, in our case the evaporator power supply. $R(s)$ represents the rate setpoint. The feedback mechanism is the error generated by the difference between the measured deposition rate, $C(s)$, and the rate set point, $R(s)$.

Figure 2-8 PID Controller Block Diagram



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

The integral of the squared error (ISE) is a commonly proposed criterion of performance for control systems.

It can be described as:

$$ISE = \int e^2(t)dt \tag{10}$$

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

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

$$IAE = \int |e(t)|dt \tag{11}$$

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

Graham and Lathrop¹² introduced the integral of time multiplied by the absolute error (ITAE) as an alternate criterion of performance:

$$ITAE = \int t|e(t)|dt \tag{12}$$

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

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

INFICON's Auto-Control-Tune is based on an open loop measurement of the system's response. From a step change in the control signal, the response characteristics of the system are calculated. The experimental determination of response characteristics is accomplished through two types of 2-point curve fits. They are determined either quickly, but less accurately (i.e., "Quick Tune") at an arbitrary deposition rate, or less quickly, but more accurately (i.e., "Complete Tune") near the desired rate setpoint. Since the process response characteristics depend on the position of the system (i.e. deposition rate for this discussion), the process response is best measured at the desired operating point of the system. This measured process information (i.e. process gain, K_p , time constant, T_1 , and dead time, L) is used to generate the best fitting PID control loop parameters for the specific system.

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

$$K_c = (1.36/K_p)(L/T_1)^{-0.947} \quad [13]$$

$$T_i = (1.19T_1)(L/T_1)^{0.738} \quad [14]$$

$$T_d = (0.381T_1)(L/T_1)^{0.995} \quad [15]$$

For slow systems, in order to help avoid controller windup (windup is the rapid increase in control signal before the system has the chance to respond to the changed signal), the time period between manipulated variable (control voltage) changes is lengthened. This allows the system to respond to the previous controller setting change, and aggressive controller settings can be used. A secondary advantage is that immunity to process noise is increased since the data used for control is now comprised of multiple readings instead of a single rate measurement, taking advantage of the mass integrating nature of the quartz crystal.

With process systems that respond quickly (short time constant) and with little to no measurable dead time, the PID controller often has difficulty with the deposition process noise (beam sweep, fast thermal shorts of melt to crucible, etc.). In these situations a control algorithm used successfully is an integral/reset type of controller. This type of controller will always integrate the error, driving the system

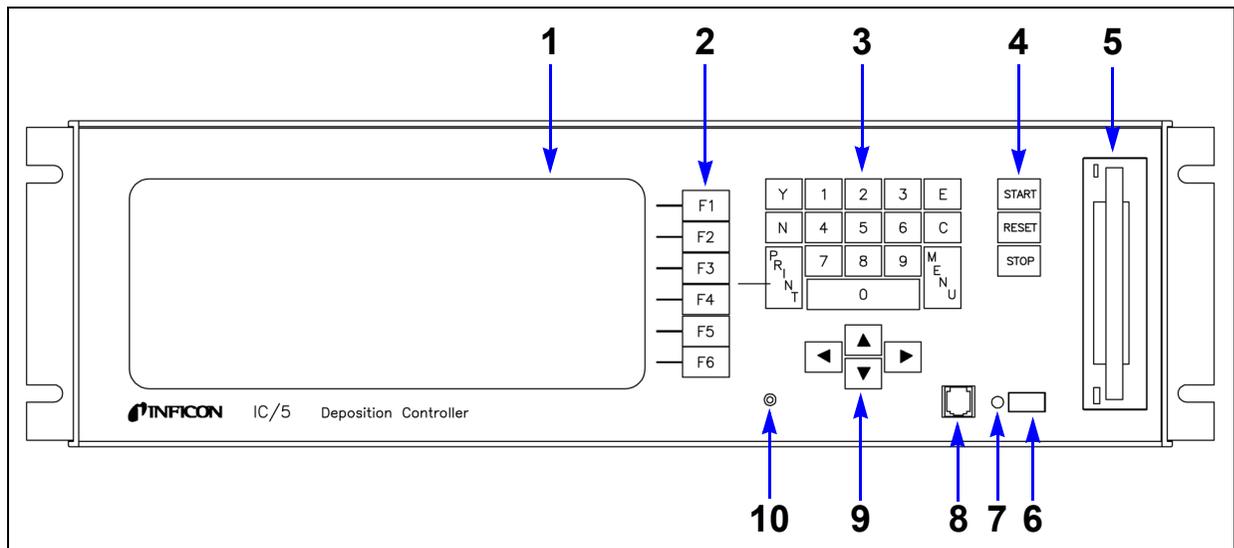
towards zero error. This technique works well when there is little or no dead time. If this technique is used on a process with measurable lag or dead time, then the control loop will tend to be oscillatory due to the control loop over-compensating the control signal before the system has a chance to respond. Auto-Control-Tune detects the characteristics of these fast response systems during measurement of the step response. This information is used to calculate the controller gain coefficient for the non-PID control algorithm.

Chapter 3 Operation

3.1 Front Panel Controls

Operational controls for the IC/5 are located on the front panel of the instrument, as depicted in Figure 3-1.

Figure 3-1 IC/5 Front Panel



1 CRT Screen

Provides graphical displays, set-up menus, status and error messages.

2 Function Keys

An array of function keys are located adjacent to the screen. These keys are labeled F1 through F6. They are used to select displays or menu items. Their function is indicated on the display and is described in subsequent sections.

3 Data Entry Keys

A keypad array with numerics 0 through 9 and keys for Yes (Y), No (N), Enter (E), Clear (C), Print, and Menu used for selection and parameter entry. All numeric and Yes/No entries need to be followed by Enter. Clear is used to erase data entry errors. If an illegal value has been entered, Clear will erase the error message and re-display the last valid data. The Print Screen key is used to send the display information to the floppy drive. The Menu key is used to navigate through the instrument's displays.

4 System Switches

An array of three keys that provide START, STOP and RESET functions, for process control. See [section 3.4.2 on page 3-23](#).

5 3.5" Floppy Disk Access Port

Receptacle for the optional 3.5", 1.44 MB floppy disk.

6 Power

This switch controls secondary power to the instrument between ON and STANDBY. Power is provided when the button is in its depressed position. The instrument is initialized for approximately 5 seconds before providing an operational screen.

7 Pilot Light

A green pilot light, adjacent to the power switch, is illuminated when power is on.

8 Remote Control Jack

Receptacle for the wired hand-held remote controller.

9 Cursor Keys

An array of four keys that are used to move the display cursor either up, down, left or right. The keys auto-repeat; the cursor will continue to move as long as the key is held down or until a display field boundary is met.

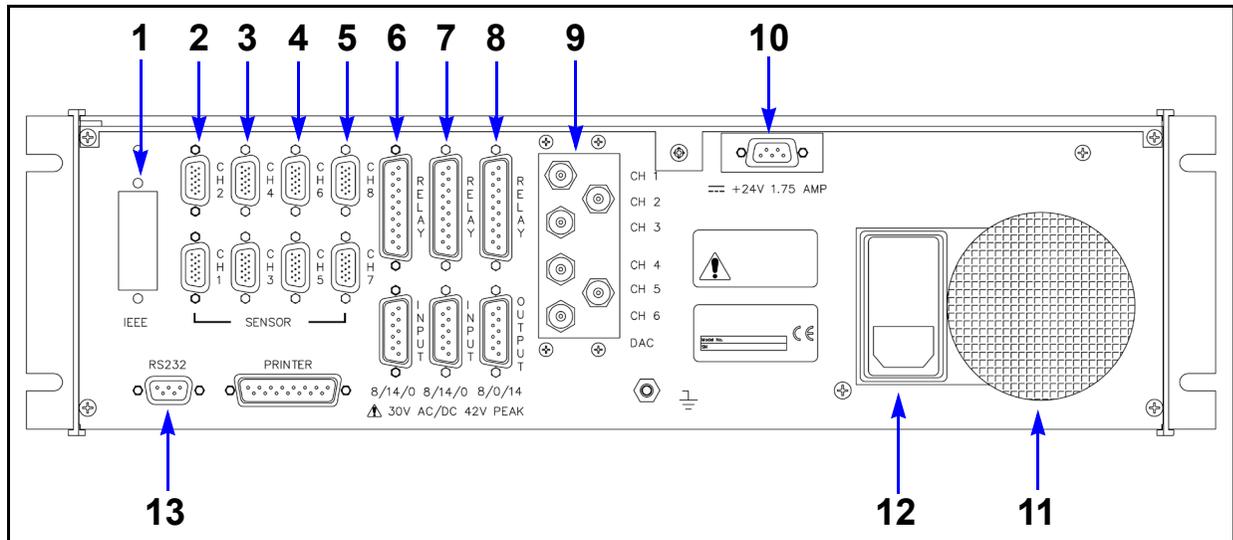
10 Brightness Adjustment

An access hole for the display's brightness adjustment potentiometer. Use a nonconductive TV adjustment tool to increase the brightness by turning the potentiometer clockwise.

3.2 Rear Panel Interfaces

Interfaces for the IC/5 are located on the rear panel of the instrument as depicted in Figure 3-2.

Figure 3-2 IC/5 Rear Panel



1 IEEE488 Connector (Optional)

Provides connections for IEEE-GPIB interface.

2 Sensor Connectors - Channels 1 & 2 (standard)

Provides connection for the unit's two standard sensor channels.

3 Sensor Connectors - Channels 3 & 4 (optional)

Expansion panel to accommodate the optional addition of two more sensors, sensors 3 & 4.

4 Sensor Connectors - Channels 5 & 6 (optional)

Expansion panel to accommodate the optional addition of two more sensors, sensors 5 & 6.

5 Sensor Connectors - Channels 7 & 8 (optional)

Expansion panel to accommodate the optional addition of two more sensors, sensors 7 & 8.

6 8 Relay x 14 Input I/O Card (standard)

Provides pin connection for 8 Relays rated for 30 V(dc) or 30 V(ac) RMS or 42 V(peak) maximum, and 14 TTL Inputs.

7 8 Relay x 14 Input I/O Card (optional)

Provides pin connection for 8 relays rated for 30 V(dc) or 30 V(ac) RMS or 42 V(peak) maximum, and 14 TTL inputs.

8 8 Relay x 14 Output I/O Card (optional)

Provides pin connection for 8 relays rated for 30 V(dc) or 30 V(ac) RMS or 42 V(peak) maximum, and 14 open collector type outputs.

9 6-Channel DAC (standard)

Provides source control voltage or recorder output for 6 channels (BNC connectors). Outputs are programmable for Source Control or Recorder Voltage.

10 24-Volt Supply (standard)

Provides one 24 V(dc) supply rated at 1.75 Amps.

11 Fan Outlet

Exhaust opening for the unit's miniature fan. A grill is attached for safety.

12 AC Power Inlet

Provides a common connector for various international plug sets. The unit is factory set for 100 V(ac), 120 V(ac), 230 V(ac) or 240 V(ac) service.

13 RS-232C Remote Communication Connector (standard)

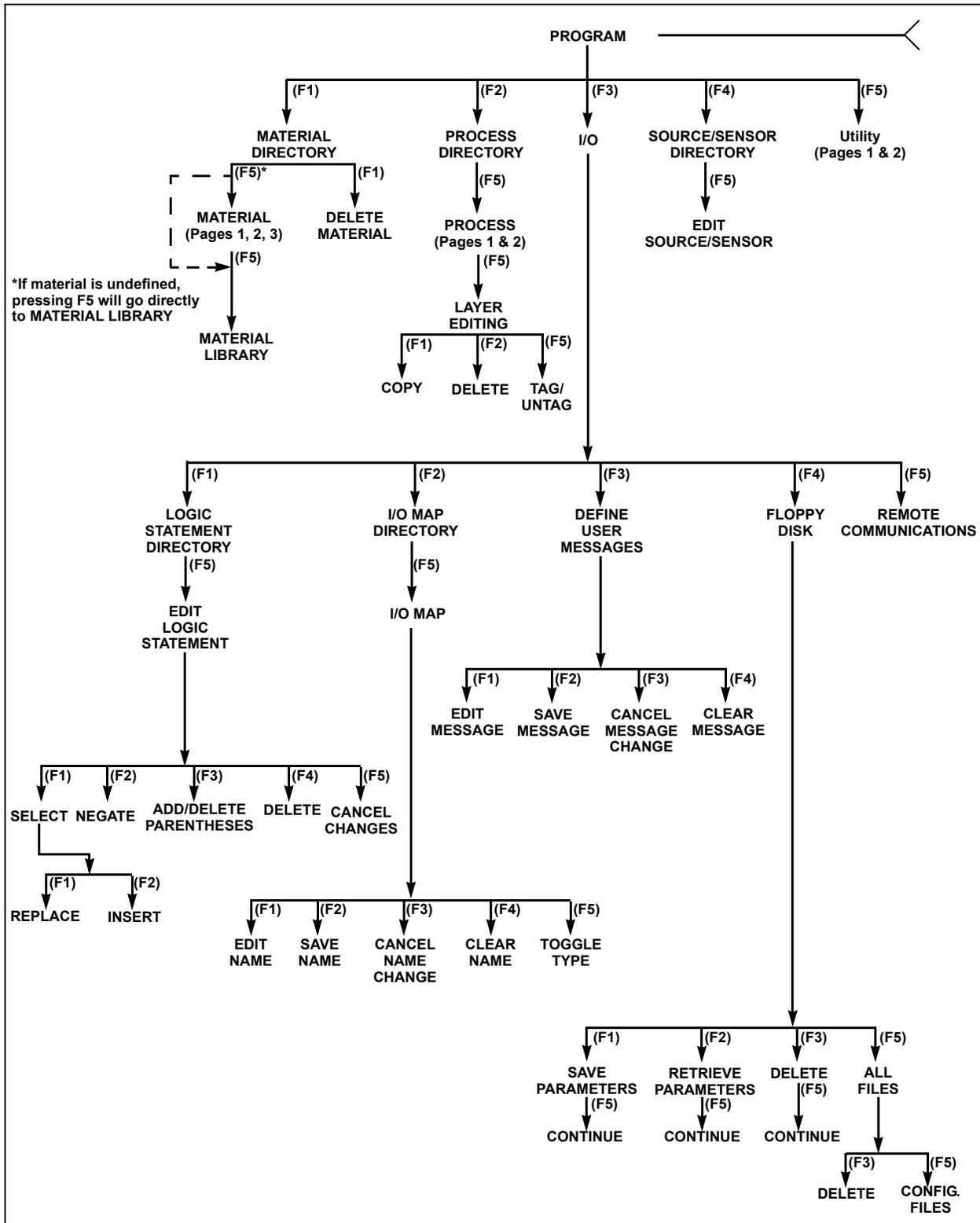
Provides a 9-pin RS-232C communications port.

3.3 Displays

The IC/5 has many display screens for monitoring and programming processes. The four main types of displays are: OPERATE; SENSORS; MAINTENANCE/DIAGNOSTICS; and PROGRAM.

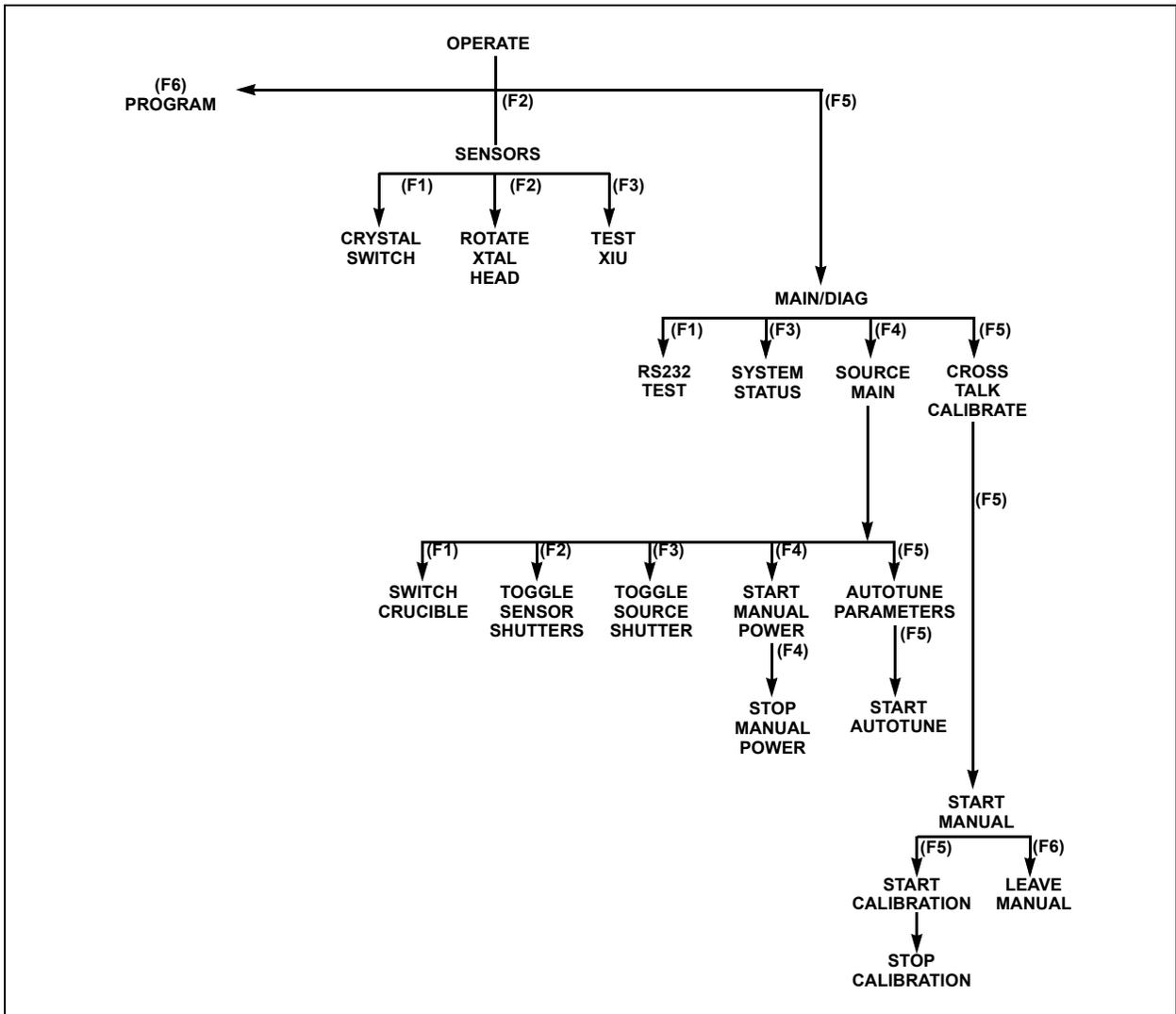
To move from one display to another, use either the function keys to the right of the screen or the MENU TREE function described in [section 3.3.1 on page 3-8](#). [Figure 3-3](#) provides an overview of the Program display hierarchy. [Figure 3-4](#) provides an overview of the Operate display hierarchy.

Figure 3-3 Display Hierarchy - Program



IPN 074-237AE

Figure 3-4 Display Hierarchy - Operate

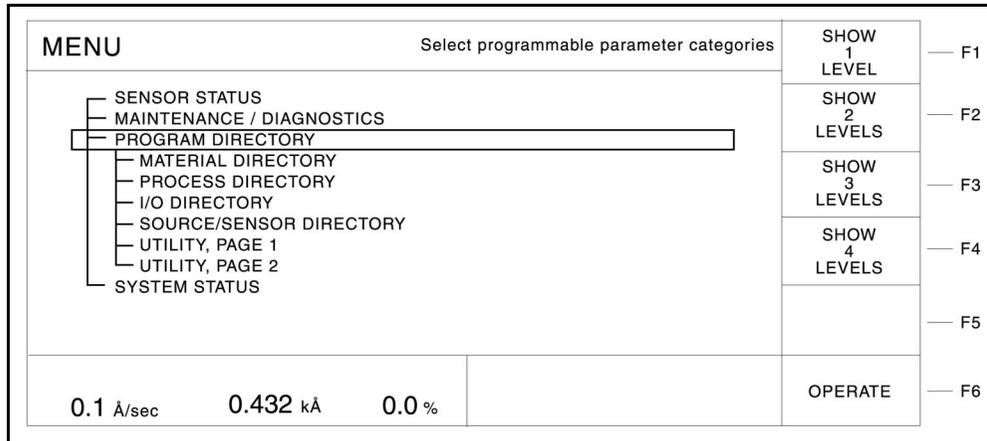


IPN 074-237AE

3.3.1 Display Navigation via the MENU TREE

Press the MENU key on the front panel to access the MENU TREE.
(See [Figure 3-5](#).)

Figure 3-5 Menu Display



During the MENU TREE display, the “F” keys (softkeys) will function as explained in [Table 3-1](#).

Table 3-1 F Key Functionality

Key	Function	Description
F1	Show 1 level	To view only the top level branches, press function key F1.
F2	Show 2 levels	To view the top two level branches, press function key F2.
F3	Show 3 levels	To view the top three level branches, press function key F3.
F4	Show 4 levels	To view all the branches, press function key F4.
F6	Operate	To move to the OPERATE display, (see Figure 3-6 on page 3-10) press function key F6.
The Cursor keys are used to move the cursor along the MENU TREE.		
↑	Up arrow	Moves the cursor up one line
↓	Down arrow	Moves the cursor down one line
←	Left arrow	Moves the cursor up one page
→	Right arrow	Moves the cursor down one page

You can move to any of the instrument's displays by positioning the cursor at the desired display and pressing the MENU key on the front panel. A second pressing of the MENU key returns the user to the MENU TREE.

The following displays cannot be accessed through the MENU TREE: AutoTune, Cross Talk Calibrate, Logic Statement Editing, Layer Editing, and I/O Map Editing Display. To access these displays, use the functions keys. The "Menu Unavailable" message is displayed when trying to access the MENU TREE from one of these displays.

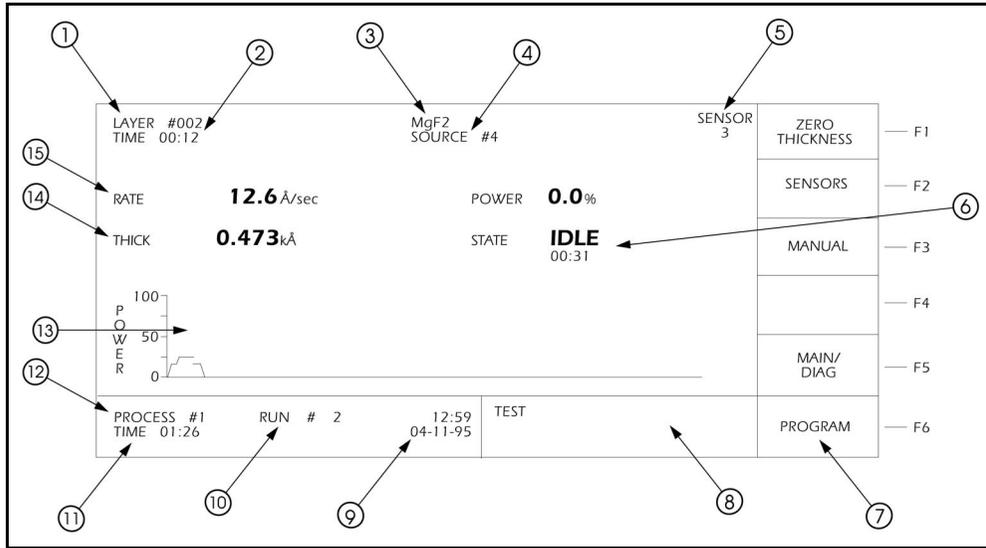
3.3.2 Operate Display

The OPERATE display (shown in [Figure 3-6](#)) provides information about the current layer(s) in process. This includes the layer #, material, source #, and sensor # currently in process. The rate, thickness, power level, state, state time, layer time, and process time are all updated once a second.

Near the bottom of the display is a graph which gives an analog display of the rate deviation from the desired rate, while depositing. Alternatively, the graph can display the percent power being output during a process. Use the UTILITY display to set parameters that control the meaning, scaling and speed of the graph. (See [section 9.3 on page 9-2.](#))

On the bottom right of the display is a status area. This area displays error messages, custom user messages and system status information, such as indicating the instrument is in TEST mode. For a complete list of error and status messages, see [Chapter 13](#).

Figure 3-6 Operate Display



Operate Display Description

- 1 Layer Currently In Process
- 2 Layer Timer
- 3 Material Being Deposited
- 4 Source Number In Use
- 5 Sensor Number(s) In Use
- 6 State of Layer
- 7 Function Key Definitions
- 8 Message Area
- 9 Date and Time
- 10 Run Number
- 11 Process Timer
- 12 Process Being Executed
- 13 Graphical Display of Rate Deviation or Power
- 14 Layer Thickness
- 15 Aggregate Rate

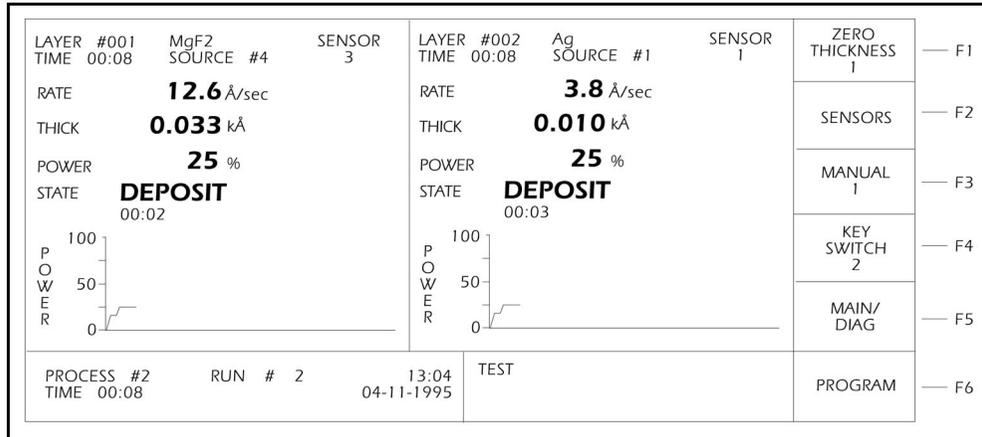
During the OPERATE display, the function keys along the right side of the screen will function as explained in [Table 3-2](#).

Table 3-2 Operate Display Function Keys

Key	Function	Description
F1	ZERO THICKNESS	To reset to zero both the displayed thickness of the current layer and the sensor thickness values shown on page 3 of the Material display, press function key F1.
F2	SENSORS	To access the SENSORS display, (see Figure 3-8 on page 3-13) which allows crystal switching and displays sensor diagnostic information, press function key F2.
F3	MANUAL	To put the layer in manual control, (so that the power level is controlled by the hand-held controller), press function key F3. When in manual, the F3 panel reads AUTO, and pressing it will remove the layer from the manual state and place it into the DEPOSIT state. See State Descriptions (section 3.5 on page 3-30) for a more complete description of manual operation.
F4	KEY SWITCH 2 (or KEY SWITCH 1)	When co-depositing two layers (see Figure 3-7), press this key to change the numeric designators for F1 and F3. The function key works in toggle fashion between the secondary (Key Switch 2) and primary (Key Switch 1) layers.
F5	MAIN/DIAG	Press this key while in the READY state to move to the Maintenance/Diagnostics display. This allows selection of Source Maintenance or Diagnostics functions for the Remote communications port, or Cross Talk Calibration. (See section 3.3.4 on page 3-17 .)
F6	PROGRAM	To move to the PROGRAM menu, press F6. (See section 3.3.7 on page 3-20 .)

In addition to the standard operational screen, if the system is configured for co-deposition, the operational screen will be divided to show information for both layers. Two options of the co-deposition OPERATE screen are available. One includes the graph information as shown in [Figure 3-7](#). The other removes the graph and shows enlarged digital information for Rate, Thickness, and Power. The format is determined by a parameter in the UTILITY screen. (See [Chapter 9](#).)

Figure 3-7 Co-deposition Operate Display



3.3.2.1 Crystal Life and Starting Frequency

On the SENSORS display, crystal life is shown as a percentage of the monitor crystal's frequency shift, relative to the 1.50 MHz frequency shift allowed by the instrument. This quantity is useful as an indicator of when to change the monitor crystal to safeguard against crystal failures during deposition. It is normal to change a crystal after a specific amount of crystal life (% change) is consumed.

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

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

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

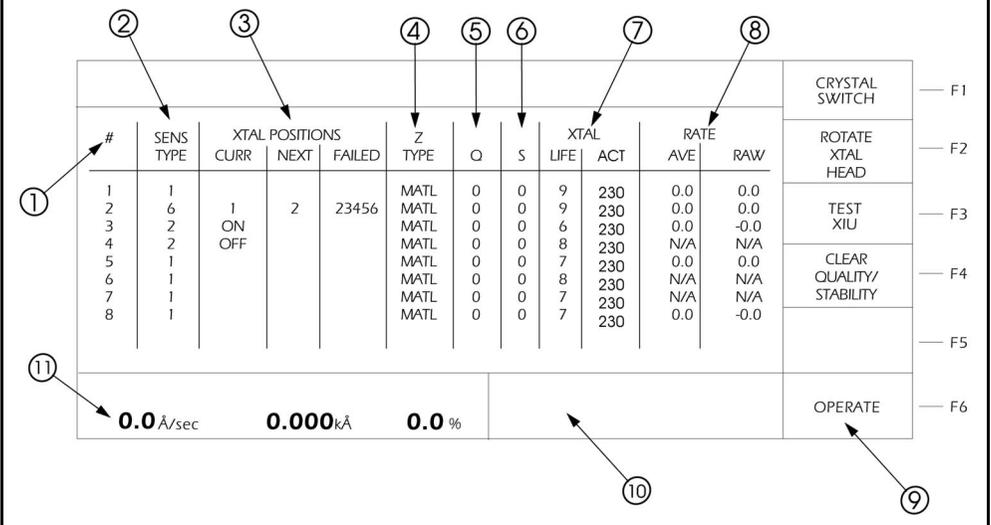
If a new crystal indicates 5% life spent, it means that either the quartz blank is slightly thicker than normal (more mechanical robustness), or the gold electrode is slightly thicker than normal (better thermal and electrical properties), or both. In either case, its useful life with regard to material deposition should not be adversely affected. To verify this assertion, laboratory testing was performed on crystals

which covered the crystal life range in question. Results indicate that a brand new crystal that indicates 3 to 5% life spent is just as good as, 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.

3.3.3 Sensors Display

Figure 3-8 Sensors Display



① #	② SENS TYPE	③ XTAL POSITIONS			④ Z TYPE	⑤ O	⑥ S	⑦ XTAL		⑧ RATE		CRYSTAL SWITCH — F1
		CURR	NEXT	FAILED				LIFE	ACT	AVE	RAW	
1	1				MATL	0	0	9	230	0.0	0.0	TEST XIU — F3
2	6	1	2	23456	MATL	0	0	9	230	0.0	-0.0	
3	2	ON			MATL	0	0	6	230	0.0	-0.0	CLEAR QUALITY/STABILITY — F4
4	2	OFF			MATL	0	0	8	230	N/A	N/A	
5	1				MATL	0	0	7	230	0.0	0.0	OPERATE — F6
6	1				MATL	0	0	8	230	N/A	N/A	
7	1				MATL	0	0	7	230	N/A	N/A	
8	1				MATL	0	0	7	230	0.0	-0.0	

⑩ 0.0 Å/sec 0.000kÅ 0.0 %

3.3.3.1 SENSORS Display Description

1 # (Sensor Number field)

These numbers correspond to the measurement channel numbers on the rear panel of the IC/5. The cursor keys are used to position the box cursor over the desired sensor number. When either the Crystal Switch, Rotate Crystal Head, Test XIU, or Clear Quality / Stability function key is pressed, the function will be performed on the sensor indicated by the box cursor. It is not allowed to cursor to sensor numbers that do not have the corresponding measurement card installed. If a crystal fail has occurred for a particular sensor this condition is indicated by displaying the sensor number in reverse video.

2 SENS TYPE

This field indicates the Sensor Type chosen for each sensor number. A “1” indicates a single crystal head, a “2” indicates a dual crystal head, and a “6” indicates a CrystalSix sensor head.

3 XTAL POSITIONS

This field is subdivided into three categories; current position (CURR), next position (NEXT), and FAILED. Information is displayed in these fields only if the sensor has a dual or CrystalSix sensor type.

For a dual sensor type the CURR field will show either the word ON or the word OFF. ON indicates the active sensor of the dual sensor head. OFF indicates the inactive (shuttered) sensor of the dual sensor head. For a dual sensor type the NEXT and FAILED fields have no meaning.

For a CrystalSix sensor type the CURR field indicates the current position of the CrystalSix sensor head. The NEXT field indicates the position to which the CrystalSix sensor head will rotate upon pressing the CrystalSwitch function key. The FAILED field indicates the CrystalSix sensor head positions containing failed crystals.

4 Z TYPE

This field displays the Z-ratio being used for the given sensor. MATL indicates the Z-ratio being used for thickness calculation is the value found in the Material parameter Z-ratio. AUTO indicates the IC/5's Auto Z feature is being used for thickness calculations. Auto Z continually calculates the Z-ratio for the "as deposited" film. If the IC/5 suddenly lost the ability to calculate Auto Z, AUTO would change to either MATL or SENS. MATL has the same meaning as described above, SENS indicates the last calculated Auto Z value (prior to failure) is being used for thickness calculations for this sensor.

The IC/5 determines to use MATL or SENS depending on the frequency of the fundamental. If the fundamental frequency closely matches the "last valid" fundamental frequency prior to Auto Z failure, the IC/5 will use the SENS value. Otherwise the IC/5 will use the MATL value.

5 Q (Crystal Quality value field)

This field displays the value currently accumulated in the Crystal Quality counter when active. DLY indicates the Crystal Quality counter is not active. The Crystal Quality counter will become active five seconds after entering DEPOSIT and if the Crystal Quality parameter is non-zero. The function of the Crystal Quality counter is described on [see page 4-8](#).

6 S (Crystal Stability value field)

This field displays the value currently accumulated in the Crystal Stability counter. The function of the Crystal Stability counter is described on [see page 4-9](#).

7 XTAL

This field is subdivided into two categories. The first category, LIFE displays the crystal life. The IC/5 allows a 1.5 MHz frequency shift on the monitor crystal corresponding to 100% crystal life. The value shown represents the amount of crystal life consumed. The amount of useful crystal life is highly dependent on the nature of the material being deposited as well as deposition conditions. The second category is a measurement of the crystal activity, ACT. Activity is a measure of the sensor's "health" or ability to conduct current. The values range from a maximum of 650 (healthiest) to a minimum of 0 (least healthy).

The activity value is useful for predicting when a crystal needs to be replaced. If a crystal is about to fail, its series resistance will increase, allowing less current to flow through the crystal and hence the activity value will decrease. The closer the activity value is to zero the more imminent a crystal failure.

It also can be used to gauge the health of the sensor head electrical contacts. For example, if a new monitor crystal is placed into the sensor head and has a crystal life of near 0%, but the activity value for this crystal is lower than 400, this indicates the sensor head or in-vacuum cable is in need of repair.

8 RATE

This field is also subdivided into two categories. The first category is AVE. The value displayed here is the sensor's average rate. This average is calculated based on a 2.5 second average minus the most recent 0.5 seconds of information. The second field is RAW representing the instantaneous rate measurement. These fields are useful in identifying if a sensor's rate measurements are becoming erratic. N/A (not available) will be displayed in these fields for sensors not in use.

9 Function Key Definition area

10 Message area

11 Aggregate Rate, Thickness, and Power display area

3.3.3.2 *Function Key Selection Choices for the Sensors Display*

F1 CRYSTAL SWITCH

To initiate a crystal switch for the sensor number selected, press function key F1. The crystal switch will be done on the sensor indicated by the box cursor. Use the cursor arrow keys to position the box cursor.

F2 ROTATE XTAL HEAD

If the sensor number chosen is a CrystalSix or rotary sensor type, press function key F2 to sequentially rotate the sensor head through all six positions. This is useful to initialize a CrystalSix or rotary sensor after replacing failed crystals. The action is taken on the sensor indicated by the box cursor. For the rotary sensor, a readout of failed (F) and good (G) crystals is shown in the lower left hand portion of the display. This readout assists the user in knowing which crystals are good and which are failed relative to the current position of the rotary sensor. This information is not retained upon leaving the SENSORS display. To re-gain this information, press the Rotate Xtal Head function key again.

F3 TEST XIU

Initiates the XIU self test. The XIU self test determines whether the crystal interface unit (XIU) and measurement card pair is operating properly.

NOTE: For the XIU self test to work properly, the XIU must have the six inch BNC cable (IPN 755-257-G6) attached and must be disconnected from the sensor feedthrough.

F4 CLEAR QUALITY STABILITY

To clear the Quality and Stability counters for the sensor chosen by the box cursor, press function key F4.

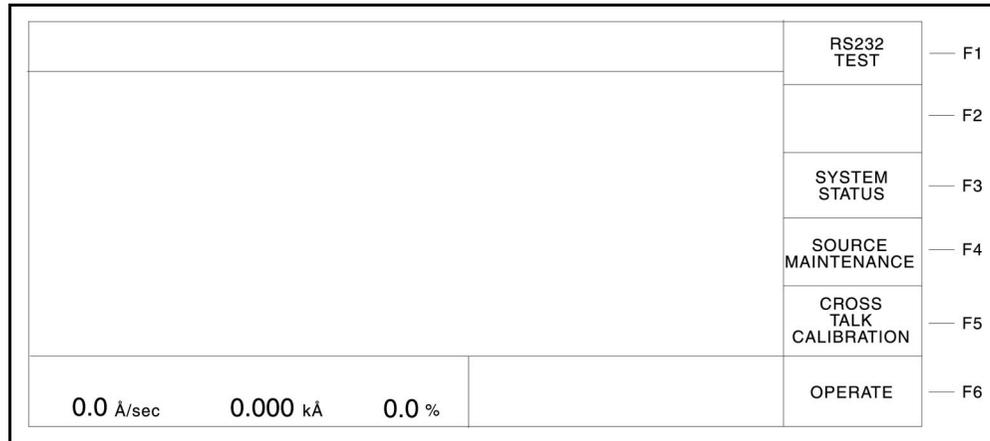
F6 OPERATE

To return to the Operate display, press function key F6.

3.3.4 Maintenance/Diagnostics Display

These displays provide a simple method for system maintenance and diagnostics. Pressing the MAIN/DIAG function key during the Operate display accesses the Maintenance/Diagnostics display.

Figure 3-9 Maintenance/Diagnostics Display



3.3.4.1 Function Key Selection Choices for the Maintenance/Diagnostics Display

F1 RS232 TEST

Press function key F1 to initiate the RS-232C COMM PORT self test. Upon completion of the test, the unit will display a message indicating the test was successful and the COMM PORT is okay; or the test failed and the COMM PORT is bad. If the COMM PORT is bad, a reminder message to make certain the RS-232C loop back connector is installed is displayed.

NOTE: The RS-232C Loop Back connector, IPN 760-406-P1 must be installed on the IC/5 RS-232C port for the self test to work properly.

F3 SYSTEM STATUS

Press function key F3 to access the SYSTEM STATUS display. The SYSTEM STATUS display can also be accessed using the MENU TREE.

F4 SOURCE MAINTENANCE

To move to the Source Maintenance display, press function key F4.

F5 CROSS TALK CALIBRATION

To enter the cross talk calibration series of displays, press function key F5. Cross talk calibration is used in co-deposition applications to correct for material flux from one source being deposited onto the sensors used to control the other material's source. See [section 12.5 on page 12-4](#) for the Cross Talk Calibration Procedure.

F6 OPERATE

To return to the Operate display, press function key F6.

3.3.5 Source Maintenance Display

Figure 3-10 Source Maintenance Display

		SWITCH CRUCIBLE	F1
		TOGGLE SENSOR SHUTTERS	F2
		TOGGLE SOURCE SHUTTER	F3
		START MANUAL POWER	F4
		AUTOTUNE	F5
		MAIN/DIAG	F6
MATERIAL INDEX	1 (1-24)		
CRUCIBLE	4 (1-64)		
0.0 Å/sec	0.000 kÅ	0.0 %	

3.3.5.1 Function Key Selection Choices for the Source Maintenance Display

F1 SWITCH CRUCIBLE

To switch the source turret to the crucible position designated by the crucible parameter, press function key F1.

F2 TOGGLE SENSOR SHUTTERS

To activate the shutter relay for the sensors associated with the designated material, press function key F2. Pressing this key a second time deactivates the sensor shutter relays.

F3 TOGGLE SOURCE

To activate the shutter relay for the source associated with the designated material, press function key F3. A second pressing of this key deactivates the source shutter relay.

F4 START MANUAL POWER

To enable the hand-held controller to effect power changes to the source output associated with the chosen material, press function key F4. Pressing this key a second time exits manual power.

NOTE: The MANUAL power level is automatically set to zero % power when exiting Manual Power while in source maintenance. This is different from executing a process. When executing a process, pressing the Manual Power key a second time will place the instrument into the Deposit State.

F5 AUTOTUNE

To activate the Autotune displays, press function key F5. See [section 12.6 on page 12-11](#) for a description of Autotune and Autotune displays.

F6 MAIN/DIAG

To return to the Maintenance/Diagnostics display, press function key F6.

3.3.6 Cross Talk and Calibration Display

Cross talk calibration is used during co-deposition to correct for material from one source being deposited onto sensors used to control the second co-deposited material's source.

When using multiple sensors and multiple sources it can be very difficult to empirically determine the required cross talk corrections. The following series of functions enables an automatic determination of cross talk values.

Figure 3-11 Cross Talk Calibration Display

CROSS TALK CALIBRATION										F1	
Material Index	<input type="text" value="1"/>	(1-24)	USER								F2
Desired Rate	10.0	Å/Sec									F3
Maximum Power	90.0	%									F4
Calibrate YES/NO	Sens1 YES	Sens2 YES	Sens3 YES	Sens4 YES	Sens5 YES	Sens6 YES	Sens7 YES	Sens8 YES		F5	
Rate	Å/SEC									START MANUAL	
Cal Thick	KA									OPERATE	
SETUP										F6	
0.0 Å/sec		0.000 kÅ		0.0 %		XTAL FAIL 1					

The Cross Talk Calibration Display provides for initiation of the automatic cross talk calibration algorithm to determine the calibration thicknesses (CAL THICK). The CAL THICK values are entered into page 3 of the Material Definition Display. These values are used during co-deposition to correct for material from one source being deposited onto the sensors used to control the second co-deposited material's source.

A calibration is done on each material to be co-deposited. See [section 12.5 on page 12-4](#) for a detailed description of cross talk calibration.

3.3.7 Program Displays

Program displays allow you to program processes and system configuration. Each program display has a section at the bottom that gives the rate, thickness, power level, and status of the process running. PROGRAM is divided into five major categories, with some of these being further subdivided. Each category has a complete section in this manual detailing the parameters in that category and any special information needed to navigate those displays. Following is a brief description of each category, with reference to the appropriate sections of the manual.

Figure 3-12 Program Display

PROGRAM		MATERIAL DIRECTORY	— F1		
TO VIEW PARAMETERS, PRESS APPROPRIATE KEY. TO CHANGE PARAMETERS, ENTER LOCK CODE.		PROCESS DIRECTORY	— F2		
		I/O	— F3		
		SOURCE/SENSOR DIRECTORY	— F4		
		UTILITY	— F5		
4.6 Å/sec	0.186 kÅ	0.0%	TEST	OPERATE	— F6

3.3.7.1 Function Key Selection Choices for the Program Display

F1 MATERIAL DIRECTORY

Material parameters include information specific to a given material to be deposited. The information includes Z ratio, density, soak times; up to 24 materials can be defined. (See [Chapter 4](#).)

F2 PROCESS

The process screens allow the user to program a series of materials into a multilayer process. Desired rate, final thickness, and other information specific to each layer is also programmed here. Fifty different processes can be defined, containing up to a total of 250 layers. (See [Chapter 5](#).)

F3 I/O

The I/O category deals with several different external links from the IC/5 to the vacuum system. This category is divided into the following subcategories, each accessed by a function key. Refer to the indicated sections for more detailed information on each subcategory.

Figure 3-13 I/O Display

I/O		LOGIC STATEMENT DIRECTORY	F1
ENTER I/O LOCK CODE TO CHANGE PARAMETERS. PARAMETERS MAY BE OBSERVED BY PRESSING APPROPRIATE KEY.		I/O MAP DIRECTORY	F2
		DEFINE USER MESSAGES	F3
		FLOPPY DISK	F4
		REMOTE COMMUNICATION	F5
0.0 Å/sec 0.000 kÅ 0.0 %	TEST	PROGRAM	F6

LOGIC STATEMENT DIRECTORY: Provides a display that facilitates selection of Logic statements for editing. (See [Chapter 6](#).)

I/O MAP DIRECTORY: Provides a display where relays, inputs, or outputs may be assigned names and where the relay type may be designated as normally open or normally closed. (See [section 6.6 on page 6-16](#).)

DEFINE USER MESSAGES: Provides a display where user messages may be assigned. (See [section 6.7 on page 6-17](#).)

FLOPPY DISK: Saves or retrieves parameters to or from floppy disk or saves Datalogging parameters to the floppy disk (See [section 3.6.8 on page 3-39](#)).

REMOTE COMMUNICATIONS: Defines configuration for external computer communications (See [Chapter 7](#).)

F4 SOURCE/SENSOR DIRECTORY

Source/Sensor displays allow the user to set up the configuration for sources and sensors connected to the IC/5. The information includes which source and sensor shutter outputs are connected, how many crucibles a source has, and whether a sensor is a single, dual or CrystalSix. (See [Chapter 8](#).)

F5 UTILITY

Parameters on the UTILITY displays deal with overall system setup, including how displays are formatted and general process choices (such as whether to STOP on max power). (See [Chapter 9](#).)

3.4 Process Description

The IC/5 allows the user to control deposition of a sequential series of single layers or two co-deposited layers of materials. This is done by defining and executing a process.

3.4.1 Defining a Process

The following procedure is used to define a process. (All steps do not necessarily have to be followed in the given order.)

1 Make sure the instrument is in READY.

Some configuration and process parameters can be changed only while the instrument is in READY. Therefore, before setting parameters, make sure READY appears as the state on the OPERATE display. If it does not, press STOP then RESET.

2 Configure the sensors.

Configuring the sensors involves designating whether the sensor is a single, dual or CrystalSix sensor, and what output relays are connected to the sensor shutter and crystal switcher, if any. Also, the Auto Z feature is activated or deactivated during sensor configuration. These parameters are on the SENSOR display of the SOURCE/SENSOR display. See [Chapter 8](#) for a detailed description for programming these parameters. Also see [section 3.6.1 on page 3-32](#) for details on crystal switching.

3 Configure the sources.

Configuring the sources involves selecting the digital-to-analog voltage converter (DAC) output, the output voltage range and polarity, and selecting the output relay for the source shutter. Also, if a source has more than one crucible, this is set up in the source configuration. The source parameters are programmed on the SOURCE screen of the SOURCE/SENSOR display. See [Chapter 8](#) for a detailed description for programming these parameters. Also see [section 3.6.2 on page 3-34](#) for details on crucible selection.

4 Define materials.

To define materials, the MATERIAL displays are used. Each distinct material used in the process must be defined. If the same material is going to be used more than once in the process, it needs to be defined only once. Final thickness and rate parameters are determined by the layer definition. The material definition includes density, Z-ratio, tooling, and soak power characteristics. Control loop characteristics also relate to the material. Also, a specific sensor and source are associated with each material. See [Chapter 4](#) for a detailed description for programming these parameters.

5 Define layer/process.

To define layers and processes, the PROCESS displays are used. A process is an ordered set of layers. Layers are entered in order on the PROCESS display. Each layer consists of a material, chosen by number from the material directory, final thickness, and rate. Additional information can be provided here for special process features; these include thickness setpoint and time limit triggers, RateWatcher, rate ramps, crucible selection and co-deposition. For a detailed description of layer parameters see [Chapter 5](#).

6 Configure utility information.

The final step in defining a process is to program any process related parameters on the UTILITY display. This includes which defined process to execute, what layer to begin the process on (typically 1), and whether to STOP on max power. It may also be desirable to modify the definition of the graphical display and analog output. See [Chapter 9](#) for a detailed description of utility parameters.

3.4.2 Executing a Process

Once a process has been defined, it is ready to execute.

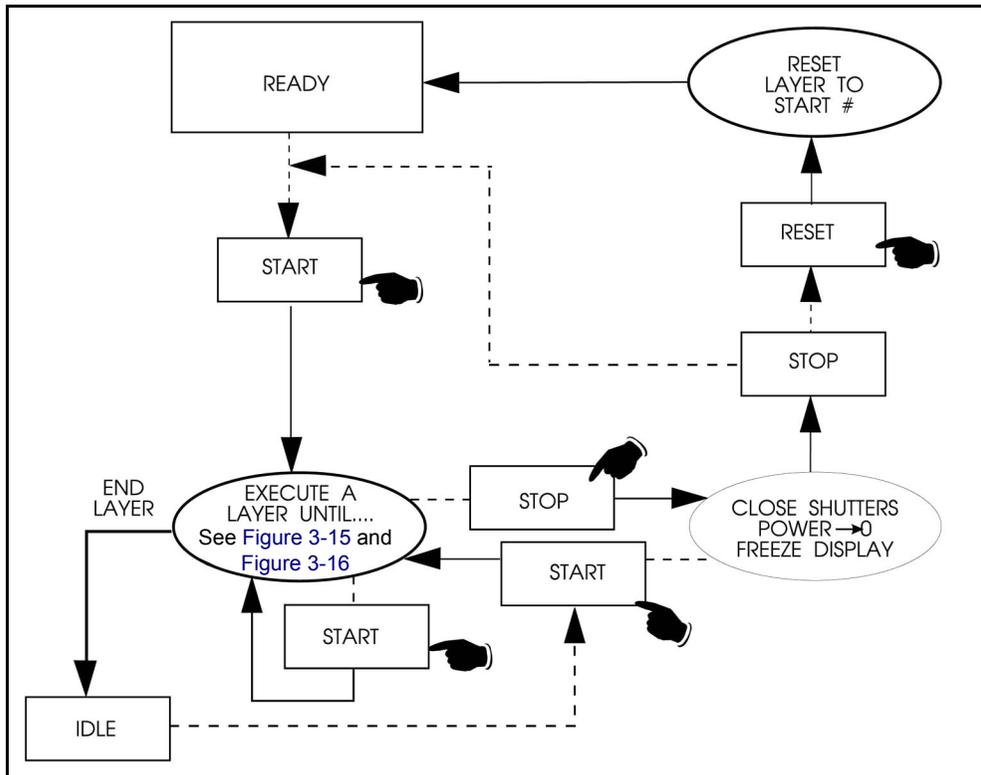
NOTE: Certain parameters cannot be changed while executing a process. The IC/5 will not allow these parameters to be changed.

- ◆ A Process is not being executed when the instrument is in the READY state, or when the Last Layer is in the IDLE state (end of process). A Layer is not being executed when the instrument is the READY, STOP, or IDLE state.
- ◆ **STOP** freezes a process, the status information on the display is maintained and the control voltage output is set to zero.
- ◆ **START**, pressed once, will continue the process from the point at which it was stopped.
- ◆ **RESET** takes a stopped process back to the beginning of the process at the designated "Layer to START."

HINT: It may be desirable to execute a new process in TEST before doing an actual deposition to check correct shutter operation, sequencing and limits.

The execution of a process is depicted in the following state diagram.

Figure 3-14 Process State Diagram



- 1 Make sure the instrument is in READY. If not, press STOP then RESET.
- 2 Press START. Assuming there are no configuration problems, the first layer will enter pre-deposition, and continue on through deposition and post-deposition. (See section 3.5 on page 3-30 for detailed information about the states of a layer.) If there are configuration problems, a message describing the problem will be displayed, see Chapter 13 for Status and Error Message definitions.
- 3 When the first layer is complete, it will go to IDLE. Press START again to begin the next layer. Repeat until the process is complete.
- 4 If at some point there is a need to interrupt or discontinue the process, press STOP. This will close the sensor and source shutters, set the power to zero, and freeze the display. The process can be restarted where it left off by pressing START. (The pre-deposition phases will be repeated.) To completely abandon the run, press RESET.
- 5 A critical error may occur while a process is running.
 For example, a sensor fail on a single sensor with a single head crystal may occur in pre-deposition. The IC/5 will automatically STOP if a critical error occurs. See section 13.1, Status and Error Messages, on page 13-1 for a list of critical errors. Assuming the error has been remedied, the process can be continued where it left off by pressing START. Pressing RESET will abandon the run.

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3.4.3 Pre-conditioning a Layer

It may be desirable to prepare a layer for deposition while the previous layer is in progress. Pressing START while a layer is running will begin the pre-deposition states of the next layer. However, there are certain restrictions and some precautions should be taken.

- 1** The next layer cannot use the same source as the current layer. Pressing START will cause a source conflict and the process will STOP. If pre-conditioning is desired, be sure the sources defined in the two consecutive layers are different.
- 2** The next layer will enter DEPOSIT while the current layer is in DEPOSIT (co-deposition) unless a Soak Hold is activated. A Soak Hold will hold the pre-deposition at the chosen Soak Power level until ready to proceed. To set these up, see [Chapter 6](#).

NOTE: If a Soak Hold is not active and two layers attempt to enter DEPOSIT using some of the same sensors, a STOP sensor conflict will occur.

3.4.4 Co-deposition

On the IC/5 it is possible to execute two layers simultaneously. A co-deposition is defined on the Layer Definition display. A YES is entered for the co-deposition parameter of the first layer to be co-deposited. This layer is referred to as the primary layer. The primary and secondary layers must both be defined before the YES is entered for the co-deposition parameter of the primary layer. In co-deposition, when the primary layer reaches final thickness, the secondary layer will also leave deposition. However, if the secondary layer reaches final thickness first, the primary layer will continue until reaching its programmed final thickness. There are two other parameters associated with co-deposition. The first is ratio control. This controls the secondary layer's rate at a percentage of the primary layer's desired rate. The second is cross-sensitivity, which compensates for interference between the two depositions. See [Sections section 5.3 on page 5-4](#) and [section 12.5 on page 12-4](#) for details on programming these parameters.

If two layers are programmed for co-deposition, pressing START once will begin both layers.

NOTE: It is also possible to run two layers at the same time by pressing START twice, but ratio control, cross-sensitivity and automatic completion of the secondary channel will not be active.

3.4.5 Automating a Process

A process can be automated so that a complete process can be executed without having to press START between all the layers. A process can be automated by any of the following three methods.

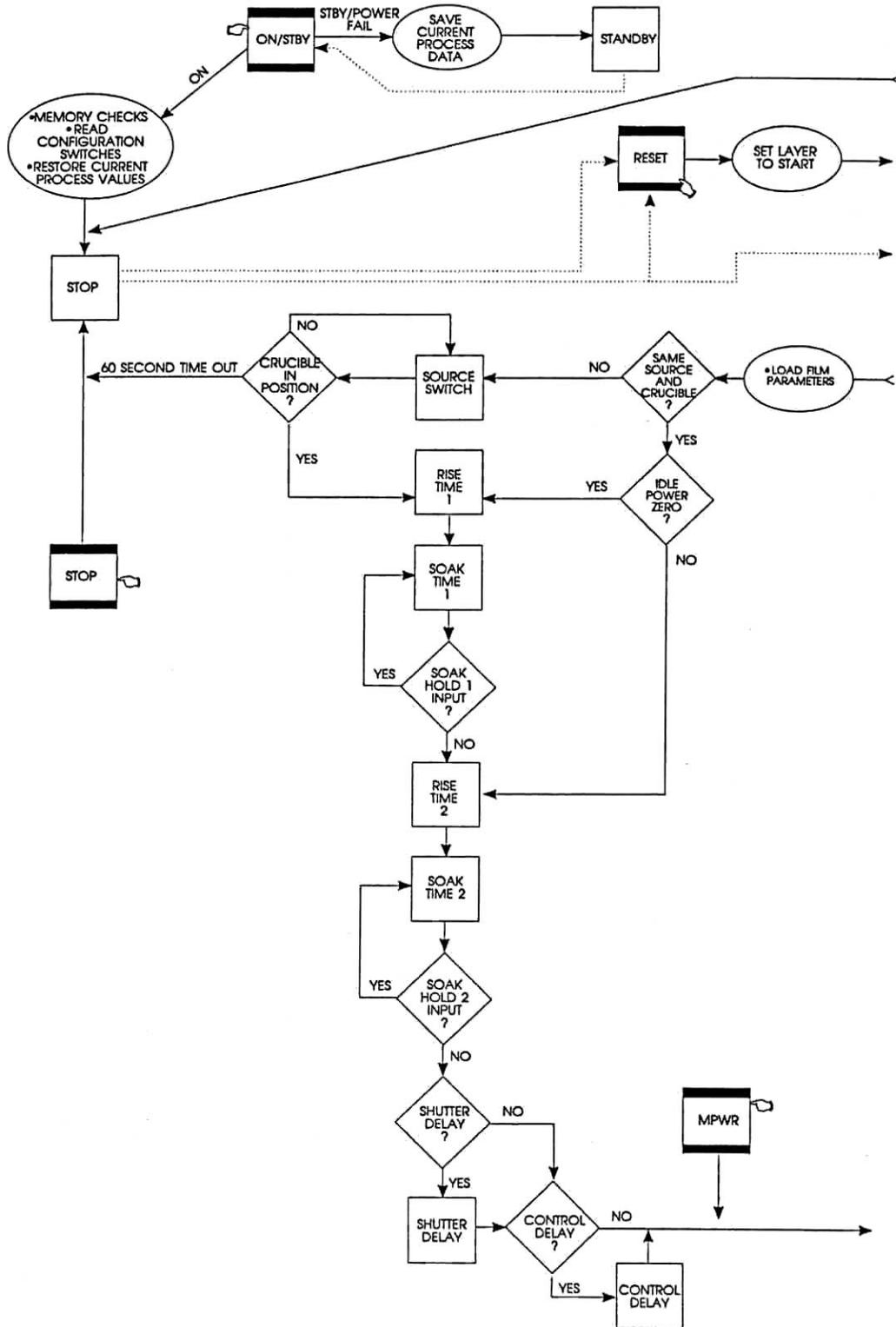
1 Setting the logic statement:

```
IF      PROCESS END ALL AND LAYER END ALL  
THEN   START
```

will cause a complete process to run by pressing START once. For a step by step procedure to set up this statement, see [section 6.5 on page 6-15](#).

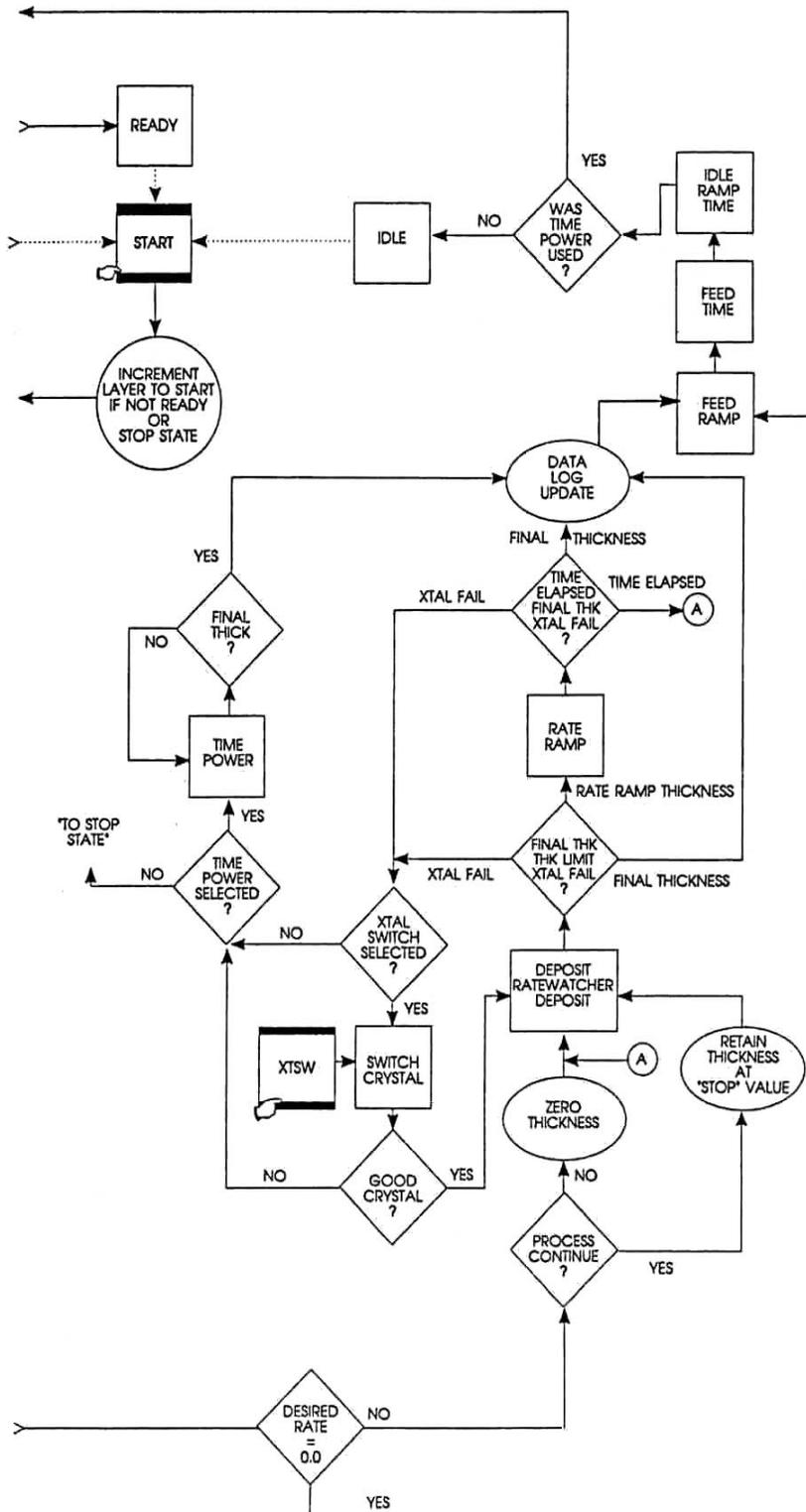
- 2** Remote communication control. An external computer could be set up to monitor the status of a process and issue START commands at desired times. (See [Chapter 7](#).)
- 3** Remote input line. A remote input line can be configured to issue a START command based on some external event. (See [Chapter 6](#).)

Figure 3-15 State Sequence Diagram - Part A



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Figure 3-16 State Sequence Diagram - Part B



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3.5 State Descriptions

Table 3-3 State Descriptions

STATE	CONDITION	RELAY CONTACT STATUS	
		Source Shutter	Sensor Shutter
NOTE: 1 through 7 are Pre-Deposit states.			
1. READY	The IC/5 will accept a START command	Inactive	Inactive
2. SOURCE SWITCH	Instrument advances to next state when "turret" input is low, or "turret" delay has elapsed. If IDLE PWR of the previous layer using this source is not equal to zero, power is set to zero before the crucible position changes. [Crucible #, Source #]	Inactive	Inactive
3. RISE TIME 1	Source is rising to Soak Power 1 level. [Rise Time 1]	Inactive	Inactive
4. SOAK TIME 1	Source is being maintained at Soak Power 1 level. [Soak Time 1, Soak Power 1]	Inactive	Inactive
5. RISE TIME 2	Source is rising to Soak Power 2 level. [Rise Time 2]	Inactive	Inactive
6. SOAK TIME 2	Source is being maintained at Soak Power 2 level. [Soak Time 2, Soak Power 2]	Inactive	Active
7. SOAK HOLD 1 SOAK HOLD 2	Source is being maintained at Soak Power level. [Soak Hold input]	Inactive Inactive	Inactive Active
8. SHUTTER DELAY	Rate is being controlled. Advances to Deposit State once the Source is in Rate Control within > of 5% or 1A/s. [Shutter Delay ON]	Inactive	Active
NOTE: 9 through 16 are Deposit states.			
9. CONTROL DELAY	Constant Power at Soak Power 2. Starts rate control when the control delay time elapses. [Control Delay, Control Delay Time]	Active	Active
10. DEPOSIT	Rate control. [Rate, Final Thickness, PID Control, Process Gain, Primary Time Constant, System Dead Time]	Active	Active
11. RATE RAMP TIME 1	Rate control, desired rate changing. [New Rate 2, Start Ramp 2, Ramp Time 2]	Active	Active

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Table 3-3 State Descriptions (continued)

STATE	CONDITION	RELAY CONTACT STATUS	
		Source Shutter	Sensor Shutter
NOTE: 1 through 7 are Pre-Deposit states.			
12. RATE RAMP TIME 2	Rate control, desired rate changing. [New Rate 2, Start Ramp 2, Ramp Time 2]	Active	Active
13. RATEWATCHER (SAMPLE)	Rate control. [RateWatch Accuracy]	Active	Active
14. RATEWATCHER (HOLD)	Constant power, based on last sample's average power. [RateWatch Time]	Active	Inactive
15. MANUAL	Source power controlled by hand-held controller.	Active	Active
16. TIME-POWER	Crystal failed; source maintained at average control power prior to crystal failure. [Time Pwr Y]	Active	Active
NOTE: 17 through 20 are Post-Deposit states.			
17. FEED RAMP	Source changing to Feed Power. [Feed Power, Feed Ramp Time]	Inactive	Inactive
18. FEED	Source maintained at Feed Power level. [Feed Time]	Inactive	Inactive
19. IDLE RAMP	Source changing to Idle Power. [Idle Ramp Time, Idle Power]	Inactive	Inactive
20a.IDLE POWER (=0%)	Source maintained at zero power; will accept a START command.	Inactive	Inactive
20b.IDLE POWER (>0%)	Source resting at Idle Power; will accept a START command.	Inactive	Inactive
21. STOP	Source output set to zero power. The display is frozen at the last rate and thickness values; will not accept a START or RESET command.	Inactive	Inactive
	NOTE: In the STOP state the instrument will accept a START provided a Crystal Failure has not occurred for the sensors used in the layer being started.		

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3.6 Special Features

The IC/5 has several special features to enhance the performance of the instrument.

3.6.1 Crystal Switching

The IC/5 offers a choice of single, dual, CrystalSix or rotary sensors. The dual or CrystalSix sensor provides a backup monitor crystal in case a crystal fails during deposition. To configure sensors, see [Chapter 8](#).

A crystal switch will *automatically* occur when:

- ◆ The instrument is configured for a dual head, a layer is running on the primary sensor, and the primary crystal fails. The primary sensor is the sensor (of the dual sensor) which has its option set to non-zero.
- ◆ The instrument is configured for a CrystalSix, a layer is running, and there is at least one good crystal from the crystal position list (see [Chapter 4](#)) left in the carousel when the active crystal fails.
- ◆ The instrument is configured for a rotary sensor, a layer is running, and there is at least one good crystal in the rotary sensor.
- ◆ The instrument is configured for a dual head or single heads, a START is executed and the designated primary sensor is different from the last sensor run.
- ◆ Using a CrystalSix and pressing START, if the current CrystalSix position is not the position listed first on the material display.

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

- ◆ During a state of STOP, READY or IDLE.
- ◆ When the designated primary sensor has already failed at the START of a layer. (A STOP will occur.)
- ◆ During deposition if the secondary crystal of a dual head fails, or the last good crystal of a CrystalSix fails. (In either case a TIME-POWER or STOP will occur, depending on the sensor option chosen.)

A crystal switch can be manually executed via the front panel, hand-held controller, remote communications, or logic statements when the system is configured for dual, CrystalSix, or rotary sensors.

NOTE: When crystal switching with the hand-held controller, the IC/5 must be on the SENSORS display.

NOTE: The active sensor of a dual sensor head is shown as ON in the SENSORS display.

3.6.1.1 CrystalSix Position Select

Used in conjunction with the position-select CrystalSix sensor (IPN 750-446-G1), the IC/5 allows crystal switching to a predetermined subset of the six crystal positions, if desired. This subset is selected using the Crystal Position parameter located on page 3 of the Material Set Up display. (See [section 4.3 on page 4-5.](#)) The position select feature allows you to select which of the six crystals are to be used for a given material. In applications involving sequential layering of different materials this allows specific crystals to be used for specific materials, eliminating the need for more than one sensor head in the deposition system.

3.6.1.2 Rotary Sensor Crystal Switching

Selecting type 7, Rotary, as the sensor type enables sequential crystal switching only. Upon a crystal switch the Crystal Switch Output will first close for one second and then open (i.e., one pulse to move one position). The IC/5 will not keep track of which position the Rotary Sensor is on nor will it keep track of which crystals are good and which are failed. The Position Selection feature available with Type 6=Multi is not available for the rotary sensor.

After the one second pulse, the IC/5 measurement system software will attempt to find the resonant frequency for the crystal in this position. If the IC/5 does not find a good resonant frequency for this crystal it will again pulse the Crystal Switch Output for one second and attempt to find a resonant frequency at this position. There will be a maximum of five attempts to find a good resonant frequency (i.e., a maximum of five pulses of the Crystal Switch Output). If a good resonant frequency is not found after five attempts, the IC/5 will then enter the Time Power or STOP state depending on the Sensor Option value chosen in the Material parameters display.

There is to be a maximum of five attempts to find a good resonant frequency however, while executing a Layer, if the IC/5 detects a crystal fail and automatically initiates a crystal switch it will recognize there has been an automatic crystal switch. The IC/5 will keep track of the number of times an automatic crystal switch has been done. Therefore if there have been five automatic crystal switches and then the sixth crystal fails, the IC/5 will go directly to either Time Power or STOP as appropriate without any additional pulses.

Start resets all crystal fail flags to 'good'.

3.6.2 Source/Crucible Selection

The IC/5 can control a source with up to 64 crucibles, through up to six binary encoded relays. This is configured by setting the Number Of Crucibles, Crucible Outputs, Turret Feedback, Turret Input, and Turret Delay parameters on the SOURCE display of the SOURCE/SENSOR Directory. (See [section 8.3 on page 8-3](#) for details on programming the parameters associated with source/crucible selection.)

To define which crucible to use for a layer, set the “crucible” parameter on the PROCESS display. When the layer is started, if the current crucible position is different from the one requested, the system’s turret controller will move into position. This will be signified on the OPERATE screen by the state indicator SOURCE SWITCH. The layer sequencing will continue on to RISE 1 after either the turret delay time expires or an input indicates the turret is in position, depending on which option is chosen. The specific method used is determined by the parameter Turret Feedback on the SOURCE screen.

NOTE: If the source has been idling at a nonzero power when the START is initiated, the power will be dropped to zero before the crucible is changed.

3.6.2.1 Example: Programming Turret Source Crucible Selection

Interfacing a turret source controller to the IC/5 requires both hardware connections to the turret controller and properly defining certain instrument parameters.

Proceed to the SOURCE/SENSOR Directory (see [Figure 8-1 on page 8-1](#)) and choose the source that is going to be defined as the turret source. This is accomplished by Editing the chosen source as follows (see [Figure 8-2 on page 8-1](#)):

- 1** Designate the Number of Crucibles; for example, 4.
- 2** Select the Crucible Output. This defines the number of the first relay that encodes the crucible number selected by the active layer. Relays are defined sequentially with the first relay containing the least significant bit (LSB). The greater the number of crucibles selected, the greater the number of relays required. The number required is based on binary encoding (actual coding is binary -1, with 00 representing position 1 and 11 representing position 4). Any unused sequence of relays may be used if it is long enough to provide sufficient selections.

- 3 Select the Crucible Output Type as normally open (NO), or normally closed (NC).

Example:

Number of crucibles = 4
 Crucible output = 6
 Crucible output type = NO

For this example, wiring to the controller is based on [Table 3-4](#). Only relays 6 and 7 are needed to encode the four possible positions.

Table 3-4 Wiring To The Controller

Crucible Position	Contact Status	
	Relay #6	Relay #7
1	Open	Open
2	Closed	Open
3	Open	Closed
4	Closed	Closed

NOTE: If the crucible output type were normally closed (NC), [Table 3-4](#) would need to be modified by exchanging open and closed.

- 4 Determine whether Turret Feedback is desired. This allows the turret position controller to stop further instrument processing until the requested turret position is satisfied. If chosen, a turret input must be connected to the turret position controller's feedback signal.

If Turret Feedback is not chosen, program a Turret Delay Time which allows an adequate time for positioning to take place. Once the delay time has expired, instrument state processing continues.

- 5 The selection of a particular crucible for a layer is defined in the process directory.
- 6 Select the process to modify.
- 7 Program the particular "Crucible Number" for each layer.

Example:

Layer 1: Crucible Number = 1
 Layer 2: Crucible Number = 2
 Layer 4: Crucible Number = 4

3.6.3 Auto Z

The Auto Z feature of the IC/5 automatically determines the Z-ratio of a crystal. This feature is enabled on the SENSOR screen of the SOURCE/SENSOR display (see [section 8.4 on page 8-6](#)). For the theory behind Auto Z, see [section 2.1.6 on page 2-9](#).

The following information briefly describes Auto-Z and details the conditions under which a crystal is "unable to Auto-Z".

Auto Z is calculated based on the slightly different mass sensitivities of the fundamental and the first anharmonic resonances of the quartz crystal oscillator. Therefore, the need to measure the frequencies of both the fundamental and the first anharmonic resonances is critical.

When inserting a monitor crystal and attempting to Auto Z, the fundamental and anharmonic frequencies are measured to determine the status of the crystal. The crystal status may be classified into four categories:

1 New Crystal

The first category is for a "new" crystal, one that does not have any material deposited onto it. If both frequencies fall within the allowed range for new crystals, the instrument will allow an Auto Z calculation with this crystal.

2 Known, Used Crystal

The second category is for a "known, used" crystal, to account for the possibility that a person would remove a good monitor crystal and then reinsert the same crystal. Whenever a crystal fail occurs the last valid crystal frequencies are stored in the instrument. Upon inserting a coated monitor crystal the measured frequencies for this crystal will fall outside of the allowed range for "new" crystals. These frequencies are then compared with the stored values to determine if this crystal is the same one as was in use prior to the crystal fail. If the crystal is the same as used previously, and Auto Z was being calculated previously, the instrument will allow an Auto Z calculation with this crystal.

3 Unknown, Used Crystal

The third category is for an "unknown, used" crystal. This category is for a used crystal that, upon insertion, shows measured frequencies that are outside of the allowed "new" crystal range and also do not match the frequencies stored within the instrument. This results in an "unable to Auto Z" condition because the initial frequencies of the uncoated monitor crystal are not known.

4 Unable to detect anharmonic frequency.

As mass is deposited onto the crystal, the oscillation is damped. This damping may be severe enough that the resonance can no longer be determined. If the instrument loses the ability to measure the first anharmonic frequency, but is still able to determine the fundamental frequency, the “unable to Auto Z” message is displayed. The instrument will then continue to use the fundamental frequency to monitor the deposition.

If the instrument loses the ability to measure the fundamental frequency, the “XTAL fail” message is displayed.

Unable to Auto Z

An “unable to Auto Z” condition occurs whenever:

- ◆ The anharmonic frequency cannot be measured.
- ◆ The fundamental and anharmonic frequencies of the monitor crystal have not been continuously measured from the uncoated to the coated state.

3.6.4 Auto Tune - Optimizing the Control Loop

The control loop parameters can often be calculated automatically by the IC/5. This is done by using the AutoTune feature. For a detailed description of AutoTune, see [section 12.6 on page 12-11](#).

3.6.5 Rate Watcher

The IC/5 includes a sample and hold function which enables periodic sampling of the deposition rate by opening and closing the sensor shutter. If you are controlling inherently stable deposition sources, this function is useful in maximizing crystal life. When RateWatcher is enabled, during deposit, rate control will be established. Then the sensor shutter will close for a designated amount of time. The shutter will once again be opened to validate and adjust the power level. This procedure is repeated throughout the deposition. Two process parameters - RateWatch time and RateWatch accuracy - control this function. See [section 5.3 on page 5-4](#) for details on programming these parameters.

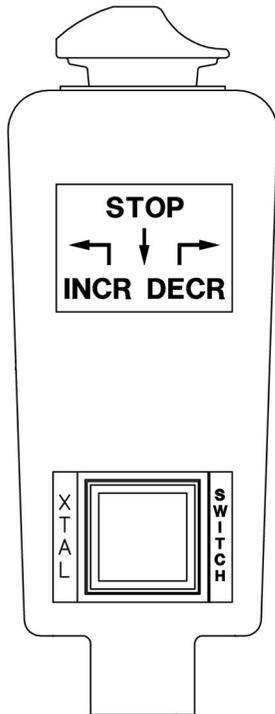
3.6.6 Hand-Held Controller

A Hand-Held Controller, see [Figure 3-17](#), is provided as an accessory with the IC/5. The Controller serves as a wired remote to manually control power, switch crystals and produce a STOP.

The Controller is attached to the instrument with a modular plug to the front panel. Power is affected (only when in Manual mode) by moving the POWER/STOP switch laterally. A STOP is produced by moving the POWER/STOP switch down (only when in Manual mode). When in a READY, IDLE, or STOP state and the instrument is on the SENSORS display, a crystal switch is activated by pressing the red button on the body of the controller.

The ship kit includes a convenience hook for the Controller that can be attached to the instrument's mounting ears or some other accessible location.

Figure 3-17 Hand-Held Controller



3.6.7 Test Mode

This instrument contains a software-controlled test mode which simulates actual operation. Optionally, time can be compressed so that a long process can be simulated in one tenth of the time. The purpose of the test mode is to verify basic operation and to demonstrate typical operation. The rate display during test mode operation is:

$$\text{Rate Display} = \frac{40}{\text{Density (gm/cc)}} \times \frac{\text{Tooling \%}}{100} \text{ \AA/sec} \quad [1]$$

Crystal fails are ignored in test mode. Crystal switching is disabled. All other relays and inputs operate normally.

3.6.8 Floppy Disk (Optional)

The floppy disk drive is an optional accessory for the IC/5. This option allows storage of all parameter information, as well as automatic datalogging information, to the 3.5 inch 1.44 MByte floppy diskette. The maximum number of files which may be stored onto the floppy disk is 224 for a 1.44 MByte diskette and 112 files when using a 720 KByte diskette. The maximum number of files includes parameter files as well as datalogging files. Diskettes must be pre-formatted.

The parameter set may be stored under a new or existing filename and retrieved from an existing file. A file containing the IC/5 parameter set is referred to as a configuration file. Datalog information will be saved to the diskette only if the datalog output is turned on and the output path is chosen as the floppy drive (as opposed to choosing output to the RS-232C port). Selection of the output path is done in the remote communications parameters display. (See [section 7.2 on page 7-2.](#))

Multiple files may be contained on one diskette. Filenames may be eight characters long; extensions are used to differentiate between configuration files and datalogging files. All files must be contained on the root directory. Storage/retrieval from sub-directories is not allowed.

The instrument supports the writing of filenames using alphanumeric characters selected using the cursor keys. Characters A through Z and numbers 0 through 9 inclusive are available. The instrument has the ability to display the files contained on the diskette. A scrolling feature is enabled to view those filenames which cannot fit on the screen. Error messages include: Disk Full; File Not Found; Disk Write Protected; Media Error; Disk not Found; File is Read Only. See [section 6.8 on page 6-19](#) for details on floppy disk operation.

Datalog files are automatically named using the process number and run number. See [section 3.6.10 on page 3-40](#) for the Datalog string details.

NOTE: A floppy disk access code is enabled when the instrument has a program lock code set. By entering a floppy disk access code the IC/5 parameters can be saved to, or retrieved from, the diskette only without entering the Program Lock Code. (See [Chapter 9](#).)



CAUTION

Do not bend the diskette.

Keep the diskette dry and do not expose the diskette to temperature extremes.

Do not remove the diskette from the instrument while a save or retrieve operation is taking place.

3.6.9 Lock and Access Codes

The IC/5 has several forms of protection to prevent unauthorized changing of parameters. Refer to the utility setup section for a description of parameter and I/O lock codes and the floppy disk access code. In addition, a method of locking the entire display is available through the remote communications. Lock codes are entered on the Utility Display. (See [Chapter 9](#).)

HINT: To clear any of the locks, except the floppy disk access code, hold down the clear key on power up. This will clear all lock codes. **HOWEVER**, if no lock codes are present, all parameters will be cleared by doing this.

3.6.10 Datalog

Datalog automatically saves to diskette or outputs to Remote Comm every time a source shutter closure occurs. When the Datalog data is saved to a diskette the information will be saved under a filename. Filenames will not be output when the Datalog information is sent out the Remote Comm port.

Datalog files saved to diskette will be automatically named using the process number and run number. The format of the filename is PXXRXXX.IDL. If the diskette already contains a file with the same filename as the new datalog information, the new datalog information will be appended to the old file.

At each source shutter close, the datalog information will be appended to the file (when saved to diskette) until the end of the Process.

The Datalog data set is defined as follows:

```

DATE:      MMDDYYYY
TIME:      XX:XX
PROCESS #1:  ##
RUN #:     ###
LAYER #:   ###
MATERIAL NAME: NNN#MM#
PROCESS TIME  XX:XX
LAYER TIME:  XX:XX
DEPOSITION TIME: XX:XX
THICKNESS:   ###.###   kÅ
AVE. AGG. RATE: ###.###   Å/s
AVE. RATE DEVIATION:  ##.#   Å/s
ENDING POWER:  ##.#   %
AVE. POWER:    ##.#   %
COMPLETION MODE:normal, time-power...ave. value,
                  crystal fail, remote, keyboard, max.
                  power, hand-held controller.
    
```

Crystal Use History (example)

SENSOR 1

XTAL	BEG. FREQ.	END FREQ.	BEG. LIFE	END LIFE	BEG. ACT.	END ACT.	STAB.	QUAL.
1	5975323	5876991	0%	2%	245	240	30	22
2	5978368	5879012	0%	2%	225	189	1200	99
3	5768733	5677987	3%	5%	176	168	0	0
4	5346278	5129870	48%	51%	150	105	0	0
5	4876789	4567899	78%	81%	101	101	25	1
6	4678843	4500000	98%	100%	100	92	0	0

SENSOR 2

XTAL	BEG. FREQ.	END FREQ.	BEG. LIFE	END LIFE	BEG. ACT.	END ACT.	STAB.	QUAL.
2	5978368	5879012	0%	2%	225	189	1200	99
3	5768733	5677987	3%	5%	176	168	0	0
5	4876789	4567899	78%	81%	101	101	25	1

SENSOR 8

XTAL	BEG. FREQ.	END FREQ.	BEG. LIFE	END LIFE	BEG. ACT.	END ACT.	STAB.	QUAL.
1	5975323	5876991	0%	2%	245	240	30	22

NOTE: A minus sign in front of the END FREQ. value indicates that crystal has failed.

If two layers are co-deposited, the first layer to have a source shutter close will be data-logged first.

The ability to turn ON/OFF datalogging and where to output the datalog data set is determined by a programmable parameter located in the Remote Communications display. The CRYSTAL USE HISTORY data is an optional subset of the datalog string. A second parameter located in the Remote Communications display is used to determine if the CRYSTAL USE HISTORY is to be output. Additionally, the datalog string format is selectable between a page format and a comma delimited format. The comma delimited format is actually comma-and-quote delimited intended for file importation into a spreadsheet program. When a spreadsheet program imports a file having the comma delimited format data groups that are strictly numbers become value entries, data groups surrounded by quotes are stored as labels. For the page format, only those sensors which are used in a particular Material for a particular Layer will be datalogged. For the comma delimited format, all the data fields are returned for all the sensors and crystals. If a sensor is not used during the deposition, the data field will contain a zero.

Outputting the Datalog Data Set to multiple outputs at the same time (for example, Save to diskette and Output to Remote Comm at the same time) is not allowed.

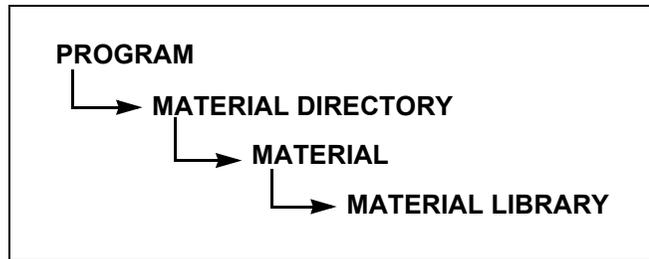
Chapter 4 Material Set Up

4.1 Material Set Up Overview

The IC/5 can store the definition parameters for up to 24 materials. Each layer in a Process references one of these materials by its directory number, ranging from 1 to 24. Any material that is to be used must be defined.

Materials are defined by referencing the internal Material Library (see [Figure 4-1](#)) and by completing a series of parameter entries at the front panel.

Figure 4-1 Display Tree for Material Set Up



Material Set Up is initiated by selecting the MATERIAL Directory (F1) key in the Program display. This will invoke the Material Directory (see [Figure 4-2](#)). Upon entry to the Material Directory, the cursor will be found at the last referenced material.

4.2 Material Definition

Material definition is initiated by selecting the MATERIAL (F5) panel in the Material Directory. If the cursor is placed at a previously defined material, the definition displays for that material will be entered. If the cursor is placed at an unassigned material, the Material Library will be entered to select from one of more than two hundred cataloged materials.

Figure 4-2 Material Directory

MATERIAL DIRECTORY				DELETE MATERIAL	F1
1. MgF2	7. Pb	13.	19.		F2
2. Ag	8.	14.	20.		F3
3. Cr	9.	15.	21.		F4
4. In	10.	16.	22.		F5
5. Ni/Cr	11.	17.	23.	MATERIAL	F6
6. Cu	12.	18.	24.		
12.6 Å/sec 2.363 kÅ 0.0 %			TEST	PROGRAM	

A previously defined material can be deleted provided it is not referenced in any process. Place the cursor at the material to be deleted and select the DELETE MATERIAL (F1) panel in the Material Directory. The Material Directory will be compressed to eliminate any gaps and Process definitions will be updated to reflect any directory number changes.



CAUTION

Logic statements will not be updated to reflect Material Directory number changes after deleting a material.

The Material Library (see Figure 4-3) provides an alphabetic list of materials by chemical name along with their density and Z-ratio. A custom USER material may also be selected. Once a material is selected from the library listing, press the Define Material (F5) function key to enter the material parameter series of displays.

You can move among and through the materials by using the cursor and panel keys, as shown in the following tables and illustrations.

Figure 4-3 Material Library

MATERIAL LIBRARY						Page 1 of 4	PAGE FORWARD	F1
DENSITY = 8.930								F2
Z-RATIO = 0.437								F3
Ag	Au	BeF2	C8H8	CdS	CrB			F4
AgBr	B	BeO	Ca	CdSe	Cs			F5
AgCl	B2O3	BI	CaF2	CdTe	Cs2SO4			
Al	B4C	BI2O3	CaO	Ce	CsBr			
Al2O3	Ba	BI2S3	CaO-SiO2	CeF3	CsCl			
Al4C3	BaF2	BI2Se3	CaSO4	CeO2	CsI			
AlF3	BaN2O6	BI2Te3	CaTiO3	Co	Cu			
AlN	BaO	BIF3	CaWO4	CoO	Cu2O			
AlSb	BaTiO3	BN	Csd	Cr	Cu2S			
As	BaTiO3	C	CdF2	CdF2	Cu2S			
As2Se3	Be	C	CdO	CdO	CuS			
0.0 Å/sec 0.000 kÅ 0.0 %						DEFINE MATERIAL	F5	
						MATERIAL	F6	

Table 4-1 Function Key Selection Choices For Material Library

Key	Function	Description
F1	PAGE FORWARD	Select this panel to access additional pages of material listings.
F2	PAGE BACK	Select this panel to return to previous pages of material listings.
F5	DEFINE MATERIAL	Select this panel to complete the definition of the selected material.
F6	MATERIAL	Select this panel to return to the Material Directory.

Figure 4-4 Material Definition (Page 1)

MATERIAL 1 - User		Page 1 of 3	PAGE FORWARD	F1
Density	<input type="text" value="10.000"/>	GM/CM^3		
Z-Ratio	<input type="text" value="1.000"/>			F2
Source	<input type="text" value="1"/>	(1-6)		
Control Loop	<input type="text" value="0"/>	(0=Non-PID, 1=PI, 2=PID)		F3
Process Gain	<input type="text" value="10.000"/>	Å/SEC/%PWR		
Master Tooling	<input type="text" value="100.0"/>	%		F4
Recorder Output	<input type="text" value="0"/>	(1-6, 0=None)		
Recorder Function	<input type="text" value="0"/>	(0=Rate 100Å/S, 1=Rate 1000Å/S, 2=Thick 100 Å, 3=Thick 1000 Å, 4=Rate Dev ±50Å/S, 5=Power)		F5
Crystal Quality	<input type="text" value="0"/>	(0-9)	MATERIAL LIBRARY	
Crystal Stability	<input type="text" value="0"/>	(0-9)		F6
4.0 Å/sec		52.96 kÅ	0.0 %	TEST
			XTAL FAIL	
			1	
			MATERIAL DIRECTORY	

Table 4-2 Function Key Selection Choices For Material Description

Key	Function	Description
F1	PAGE FORWARD	Select this panel to access the second page of material definition parameters.
F2	PAGE BACK	Select this panel to return to the first page of material definition parameters.
F5	MATERIAL LIBRARY	Select this panel to access the Material Library.
F6	MATERIAL DIRECTORY	Select this panel to return to the Material Directory.

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Figure 4-5 Material Definition (Page 2)

MATERIAL 1 - User		Page 2 of 3	PAGE FORWARD	F1
Maximum Power	<input type="text" value="90.0"/> %			
Soak Power 1	0.0 %		PAGE BACK	F2
Rise Time 1	00:00 MM:SS			
Soak Time 1	00:00 MM:SS			
Soak Power 2	0.0 %			F3
Rise Time 2	00:00 MM:SS			
Soak Time 2	00:00 MM:SS			
Auto-Soak 2	NO YES/NO			
Delay Option	2 0=None, 1=Shutter, 2=Control, 3=Both			F4
Control Delay Time	00:00 MM:SS			
Feed Power	0.0 %			
Feed Ramp Time	00:00 MM:SS			F5
Feed Time	00:00 MM:SS			
Idle Power	0.0 %			
Idle Ramp Time	00:00 MM:SS			
4.0 Å/sec 53.16 kÅ 0.0 %		TEST XTAL FAIL I	MATERIAL DIRECTORY	F6

Figure 4-6 Material Definition (Page 3)

MATERIAL 1 - User		Page 3 of 3									F1
Rate Avg	Å/SEC 4.0	Sens1	Sens2	Sens3	Sens4	Sens4	Sens5	Sens7	Sens8		
Thickness	kÅ 53.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	PAGE BACK	F2
Option	(0-4) <input type="text" value="1"/>	0	0	0	0	0	0	0	0		
Weight	% 100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		F3
Tooling	% 100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		
Cal Thick	kÅ 0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240		F4
XL Position (0-6)	0	0	0	0	0	0	0	0	0		F5
Options: 0 = Off 1 = Ignore fail unless last xtal then STOP 2 = Ignore fail unless last xtal then TIME POWER 3 = STOP on xtal fail 4 = TIME POWER on xtal fail											
4.0 Å/sec 53.35 kÅ 0.0 %		TEST XTAL FAIL I								MATERIAL DIRECTORY	F6

4.3 Material Definition Parameters

Rate Avg. and Thickness values are shown on Material definition page 3, for each sensor in use. The Rate Avg. shown is the rate averaged over the last 2.5 seconds minus the most recent 0.5 seconds. This is the same average as shown in the SENSORS display. Thickness is the value at each sensor. The thickness values are zeroed when the zero thickness function key is pressed when in the OPERATE display. N/A is shown for sensors which are not in use.

DENSITY 0.100 to 99.999 gm/cc

This parameter is specific to the material being deposited onto the Crystal. It is one of two parameters that relate the mass loading on the crystal to a thickness. Values range from 0.100 to 99.999. If a material is chosen from the Material Library the density is automatically entered. The default value is 10.00.

Z-RATIO 0.100 to 15.000

This parameter is specific to the material being deposited. It is one of two parameters that relate the mass loading on the crystal to a thickness. Values range from 0.100 to 15.000. If a material is chosen from the Material Library the Z-ratio is automatically entered. The default value is 1.00. This parameter is superseded if Auto Z-ratio is selected in Source/Sensor Set-Up.

SOURCE 1,2,3,4,5,6

This parameter determines which source, defined in the Source Set Up display, is to be used for source control voltage for the material being defined. Values can range from 1 to 6. The default is 1. This parameter cannot be changed while a process is running.

CONTROL LOOP 0,1,2

This parameter establishes the control loop algorithms pertaining to either a slow responding source or a fast responding source. Permissible values are 0, 1, or 2. Select a 0 to choose the non-PID control loop, good for fast- and medium-speed responding systems with **high noise** levels (e.g., an electron beam gun with or without a liner, having a large sweep amplitude of low frequency, 10 Hz or less). Select a 1 for the PI control loop, good for fast, medium, or slow systems with **medium noise** levels (e.g., an electron beam gun with medium sweep amplitude frequency, 20 to 100 Hz; also, sputtering and resistive sources). Select a 2 for the PID Control Loop, good for fast, medium or slow systems with **low noise** levels (e.g., an electron beam gun with sweep off or at a high frequency, 100+ Hz; also, sputtering and resistive sources).

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PROCESS GAIN 0.01 to 99.999 Å/sec/% pwr

This parameter determines the change in % Power for a given rate deviation (dRate/dPower). The larger the process gain value, the smaller the change in power for a given rate error. Values range from 0.01 to 99.999. The default value is 10.00.

PRIMARY TIME CONSTANT 0.010 to 999.999 sec

This is the evaporation source's time constant. This value is defined as the time difference between the actual start of a change in rate and the time at which 63% of the rate step is achieved. This value may be measured according to the above criterion or it may be determined empirically. Values range from 0.010 to 999.999 seconds. The default value is 1. This parameter is disabled if the CONTROL LOOP option parameter is set to 0.

SYSTEM DEAD TIME 0.010 to 999.999 sec

This value is defined as the time difference between a change in % power and the start of an actual change in rate. Values range from 0.010 to 999.999 seconds. The default value is 1.0. This parameter is disabled if the CONTROL LOOP option parameter is set to 0.

MASTER TOOLING 10.0 to 400.0%

This is a correction factor used for correlating the aggregate rate and thickness accumulation on the crystal with the thickness accumulation on the substrate. This thickness difference is due to the geometric distribution of material flux from the source.

The tooling factor is calculated using the equation

$$\text{TOOLING} = \text{TF}_i \times (T_m / T_x) \quad [1]$$

where TF_i = Initial Tooling Factor, T_m = Actual Thickness at the Substrate, and T_x = Thickness on the Crystal.

Values range from 10.0 to 400.0%. The default value is 100%.

If the MASTER TOOLING parameter is changed, the new MASTER TOOLING value is used for subsequent calculation of the individual as well as aggregate rate and thickness. Also, the aggregate thickness and each sensor's thickness accumulated thus far will be re-scaled based on the change to the MASTER TOOLING.

For *single* sensor applications, this is the recommended parameter to use to get agreement between sensor and substrate thicknesses. The sensor tooling should be left at 100%. For *multiple* sensor applications, the sensor tooling factors should first be adjusted so all sensors read the same rate. Next, adjust the MASTER TOOLING to get agreement between the thickness measured by the IC/5 and the thickness measured at the substrates.

RECORDER OUTPUT 0 to 6

The recorder output number can be programmed for aggregate rate. There are six outputs available which may be divided among source control voltage outputs, individual sensor rate/thickness recorder outputs, aggregate rate/thickness or power level recorder outputs. A value of zero indicates there is not a recorder output chosen for that function. Values 1 through 6 refer to the 6 DAC outputs on the back of the instrument. The default value is zero. Refer to [section 8.5 on page 8-8](#) for DAC output selection rules.

RECORDER FUNCTION 0 to 9

This parameter determines the function of the recorder output. Values range from 0 to 8.

- 0 = Aggregate Rate in the range of 0 to 100 Å/s
- 1 = Aggregate Rate in the range of 0 to 1000 Å/s
- 2 = Aggregate Thickness in the range of 0 to 100 Å
- 3 = Aggregate Thickness in the range of 0 to 1000 Å
- 4 = Aggregate Rate Deviation on a scale of +/- 50 Å/s
- 5 = % Power
- 6 = Aggregate Rate in the range of 0 to 10 Å/s
- 7 = Aggregate Rate Deviation in the range of 0 to 50 Å/s
- 8 = Aggregate Thickness in the range of 0 to 5000 Å
- 9 = Aggregate Rate in the range of 0 to 1 Å/s

CRYSTAL QUALITY 'Q' 0 to 9

This parameter is used to ensure tight rate control by monitoring the information obtained from the crystal. It can be used to effect a crystal fail when operating in the single frequency mode. In the case of the dual sensor, Q only affects the primary crystal. The “single frequency” mode is when the Z-ratio type is set for Material Z, “dual frequency” mode is when the Z-ratio type is set for Auto Z.

Table 4-3 Crystal Quality Number and Threshold of Rate Deviation

Crystal Quality Number	Threshold of Rate Deviation
9	2.5%
8	5.0%
7	7.5%
6	10.0%
5	12.5%
4	15.0%
3	20.0%
2	25.0%
1	30.0%
0	Disabled

For each sensor’s rate reading, the percent relative deviation from the sensor’s rolling average rate is calculated. Each time this deviation is greater than the allowed percent relative deviation, as determined by the Crystal Quality value, a counter is incremented by one count. If the deviation is within tolerance, the counter will count down. (The counter will not count below zero.) When the count reaches 100, a crystal fail will be initiated. In this manner only sustained erratic rate readings will trigger a crystal fail and instantaneous noise will be ignored.

If Auto Z is in use, the crystal quality will trigger an Auto Z failure instead of a crystal fail. This will change the instrument from dual frequency measurement mode to single frequency measurement mode. For some materials, it is possible to regain rate stability by this change. Once the switch to single frequency has occurred and a waiting period has elapsed (four times the Primary Time Constant plus the System Dead Time plus ten seconds), the counter will again track the rate deviation. If the counter reaches 100 a second time, a crystal fail will be triggered.

CRYSTAL STABILITY 'S' 0 to 9

The Crystal Stability parameter can also be used to effect a crystal fail. In normal operation, when mass is added to a crystal its frequency of oscillation will decrease. In the case of the dual sensor, S only affects the primary crystal. There are, however, a number of reasons, such as thermal shock, high stresses in the film, electrical arcing from an electron beam gun, or frequency instabilities, that may cause a positive frequency shift between successive measurements. The Crystal Stability function is used to monitor these positive frequency excursions. Values range from 0 to 9. The default value of 0 disables the function. Values 1 through 9 correspond to the maximum positive frequency accumulation permitted.

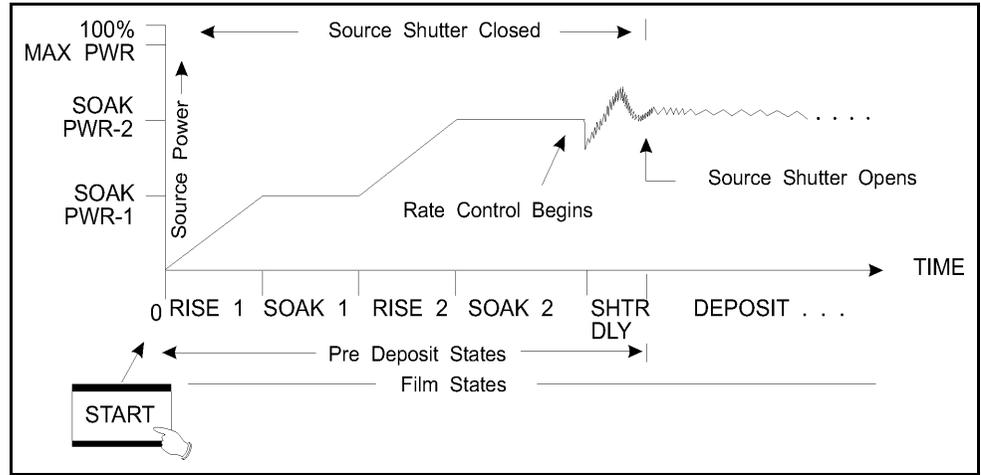
Table 4-4 Crystal Stability Number and Positive Frequency Accumulation

Crystal Stability Number	Positive Frequency Accumulation (Hz)
9	25
8	100 (max single shift of 50)
7	100
6	200 (max single shift of 100)
5	200
4	400
3	500
2	1000
1	5000 (max single shift of 1250)
0	Disabled

Each time there is a positive shift in frequency, the magnitude of the positive frequency excursion is accumulated. If the cumulative total, or the maximum single shift, exceeds the limit set by the Crystal Stability value a crystal fail function is triggered.

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Figure 4-7 Source Power Level Profile



MAXIMUM POWER 0.0 to 99.9%

This parameter is used to set the maximum permissible % power level. The control voltage output will not exceed this limit. Values range from 0.0 to 99.9%. The default value is 90%.

Power Ramps (Pre deposit states)

The next six parameters—Soak Power 1, Rise Time 1, Soak Time 1, and Soak Power 2, Rise Time 2 and Soak Time 2—are used to define two power ramps provided to precondition materials.

NOTE: The first power ramp consisting of Rise 1 and Soak 1 is skipped if the previous layer had the same source, same crucible and its idle power is nonzero.

SOAK POWER 1 0.0 to 99.9%

This parameter is usually set to the power level at which the source material just begins to melt. The instrument ramps the power level from zero to Soak Power 1 linearly over the time period Rise Time 1. Values range from 0.0 to 99.9%. The default value is 0.

RISE TIME 1 00:00 to 99:59 min:sec

This parameter provides the time period over which the source power is ramped from 0 to Soak Power 1. Values range from 00:00 to 99:59 minutes:seconds. The default values is 00:00.

SOAK TIME 1 00:00 to 99:59 min:sec

This parameter provides the time period for which the instrument holds at Soak Power 1. Values range from 00:00 to 99:59 minutes. The default value is 00:00.

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SOAK POWER 2 0.0 to 99.9%

This parameter sets the power level at which the rate from the source very nearly matches the desired deposition Rate. Values range from 0.0 to 99.9%. The default value is 0%.

RISE TIME 2 00:00 to 99:59 min:sec

This parameter sets the time period in which the instrument linearly ramps the power level from Soak Power 1 to Soak Power 2. Values range from 00:00 to 99:59 minutes:seconds. The default value is 00:00.

SOAK TIME 2 00:00 to 99:59 min:sec

This parameter sets the time period for which the instrument holds the power level at Soak Power 2. Values range from 00:00 to 99:59 minutes:seconds. The default value is 00:00.

AUTO SOAK 2 YES/NO

The Auto Soak 2 option, when enabled, calculates an average power setting over the last few seconds of the DEPOSIT state. This average power replaces the value programmed in Soak Power 2 so the next time this material is executed, the Soak Power 2 level is the Auto Soak 2 value. In this manner the Soak Power 2 value closely matches the power level required to achieve the desired deposition rate. The power is averaged over the last 2.5 seconds of the deposition. The default value is NO.

DELAY OPTION 0,1,2,3

0 = no delay chosen. The default value is 0.

1 = Shutter Delay state immediately following Soak Power 2 and preceding DEPOSIT. The source shutter relay remains in its normal state and the crystal shutter relay is active. The sensor, which must be positioned to sample the source flux with the source shutter closed, provides closed loop rate control. The rate control must be within +/-5% or 1 Å/s of the desired deposition rate for 5 seconds before the instrument will enter the DEPOSIT state, opening the source shutter and thus exposing the substrate to a well controlled rate of evaporant flux. If the required rate control accuracy cannot be achieved within 60 seconds the process will STOP.

2 = Control Delay state. Control delay suspends control loop action on the source control power for the time interval programmed in Control Delay Time. During Control Delay, the source and sensor shutters are activated.

3 = Instrument will first enter a shutter delay state followed by the control delay state.

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CONTROL DELAY TIME 00:00 to 99:59

This is the time interval for the instrument to be held in the Control Delay state. The parameter is displayed only if the control option value chosen is a 2 or a 3. The default value is 00:00.

Feed Ramp State

The next three parameters define a feed ramp provided to maintain power levels during a wire feed. After reaching Final Thickness, the instrument will enter the Feed Ramp state for the specified time. Control voltage is ramped from the power level at the end of the DEPOSIT state to the Feed Power level. Feed Power is held constant until the end of Feed Time. At the end of Feed Time, the instrument will proceed to the Idle ramp state.

FEED POWER 0.0 to 99.9%

This is one of three parameters used to affect a Feed Ramp. This value establishes the control voltage power level at which the source is maintained during wire feed. Values range from 0.0 to 99.9%. The default value is 0.

FEED RAMP TIME 00:00 to 99:59 min:sec

This is the time interval for the source power to ramp linearly from the power level at the end of Deposit to Feed Power. The Feed state is active during Feed Ramp Time. Values range from 00:00 to 99:59 minutes:seconds. The default value is 00:00.

FEED TIME 00:00 to 99:59 min:sec

This is the time interval for which the source power is maintained at Feed Power. The Feed state is active during Feed Time. Values range from 00:00 to 99:59 minutes:seconds. The default value is 00:00.

Idle Ramp State

The next two parameters define an idle ramp provided to maintain the control voltage power level after the Deposit or Feed state. Control voltage is ramped from the power level at the end of the Deposit state (or Feed Power, if one is set) to the Idle Power level. The control voltage is maintained at the Idle Power level until the instrument enters the STOP state or until the next layer, using the specified source, is started, or the turret source is rotated.

IDLE POWER 0.0 to 99.9%

This is one of two parameters used to affect an Idle Power Ramp. This value is the power level at which the source is maintained after the DEPOSIT phase (or after Feed phase if one is set up). Idle Power is usually the same as Soak Power 1. Values range from 0.0 to 99.9%. The default value is 0%.

IDLE RAMP TIME 00:00 to 99:59 min:sec

This is the time interval over which the source power is ramped linearly from the power level at the end of Deposit (or Feed Power if one is set) to Idle Power. Values range from 00:00 to 99:59 minutes:seconds. The default value is 00:00.

OPTION 0 to 4

This parameter determines which of the sensor inputs are to be used for the material being deposited. Up to 8 sensors may be used to control an “aggregate” rate. The aggregate rate is determined from averaged rate information at each sensor scaled by the sensor tooling and sensor weight parameters. The standard IC/5 includes sensor channels 1 and 2. The unit will support 6 additional sensor channels with the addition of optional measurement cards.

The sensor option parameter of the Material Set-Up display allows the ability to:

- 0 Turn off the use of this sensor
- 1 STOP if this is the last sensor to fail during deposition
- 2 Go to TIME POWER if this is the last sensor to fail during deposition
- 3 STOP when this sensor fails
- 4 Go to TIME POWER if this sensor fails

NOTE: When using either the double start (i.e., pressing the START key twice) or the codeposition feature, a sensor may not be used by two layers each in Deposit at the same time. If this is attempted, a sensor conflict error will occur and the instrument will enter the STOP state. If one layer is in either a pre-Deposit or post-Deposit state, and the other layer in Deposit, the layer in Deposit has use of the sensor. Once both layers are started, a sensor cannot be enabled if it is used by the other material.

If the sensor OPTION is changed, the subsequent aggregate rate will be affected only if the option is changed from zero to non-zero (addition of the sensor’s rate information), or from non-zero to zero (removal of the sensor’s rate information). Remember, the aggregate rate is a weighted average of the sensors’ rate information that have a non-zero sensor OPTION.

NOTE: The parameter change affects only the aggregate rate calculation. The aggregate thickness accumulated thus far is not affected by the addition or removal of a sensor.

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WEIGHT 1.0 to 400.0%

The Sensor Weight parameter is used to gauge the relative importance of each sensor's measured rate in calculating a weighted average "aggregate" rate. The default value is 100%.

If the WEIGHT parameter for a sensor is changed, the new WEIGHT for this sensor will be used for subsequent calculations of the aggregate rate, if the sensor's OPTION is non-zero.

NOTE: This parameter affects the aggregate rate calculation. The aggregate thickness accumulated thus far is not re-scaled based on the change to the weighting factor.

TOOLING 10.0 to 400.0%

The Sensor Tooling factor is used to account for the geometric tooling factor of each sensor. The default value is 100%.

If the TOOLING parameter for a sensor is changed, the new TOOLING value is used for subsequent calculations of the sensor rate, and therefore the aggregate rate, if the sensor's OPTION is non-zero.

NOTE: This parameter affects the aggregate rate calculation. The aggregate thickness accumulated thus far is not re-scaled based on the change to the TOOLING of a sensor. The individual sensor's accumulated thickness is also not re-scaled.

For installations using only a *single* sensor, use a value of 100% here, and adjust the MASTER TOOLING factor to match the thickness measured by the IC/5 to the thickness measured at the substrate. For *multiple* sensor applications, use the sensor tooling factors to adjust each sensor until they all read the same deposition rate, then use the MASTER TOOLING factor as described above.

CAL THICK

Calibration Thickness values are only used in co-deposition applications and do not pertain to single layer sequential deposition. These thickness values are used to compensate for the cross talk (or interference) from each source onto sensors used to control the other source's flux. The values range from 0.000 to 999.8 kÅ or UNCAL. UNCAL indicates the sensor has not been calibrated.

Values may be entered by the user or may be entered automatically using the cross talk calibration feature of the IC/5. See [section 12.5 on page 12-4](#) for a discussion of cross talk calibration.

XL POSITION 0 to 6

When using a CrystalSix sensor head, this allows selection of which of the six crystals are to be used. This incorporates automatic crystal switching (upon a crystal fail) to a predetermined subset of the 6 crystal positions if desired. A value of 0 enables sequential positioning.

4.4 Error Messages in Material Set-Up

BAD XTAL AND RUNNING

This message is displayed when the user attempts to turn on a sensor which has a failed crystal while executing a process.

DUPLICATE XTALS

The XL Position parameter must have unique positions for each of the 6 crystal positions. For example, the sequence 135 is valid. The sequence 155 will return a DUPLICATE XTALS error message.

ILLEGAL INPUT - VALUE TOO LARGE

ILLEGAL INPUT - VALUE TOO SMALL

Parameter entry is out of range. Allowable values will vary according to your unit configuration or the parameters being defined. Press Clear to delete the value and enter again.

MUST USE 1 SENSOR

At least one sensor for each defined Material must have its Option parameter non-zero.

OTHER DUAL IN USE

This error message is displayed when attempting to turn on a sensor that is configured as a Dual sensor head on the Sensor Set-Up display. When two sensors are configured as a Dual sensor type, only one of those sensors can be turned on in the Material display. The sensor which is turned on is considered the primary sensor of the Dual head.

SENSOR IN USE

An attempt is being made to turn on a sensor which is already in use for the other of the co-deposited materials.

SET AS RECORDER OUT

The value you are attempting to enter has been previously defined as a recorder output in either the Material Set-Up display or one of the Sensor Set-Up displays.

SET AS SOURCE OUT

The value you are attempting to enter has been previously defined as a Source DAC output in one of the Source Set-Up displays.

XTAL CANNOT EQUAL 0

A value in the XL Position parameter cannot be zero. For example, the sequence 135 is valid. The sequence 105 is not valid.

XTAL GREATER THAN 6

A value in the XL Position parameter cannot be greater than six. For example, the sequence 246 is valid. The sequence 247 is not valid.

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Chapter 5 Process Set-Up

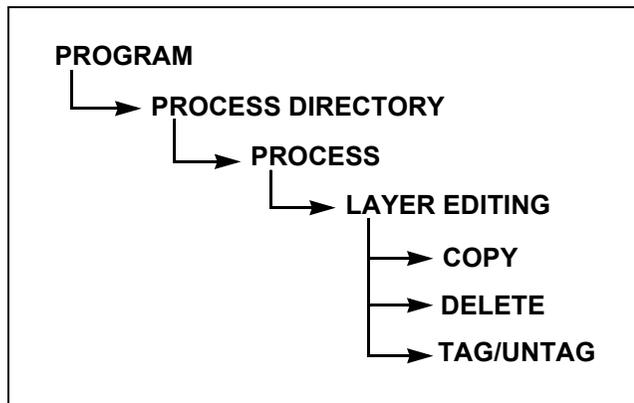
5.1 Process Set-Up Overview

The IC/5 is capable of storing the descriptions and parameters for up to fifty processes. Processes are made of sequential layers of materials. The layers may be allocated to any process, but the total number that can be defined is limited to 250 layers. A layer or sequence of layers may be copied up to 99 times, provided the maximum number of layers is not exceeded.

Process layer definition includes the specification of a previously defined material (See [Chapter 4, Material Set Up](#)), deposition rate, thickness and time limits and rate ramps. The co-deposition capability of the IC/5 allows establishing material ratio and cross-sensitivity relationships.

Processes are defined by sequencing layers. Layers must be defined sequentially starting with Layer 1. Defined layers may be inserted, deleted or copied using the LAYER EDITING feature.

Figure 5-1 Display Tree for Process Set Up



Process Set-Up is initiated by selecting the PROCESS Directory function (key F2) in the Program display. This will invoke the Process Directory (see [Figure 5-2](#)). Upon entry to the Process Directory, the cursor will be placed at the last referenced process.

Figure 5-2 Process Directory

PROCESS DIRECTORY			Active Process is 1	
PROCESS 1:	Cu, Ag, Dy			F1
PROCESS 2:	Cu, Cu, Cu, Cu, Cu			F2
PROCESS 3:	Ni, Cr+Cu			F3
PROCESS 4:	Ag			F4
PROCESS 5:				F5
PROCESS 6:				F6
0.0 Å/sec 0.000 kÅ 0.0 %			PROCESS	
			PROGRAM	

5.2 Process Definition

Selecting the PROCESS function (key F5) in the Process Directory will take you to a display that enables layer by layer specification (see Figure 5-3). Four adjacent layers from left to right are visible at any time on a display page. The parameters for each layer can extend ahead to a second page.

You move among and through the layers by using the cursor and function keys. Parameters are entered with the numeric keypad. See Table 5-1.

Figure 5-3 Layer Definitions

PROCESS 1		Page 1 of 2 Layers Defined 4				PAGE FORWARD
		Layer 1	Layer 2	Layer 3	Layer 4	
Material Index	(1-24)	Cu 1	Ag 2	Dy 3	Dy 3	F1
Rate	Å/SEC	0.0	0.0	0.0	0.0	F2
Final Thickness	kÅ	0.000	0.000	0.000	0.000	PAGE RIGHT
Thickness Limit	kÅ	0.000	0.000	0.000	0.000	
Time Limit	MM:SS	00:00	00:00	00:00	00:00	F3
Co-Deposition	YES/NO	YES		NO	NO	F4
Ratio Control	%	0.0				
Cal Status		AUTO				
Cross Talk %		6				F5
RateWatch Time	MM:SS	00:00	00:00	00:00	00:00	LAYER EDITING
RateWatch Accuracy	%	5	5	5	5	
Crucible	(1-64)	1	1	1	1	F6
0.0 Å/sec 0.000 kÅ 0.0 % 0.0 Å/sec 0.000 kÅ 0.0 %						PROCESS DIRECTORY

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Table 5-1 Function Key Selection Choices for Process Layer Definition

Key	Function	Description
F1	PAGE FORWARD	Select this function to access the second page of Layer Parameters.
F2	PAGE BACK	Select this function to return to the first page of Layer Parameters.
F3	PAGE RIGHT	Select this function to advance beyond the currently defined four layers.
F4	PAGE LEFT	Select this function to view previously defined layers.
F5	LAYER EDITING	Select this function to add, delete or copy layers.
F6	PROCESS DIRECTORY	Select this function to return to the Process Directory.

5.2.1 Layer Editing

Selecting the LAYER Editing function in the Process display will take you to a display that enables copying layers (see Figure 5-4 and Table 5-2). A layer or sequence of layers may be copied up to 99 times provided the total number of layers does not exceed 250.

Figure 5-4 Layer Editing

PROCESS 1						Page 1 of 2 Layers Defined 4	COPY	F1
		Layer 1	Layer 2	Layer 3	Layer 4			
Material Index	(1-24)	Cu 1	Ag 2	Dy 3	Dy 3		DELETE	F2
Rate	Å/SEC	0.0	0.0	0.0	0.0		PAGE RIGHT	F3
Final Thickness	kÅ	0.000	0.000	0.000	0.000			F4
Thickness Limit	kÅ	0.000	0.000	0.000	0.000			
Time Limit	MM:SS	00:00	00:00	00:00	00:00			
Co-Deposition	YES/NO	YES		NO	NO			
Ratio Control	%	0.0						
Cal Status		AUTO						
Cross Talk %		6						
RateWatch Time	MM:SS	00:00	00:00	00:00	00:00		TAG/ UNTAG	F5
RateWatch Accuracy	%	5	5	5	5			
Crucible	(1-64)	1	1	1	1			
		0.0 Å/sec	0.000 kÅ	0.0 %			PROCESS	F6
		0.0 Å/sec	0.000 kÅ	0.0 %				

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Table 5-2 Function Key Selection Choices for Layer Editing

Key	Function	Description
F1	COPY	Identify the layer(s) to be copied using the TAG/UNTAG (F5) function. After tagging the layer(s), move the cursor to the location where the sequence of layers is to be inserted. This must be done before the COPY function is selected. Once the layers are identified (tagged) and the cursor is positioned, select the COPY function. This will place the cursor at the “# of times to copy” parameter. Enter the number of times the layer or sequence of layers should be copied and then press the enter (E) key. Select the COPY function a second time to complete the copying of layers into the process. The sequence of layers will be inserted at the cursor’s last position before COPY was selected. Untag the layers after copying is completed.
F2	DELETE	Select this function to delete the tagged layer or sequence of tagged layers.
F3	PAGE RIGHT	Select this function to advance beyond the currently displayed four layers.
F4	PAGE LEFT	Select this function to view previously displayed layers.
F5	TAG/UNTAG	Use this function to identify the layer or layers to copy (or delete) selecting the TAG/UNTAG function will designate the tagged layer in reverse video. Untag will return the layer to normal video. NOTE: Once a layer or sequence of layers is tagged, use the cursor keys to select the position within the process to copy the layer(s).
F6	PROCESS	Select this function to return to the Process Directory.

5.3 Layer Definition Parameters

MATERIAL INDEX 1 to 24

This indicates which of the predefined materials is to be run with the Layer being defined. Values range from 1 to 24, corresponding to the materials listed in the Material Directory. The default value is 1. This value cannot be changed while running a process. It is not permitted to enter a value corresponding to an undefined material.

AGGREGATE RATE 0.0 to 999 Å/sec from front panel, 0.00 to 999 Å/sec via communications

This specifies the rate at which the deposition is to be controlled during the DEPOSIT and Shutter Delay states. The Aggregate Rate is calculated based on:

- ◆ The rate information acquired by each sensor in use.
- ◆ A sensor weighting factor that indicates the relative importance of each sensor's information
- ◆ The sensor tooling factor that corrects for any relative difference in flux distribution reaching the sensors.

The aggregate rate is calculated from a combination of the above information into a weighted average. Values range from 0.00 to 999 Å/sec. The front panel display is rounded up or down to the nearest 0.1Å. A value of 0.0 Å/sec allows skipping of the deposit state (see [section 5.5 on page 5-9](#)). The default value is 0.0 Å/sec.

FINAL THICKNESS 0.000 to 999.9 kÅ

This is the thickness setting that triggers the end of the DEPOSIT state. A value of 0.000 kÅ allows skipping of the deposit state (see [section 5.5 on page 5-9](#)). The Source Shutter and Crystal Shutter relays return to their normal states and the Layer enters the Idle Ramp or the Feed Ramp state. Values range from 0.000 to 999.9 kÅ. The default value is 0.000 kÅ.

THICKNESS LIMIT 0.0 to 999.9 kÅ

This sets the thickness at which the Thickness Limit is triggered. This thickness begins to accumulate after entering the Deposit state. The state remains active after reaching Thickness Limit until the beginning of the IDLE state. Values range from 0.000 to 999.9 kÅ. The default value is 0.000 kÅ. See also [THICK LIMIT on page 6-11](#).

TIME LIMIT 00:00 to 99:59 min:sec

This is the deposition time at which the Time Limit is triggered. This time begins to accumulate at the start of the Deposit state. The Time Limit, once triggered, remains active until the start of the IDLE state. Values range from 00:00 to 99:59 minutes:seconds. The default value is 00:00. See also [TIME LIMIT on page 6-11](#).

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CO-DEPOSITION Yes/No

This feature allows two Layers to be run concurrently with the pertinent sources controlled independently. The Layers to be co-deposited must be sequential in the Process. The default value is NO. This parameter cannot be changed while running a Process. To specify co-deposition, enter YES in the co-deposition parameter for the first layer *after* both layers are defined.

When the first Layer reaches Final Thickness prior to the second Layer, the second Layer will terminate. When the second Layer reaches Final Thickness prior to the first Layer, the first Layer will continue in DEPOSIT until reaching its own Final Thickness.

RATIO CONTROL 0.0 to 999.9%

This parameter is used with the co-deposition feature. It establishes a Master/Slave relationship between the two sources being co-deposited. The first Layer is always the Master, with the second Layer's rate being controlled to a percentage of the first Layer's rate. Allowable values range from 0.0 to 999.9%. The default is 0.0, which disables the function.

RateWatcher™ Sample and Hold Feature

Two parameters, Ratewatch Time and Ratewatch Accuracy, enable the Sample and Hold feature. When enabled, this feature periodically samples the deposition rate by automatically opening the sensor shutter and exposing the sensor to the deposition source. The power is adjusted so the actual rate is set to the desired rate. The sensor shutter is then automatically closed and power is held constant at the adjusted level. A five second time delay for thermal stabilization occurs between opening the shutter and taking measurements. During this time, "DELAY" in the IC/5 message area.

RATEWATCH TIME 00:00 to 99:59 min:sec

Ratewatch Time determines the time interval between sample periods. The crystal shutter relay is in its normal state during this time. Values range from 00:00 to 99:59 minutes:seconds. The default value is 00:00, which disables the function.

During a Rate Ramp, the Sample and Hold feature is inactive; the crystal shutter is open and the rate is controlled by the crystal.

RATEWATCH ACCURACY 1 to 99.9%

During the rate sampling period, the deposition rate is measured by the crystal; source power control is active. When the rate is within the desired accuracy continuously for five seconds, the shutter is closed and the deposition state returns to HOLD. The minimum accuracy is 1% or 0.1 Å/s, whichever is greater. Values range from 1 to 99.9%. The default value is 5%.

CRUCIBLE 1 to 64 (max)

This value is used in conjunction with the Number of Crucibles selected in Source Set-Up (see page 8-3). The integer value entered here sets the state of the Crucible relays. Values range from 1 to the number of Crucibles chosen, up to a maximum of 64. The default value is 1. This parameter is set to 1 if the Crucible function is not chosen in configuring the Source/Sensors.

RATE RAMP 1

Rate Ramp 1 is provided to effect an aggregate rate change while depositing a Layer. The aggregate rate is ramped linearly from the original rate setpoint to the New Rate 1 value over the time interval Ramp Time 1. It is allowed to ramp to a higher or a lower rate. See section 5.5 on page 5-9 for the Rate Ramp trigger of Final Thickness feature.

NEW RATE 1 0.0 to 999 Å/sec from front panel, 0.00 to 999 Å/sec via communications

This value sets the newly desired aggregate rate. Values range from 0.00 to 999 Å/sec. The default value is 0.0.

START RAMP 1 0.000 to 999.9 kÅ

This value sets the thickness at which to start the Rate Ramp. Values range from 0.000 to 999.9 kÅ. This thickness value must be less than or equal to the Start Ramp 2 thickness value if the value of Start Ramp 2 is non-zero. A value of zero disables the feature.

RAMP TIME 1 00:00 to 99:59 min:sec

This value determines the time period over which to ramp the rate from the original rate to New Rate 1. Values range from 00:00 to 99:59 minutes:seconds. The default value is 00:00.

RATE RAMP 2

Rate Ramp 2 is provided to effect a second change in aggregate rate during the deposition of a Layer. The rate is ramped linearly from New Rate 1 to New Rate 2 over the time interval Ramp Time 2. It is allowed to ramp to a higher or lower rate.

NEW RATE 2 0.0 to 999 Å/sec from front panel, 0.00 to 999 Å/sec via communications

This value sets the newly desired aggregate rate. Values range from 0.00 to 999 Å/second. The default is 0.0.

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START RAMP 2 0.000 to 999.9 kÅ

This value determines the thickness at which to begin Rate Ramp 2. Values range from 0.000 to 999.9 kÅ. The default value is 0. A value of zero disables this feature. Start Ramp 2 thickness must be greater than Start Ramp 1 thickness. Also, Rate Ramp 2 can not be started until the completion of Rate Ramp 1. If the thickness of Start Ramp 2 is exceeded while in Rate Ramp 1, Rate Ramp 2 will begin immediately after Rate Ramp 1.

RAMP TIME 2 00:00 to 99:59 min:sec

This value is the time interval over which the aggregate rate is ramped linearly from New Rate 1 to New Rate 2. Values range from 00:00 to 99:59 minutes:seconds. The default value is 00:00.

5.4 Error Messages in Process Set-Up

CANNOT DELETE CO-DEP

A layer being co-deposited cannot be deleted. Set the parameter co-deposition to NO prior to deleting the layer.

CANNOT EMPTY PROCESS

The last layer of Process 1 cannot be deleted.

CANNOT INSERT CO-DEP

A layer cannot be inserted between two co-deposited layers. Set the co-deposition parameter to NO prior to inserting a layer.

DEL LAST PROCESS FIRST

Delete last process first. The last layer of a process cannot be deleted unless it is the last layer of the last defined process. The last layer of Process 1 can never be deleted.

ILLEGAL INPUT - VALUE TOO LARGE

ILLEGAL INPUT - VALUE TOO SMALL

Parameter entry is out of range. Allowable values will vary according to your unit configuration or the parameters being defined. Press Clear to delete the value and enter again.

MATERIAL UNDEFINED

Material must be previously defined in the Material Directory.

MUST SET TAG(S)

A copy or delete operation cannot be done without first “tagging” the layer(s) to be copied or deleted.

NO MATERIAL DEFINED

Materials must be defined to be used in a Process Layer.

NOT ENOUGH LAYERS

This message is displayed if the number of layers to copy combined with the number of layers already programmed into the IC/5 will exceed the capacity of the instrument. The total capacity of the IC/5 is 250 layers.

RAMP 1 MORE THAN 2

Start Ramp 1 Thickness value must be less than Start Ramp 2 value.

RAMP 2 LESS THAN 1

Start Ramp 2 Thickness value must be greater than Start Ramp 1 value.

2 TAGS ALREADY SET

During layer editing this message indicates an attempt to Tag a layer after the user has already tagged two layers.

5.5 Special Layer Parameter Features

5.5.1 Skip Deposit

If the Rate parameter is set to 0.0Å/s or the Final Thickness is set to 0.000 kÅ, the instrument will skip the DEPOSIT State. State processing will go directly to the first programmed post-Deposit state from the last pre-Deposit state. Also, if the Rate parameter is set to zero during deposit, the Final Thickness will be triggered.

5.5.2 Rate Ramp Trigger of Final Thickness

If either of the rate ramps is programmed for zero New Rate and a non-zero Start Ramp, the Final Thickness will be triggered upon completion of the Rate Ramp.

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Chapter 6

I/O Logic Statement Set-Up

6.1 I/O Logic Statement Overview

The IC/5 has programmable logic capabilities that allow it to specifically respond to various external stimuli (Inputs), to send control signals to external devices based on Inputs or specific instrument conditions (Outputs) and also to internally branch and control the execution of a process or series of processes without operator intervention. You can tailor these capabilities by programming the logic statements.

- ◆ Programming is accessed through the I/O branch of the menu tree.
- ◆ Single or multiple actions may be triggered by Inputs or the fulfillment of a user specified logical condition.
- ◆ Inputs are only processed when they or the statement they are used in undergo a transition and on instrument power-up.
- ◆ Single or multiple complex defined conditions are used to define an event.
- ◆ The Logical operators; AND, OR, and NOT (negate) as well as grouping operators (parentheses) are available to define very precise conditionality. An additional operator, ON, specifically ties certain events together.
- ◆ It is possible to execute an action immediately or delay it for a definable period of time through use of a timer or a counter.
- ◆ Each Logic statement is evaluated every measurement cycle of 100 ms.
- ◆ Layer, process, or material entries for each logic statement can be made exclusive or inclusive.
- ◆ The components of the Logic statements may be the transition between or entry of a specific state, specific programmable time limits, programmable thickness limits or various error conditions.
- ◆ There are user defined messages which may be displayed.
- ◆ Inputs and outputs may be named on an I/O map display. Additionally on this display, the outputs may be defined as normally open (NO) or normally closed (NC).
- ◆ Logic statements may be chained together using the Statement ### Event.

These features, combined with layer based process sequencing, allow moderately complex vacuum processing plants to be controlled without the addition of any other intelligent machines. It is possible that a user may program certain layers within the process definition whose only purpose is to trigger certain other internal

sequencing and/or external control events. These “dummy” layers execute very rapidly if the pre and post deposit state times, rate, and final thickness values are all set to zero.

Fourteen TTL inputs and eight relay outputs are standard. An additional fourteen inputs and eight relay outputs are available with an optional I/O card. With a second optional I/O card, eight more relays and fourteen open collector outputs are available.

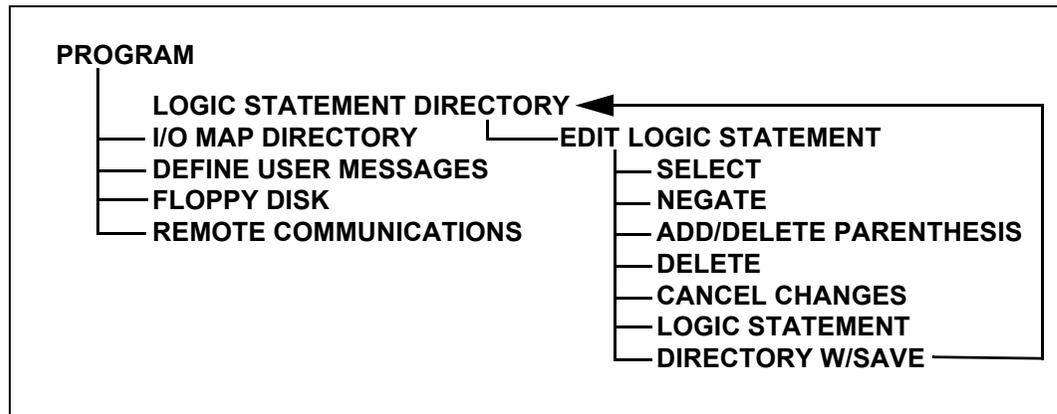
The IC/5 has the capacity for 100 logic statements.

6.2 Editing the Logic Statements

A series of conditional events and a related series of actions may be defined through the Logic Statements. When the event string is determined to be true the associated actions are executed in left to right order. The state of the Logic statement is indicated on the Logic Directory display. *Three small asterisks under the Logic Statement number indicate the statement is true (active).* The expressions are evaluated in numerical sequence starting with logic statement 1.

To initiate Logic Statement Set-Up, press function key F3 (I/O) in the Program display; then press function key F1 (Logic Statement Directory). This will invoke the Logic Statement Directory (see Figure 6-1). Upon entry, the cursor will be placed at the last referenced Logic statement. Entries for four statements are shown on each display page.

Figure 6-1 Display Tree for Internal Logic Set-Up



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6.2.1 Logic Statement Directory

A logic statement is selected for editing by positioning the box cursor at the desired statement number and pressing key (F5). Then, by selecting the SELECT function (F1), see [Figure 6-2](#) and [Table 6-1](#). The edit mode will be entered where events and actions can be inserted. See [Figure 6-3](#) and [Table 6-2](#).

Figure 6-2 Logic Statement Directory

LOGIC STATEMENT DIRECTORY		PAGE FORWARD	F1
1.	IF THEN		F2
2.	IF THEN		F3
3.	IF THEN		F4
4.	IF THEN	EDIT LOGIC STATEMENT	F5
1.7 Å/sec 0.079 kÅ 0.0 %		I/O	F6

Table 6-1 Function Key Selection Choices for the Logic Statement Directory

Key	Function	Description
F1	PAGE FORWARD	Select this function to access the next page of statements.
F5	EDIT LOGIC STATEMENT	Select this function to select or change event or action definitions. Editing of a logic statement can only be done when in the READY state.
F6	I/O	Select this function to return to the I/O display.

6.2.2 Logic Statement Editing

Figure 6-3 Logic Event Selection

LOGIC STATEMENT 1		SELECT
IF	<input type="text"/>	NEGATE
THEN		ADD/ DELETE PAREN- THESIS
		DELETE
		CANCEL CHANGES
		LOGIC STATEMENT DIRECTORY w/SAVE

Table 6-2 Function Key Selection Choices for Logic Statement Editing

Key	Function	Description
F1	SELECT	If the cursor is on IF (Event), or THEN (Action), pressing this key will bring up the respective Event or Action List.
F2	NEGATE	If the cursor is on an Event pressing this key will negate the Event.
F3	ADD/DELETE PARENTHESIS	If on an Event pressing this key will insert a parenthesis: a left parenthesis will be added if no previous parenthesis is defined; a right parenthesis is added if the cursor is on an Event which does not have a left parenthesis and a left parenthesis is already defined. If the cursor is on an Event which has a parenthesis defined, pressing this panel will delete the parenthesis.
F4	DELETE	If on an Event or Action, pressing this key will delete the Event or Action as well as associated connector and parenthesis.
F5	CANCEL CHANGES	Pressing this key will cancel any changes and return the Logic Statement to be the same as when the display was entered.
F6	LOGIC STATEMENT DIRECTORY w/SAVE	Pressing this key returns to the Logic Statement Directory and saves the Logic Statement.

Figure 6-4

LOGIC STATEMENT 1				REPLACE	F1
IF	[REDACTED]			INSERT	F2
THEN					
EVENTS					F3
EXTRNL INPUT	RATE RAMP 1 RATE RAMP2 TIME POWER MANUAL	PROCESS END LAYER END MATERIAL END	TIMER ACTIVE TIMR EXPIRED		F4
PRE-DEPOSIT DEPOSIT POST-DEPOSIT	FEED RAMP REED IDLE RAMP IDLE	PROCESS LAYER MATERIAL SOURCE SENSOR	CNTR EXPIRED STATEMENT COMPUTER CTL		F5
READY SRC SHTR RISE 1 SOAK 1 RISE 2 SOAK 2 SHUTTER DLAY	THICK LIMIT FINAL THICK TIME LIMIT	LAST LAYER CHOPPER WHL AUTOTUNE	STOP XTAL FAIL MAX POWER SHUTTER ERR AUTO-Z FAIL	LOGIC STATEMENT	F6

F1	REPLACE	Changes the Event or Action in reverse video to what is contained in the box cursor.
F2	INSERT	Inserts the Event or Action in the box cursor into the Logic Statement at the position indicated by reverse video. Previously entered Events or Actions are moved to the right.
F6	LOGIC STATEMENT	Exits the Event or Action List display and returns to the Logic Statement Editing display.

Logic Connectors

If the cursor is on a connector designated by ccc, pressing F1 (SELECT) will toggle the ccc between a logical AND and a logical OR.

For those Events which are layer or material specific an additional operator can be selected. This is the ON operator and pressing the F1 (SELECT) key will now toggle between AND, OR, and ON.

The ON operator is designed for use in co-deposition applications to link an Event to a particular layer or material. Therefore only those Events which can be directly associated with a layer or material can precede the ON connector. This includes all the Pre-Deposit, Deposit, and Post-Deposit states, Thick Limit, Final Thickness, Time Limit, Layer, Material, Source, Sensor, Chopper Wheel, XTAL Fail, Max Power, Shutter Err, Auto Z Fail, Layer End, Material End and AutoTune.

Additionally, there are certain rules to follow when using the ON connector. These are:

- 1 There cannot be two consecutive ONs in a statement. A ON B ON C is not allowed. A ON B and C ON D is acceptable.
- 2 Neither the Event preceding nor following the ON can have a negate or a parenthesis. That is: A ON (B AND C) or (A AND B) ON C is not allowed.

- 3 The ON connector always takes precedence over the AND and OR operators no matter where it appears in the statement. That is A AND B ON C will be evaluated as A AND (B ON C) not (A AND B) ON C.
- 4 The only Events allowed following the ON connector are Layer ### and Material ###.

6.3 'IF' Event Definitions

NOTE: If two layers are active simultaneously, an Event condition is considered TRUE if it is true for one or both of the two layers (e.g. if the first layer is in DEPOSIT and the second layer is in PRE-DEPOSIT, both the DEPOSIT and the PRE-DEPOSIT Events would be TRUE).

NOTE: The presence (or absence) of an input is leading edge detected on the transition from high to low (or low to high). Inputs are not "re-evaluated" if held level at either the high or low state.

AUTO Z FAIL #

Sets the logic condition to be true whenever an Auto Z fail condition occurs for the designated sensor. The condition remains true until the Auto Z Fail condition is cleared.

AUTOTUNE

Sets the logic condition to be true when AutoTune is started. The condition remains true until Autotune is completed, exited, or until an AutoTune Fail condition occurs.

CHOPPER WHEEL

Sets the logic condition to be true at the end of the SOAK 2 state or MANUAL. The condition remains true until the end of DEPOSIT or until a STOP command is received.

COMPUTER CONTROL

Sets the logic condition to be true when a Set Logic Statement vvv command is received from the remote communications port. The logic condition remains true until a Clear Logic Statement vvv command is received from the remote communications port. See Remote Commands RG5 and RG6 (see [section 7.7 on page 7-10](#)).

COUNTER EXPIRED #

Indicates the counter number designated has been set and counted down to zero.

DEPOSIT

Sets the logic condition to be true at the beginning of the Deposit state or in the Manual state. The condition remains true until the end of the DEPOSIT state, when a STOP/RESET or STOP/START sequence is executed. Rate Ramps are considered part of the Deposit state.

EXTERNAL INPUT

Designates a hardware input which, when it changes state, can be used to trigger an Action. Inputs can be given names up to 10 characters long. See [section 6.6 on page 6-16](#). Inputs are activated by pulling the specific input's terminal to ground (<0.8 V) through a contact closure to common (GND) or with TTL/CMOS logic having current sink capability of 2 mA (1 low power TTL load).

FEED RAMP TIME

Sets the logic condition to be true at the start of Feed Ramp. The condition remains true until the end of Feed Ramp. The condition is also cleared when entering the Manual state, when a STOP/RESET or a STOP/START sequence is executed.

FEED TIME

Sets the logic condition to be true at the start of Feed Time. The condition remains true until the end of Feed Time. The condition is also cleared when entering the Manual state, when a STOP/RESET or a STOP/START sequence is executed.

FINAL THICK

Sets the logic condition to be true once the Final Thickness is achieved while in Deposit or Manual or when the Final Thickness Trigger action is activated. The condition remains true until the Layer which has achieved Final Thickness enters the IDLE state or until a STOP/RESET sequence is executed.

IDLE

Sets the logic condition to be true at the beginning of the Idle state. The condition remains true until the end of Idle. The condition is also cleared when entering the Manual state, when a STOP/RESET or a STOP/START sequence is executed.

IDLE RAMP

Sets the logic condition to be true at the start of Idle Ramp. The condition remains true until the end of Idle Ramp. The condition is also cleared when entering the Manual state, when a STOP/RESET or a STOP/START sequence is executed.

LAST LAYER

Sets the logic condition to be true at the beginning of the Last Layer defined for the active process. The condition remains true until the last Layer enters the IDLE state.

LAYER ###

Sets the logic condition to be true at the beginning of Layer ### (when Layer ### is in the READY state at the beginning of a Process or when STARTed during a Process). The condition remains true until the layer is no longer active. Numeric inputs range from 1 to the maximum number of defined layers.

LAYER END ###

Sets the logic condition to be true when the specified Layer enters the IDLE state. The condition remains true until a START or a STOP/RESET command is received. Numeric inputs range from 0 to the maximum number of defined layers, with 0 indicating all Layers.

MANUAL

Sets the logic condition to be true when the Manual state is entered. The condition remains true until leaving the Manual state, when a STOP/RESET or a STOP/START sequence is executed.

MATERIAL ##

Sets the logic condition to be true whenever a Layer containing Material ## is in the READY state at the beginning of a Process or when it is STARTed during a Process. The condition remains true until the material is no longer active and can stay true across layers if the same material is used in 2 or more consecutive layers. Numeric inputs range from 1 to the maximum number of defined materials.

MATERIAL END ##

Sets the logic condition to be true when the Layer for the specified Material enters the IDLE state. The condition remains true until a START or a STOP/RESET command is received. Numeric inputs range from 0 to the maximum number of defined materials, with 0 indicating all materials.

MAX POWER

Sets the logic condition to be true as long as any source is at Maximum Power. The condition remains true until every source is less than Maximum Power.

PRE-DEPOSIT

Sets the logic condition to be true at the beginning of the Ready, Source Switch, Shutter Delay, Rise 1, Rise 2, Soak 1, or Soak 2 state. The condition remains true until the Deposit, Manual, or any Post-Deposit state is entered.

POST-DEPOSIT

Sets the logic condition to be true at the beginning of the Feed state or the beginning of the Idle Ramp state. The condition remains true until a START command is received or until a STOP/RESET sequence is executed.

PROCESS

Sets the logic condition to be true when Process # is designated as the Active Process. The condition remains true until the Process number is changed. Numeric inputs range from 1 to 50, indicating the respective Process.

PROCESS END

Sets the logic condition to be true at the end of the specified process when Idle is entered. The condition remains true until a START or a STOP/RESET command is received. Numeric inputs range from 0 to 50, with 1 through 50 indicating the respective Process and 0 indicating all Processes.

RATE <0.1

This condition will evaluate true when the actual deposition rate is less than 0.1 Å/s for more than 5 seconds while in Deposit or Manual. The condition remains true until the actual deposition rate is greater than 0.1 Å/s for 5 seconds or more.

RATE RAMP 1

Sets the logic condition to be true at the beginning of Rate Ramp 1. The condition remains true until the end of Rate Ramp 1. The condition is also cleared when entering the Manual state, when a STOP/RESET or a STOP/START sequence is executed.

RATE RAMP 2

Sets the logic condition to be true at the beginning of Rate Ramp 2. The condition remains true until the end of Rate Ramp 2. The condition is also cleared when entering the Manual state, when a STOP/RESET or a STOP/START sequence is executed.

READY

Sets the logic condition to be true as long as the instrument is in the READY state. The condition remains true until a START command is received.

RISE 1

Sets the logic condition to be true at the start of Rise Time 1. The condition remains true until the end of the Rise Time 1. The condition is also cleared when entering the Manual state, when a STOP/RESET or a STOP/START sequence is executed. **Note:** This state and SOAK 1 are skipped if the same material was used in a previous layer and has a non-zero Idle power. The next layer using this material will immediately proceed to the Rise 2 state.

RISE 2

Sets the logic condition to be true at the start of Rise Time 2. The condition remains true until the end of Rise Time 2. The condition is also cleared when entering the Manual state, when a STOP/RESET or a STOP/START sequence is executed.

SENSOR #

Sets the logic condition to be true whenever a Layer containing the Sensor # is in the READY state, or when it is STARTed. The condition remains true until a Layer containing a Material that does not use this Sensor # is STARTed or placed in the READY state, or until a Crystal Switch on a dual sensor head is done. Numeric inputs range from 1 through 8.

SHUTTER DELAY

Sets the logic condition to be true at the start of Shutter Delay. The condition remains true until the end of Shutter Delay. The condition is also cleared when entering the Manual state, when a STOP/RESET or a STOP/START sequence is executed.

SHUTTER ERROR

Sets the logic condition to be true when a Shutter Delay Error condition occurs. The condition remains true until a START or a RESET command is received.

SOAK 1

Sets the logic condition to be true at the start of Soak Time 1. The condition remains true until the end of Soak Time 1. The condition is also cleared when entering the Manual state, when a STOP/RESET or a STOP/START sequence is executed. **Note:** This state and RISE 1 are skipped if the same material was used in a previous layer and has a non-zero Idle power. The next layer using this material will immediately proceed to the Rise 2 state.

SOAK 2

Sets the logic condition to be true at the start of Soak Time 2. The condition remains true until the end of Soak Time 2. The condition is also cleared when entering the Manual state, when a STOP/RESET or a STOP/START sequence is executed.

SOURCE #

Sets the logic condition to be true whenever a Layer containing Source # is in the READY state, or when it is STARTed. The condition remains true until a Layer containing a Material with a different Source # is STARTed or placed in the READY state.

SOURCE SWITCH

Sets the logic condition to be true at the beginning of the Source Switch state. The condition remains true until the end of the Source Switch state. The condition is also cleared when a STOP/RESET or a STOP/START sequence is executed.

STATEMENT #

This Event can be used to test a logic statement transition and the appropriate Action is taken when the statement designated becomes “true.” A “true” statement is indicated by three small asterisks below the statement number.

STOP

Sets the logic condition to be true as long as the instrument is in STOP. The condition remains true until a RESET or a START command is received.

TEST

Sets the condition to be true when the IC/5 is in TEST.

THICK LIMIT

Sets the logic condition to be true once the Thickness Limit is achieved. The condition remains true until entering the IDLE state for that Layer or until a STOP/RESET sequence is executed.

TIME LIMIT

Sets the logic condition to be true once the Time Limit is achieved. The condition remains true until the Layer which has achieved Time Limit enters the IDLE state or until a STOP/RESET sequence is executed.

TIME POWER

Sets the logic condition to be true upon entering a Time Power state. The condition remains true until the end of the DEPOSIT state.

TIMER ACTIVE ###

Indicates the Timer number designated has been set and not cancelled. *An expired timer will remain active until canceled.*

TIMER EXPIRED #

Indicates the timer number designated has been set and the time expired. *An expired timer remains in the TIMER EXPIRED state until it is cancelled with the CANCEL TIMER # action.*

XTAL FAIL #

Sets the logic condition to be true as long as there is a Crystal Fail without having a Crystal Switch for the designated sensor. The logic condition remains false if the XTAL FAIL INHIBIT Action is active. The condition remains true until a working crystal is input to the appropriate sensor.

6.4 'THEN' Action Definitions

NOTE: The following are level outputs and once turned on will remain active until turned off. This is true even if the Logic string is cleared.

START INHIBIT (ON/OFF)	CRYSTAL FAIL INHIBIT (ON/OFF)
RW HOLD (ON/OFF)	RW HOLD INHIBIT (ON/OFF)
SOAK HOLD 1 (ON/OFF) ###	SOAK HOLD 2 (ON/OFF) ###
EXTERNAL OUTPUT (ON/OFF) ##	MESSAGE (ON/OFF) ##
NON-DEPOSIT CLOCK HOLD (ON/OFF)	

CANCEL TIMER

Deactivates the designated timer to restore its status to 'Not Active' and 'Not Expired'.

COUNT ###

Sets the designated counter to the value programmed in ###. The first field, ###, designates the counter number. The second field, ###, designates the number of counts. Up to 20 counters may be set.

CRYSTAL FAIL INHIBIT (ON/OFF)

This Action prohibits the Crystal Fail state from becoming active. This is useful when changing crystals.

DECREMENT COUNTER

Decreases the count by one (if nonzero) in the designated counter.

EXTERNAL OUTPUT (ON/OFF)

Designates a hardware output and places it into its ON or OFF state. Outputs can be given names up to 10 characters long. Outputs are named in the I/O Map display, see [section 6.6 on page 6-16](#).

MESSAGE (ON/OFF)

Designates the user-defined message indicated and displays the message on the CRT (or removes it from being displayed). The message is displayed on the Operate Screen in the error message section of the display (the lower right hand corner of the CRT display). Messages are defined in the User Message display. (See [section 6.7 on page 6-17](#).)

NON-DEPOSIT CLOCK HOLD (ON/OFF)

This feature “holds” the state timer during any non-deposit state. Non-deposit states include the pre-deposit states: Ready, Source Switch, Rise 1, Soak 1, Rise 2, Soak 2; and the post-deposit states: Feed Ramp, Feed Time, Idle Ramp and Idle Time. For the feature to be activated the state’s time must be non zero. The message NON-DEPOSIT HOLD is displayed in the lower right hand corner of the CRT and is shown in reverse video.

If the instrument is in the READY or IDLE state and a START command is executed while NON-DEPOSIT HOLD is active, the instrument will progress to the first pre-deposit state with a non zero state time. If the instrument is in the Source Switch state, waiting for the Turret Feedback Input, and NON-DEPOSIT HOLD is activated, when the Turret Positioned input is activated, the instrument will progress to the next pre-deposit state having a non zero state time.

The instrument is prevented from continuing state processing until the action is turned OFF.

RESET

This action is identical to pressing the RESET button on the front panel. (Refer to [section 3.4.2 on page 3-23](#)).

RW HOLD (ON/OFF)

When active (ON), this Action will place the Deposit state into the Hold portion of the RateWatcher feature. The Sample portion of RateWatcher will not be entered until the action is turned OFF. If Sample is already active, remains in Sample until accuracy requirement is met.

RW HOLD INHIBIT (ON/OFF)

When active (ON) this will immediately cause the Deposit state to leave HOLD and not return until turned OFF. If both RW HOLD and RW HOLD INHIBIT are active, RW HOLD INHIBIT takes priority.

SELECT PROCESS #

This action selects which Process # is to be the Active Process; values range from 1 to 50. The value entered must correspond to a defined Process. If the instrument is already executing a Process, i.e. not in Ready or Idle of last layer in process when this Action is activated, the Action is ignored.

START

This action is identical to pressing the START button on the front panel. (Refer to [section 3.4.2 on page 3-23](#)).

START INHIBIT (ON/OFF)

This feature, when active, prohibits the START of a process. Once ON, a process cannot be started until the START INHIBIT is deactivated (OFF).

STOP

This action is identical to pressing the STOP button on the front panel. (Refer to [section 3.4.2 on page 3-23](#)). The condition remains true until a RESET or START command is received.

SOAK HOLD 1 (ON/OFF) #

If active (ON), the source # designated will pause execution and maintain Soak Power 1 until Soak Hold 1 is turned OFF.

SOAK HOLD 2 (ON/OFF) #

If active (ON), the source # designated will pause execution and maintain Soak Power 2 until Soak Hold 2 is turned OFF.

SWITCH CRYSTAL ###

This Action activates the Crystal Switch output for the sensor number indicated. It sets the alternate crystal active when using a Dual sensor head. It indexes to the next crystal position listed when using the Crystal Six or Rotary sensor. This function is available only if a Dual, Crystal Six or Rotary sensor type is chosen in Source/Sensor Set Up.

TIMER - HH:MM ## hh:mm

Sets the designated timer, counting down from the programmed time. Up to 20 timers may be set.

TIMER SECONDS ## sss.s

Sets the designated timer, counting down from the programmed time. Up to 20 timers may be set.

TRIGGER FINAL THICKNESS #

This action triggers Final Thickness and the Layer proceeds to the Feed Ramp or Idle Ramp state. This will trigger on the primary layer if the number is 1, the secondary channel if the number is 2, or both layers if the number is 0. This Action is ignored if not in the Deposit state.

ZERO THICKNESS #

This Action is identical to selecting the ZERO THICKNESS panel in the OPERATE display. The Action will zero the thickness accumulated on the display for the Layer being deposited, and also will zero each of the sensor thicknesses in use for this layer. The thickness will zero on the primary layer if the number is 1, the secondary channel if the number is 2, or both layers if the number is 0.

ZERO TIME

This Action will zero the Layer Deposit time for the Layer being deposited. If two layers are in deposit simultaneously, the time will zero for both layers. If an output is triggered on a Time Limit, the output will remain triggered even after resetting the Layer Time.

6.5 Logic Statement Example

The logic statement capability of the IC/5 allows for automation of a thin film process. For example, it is possible to run a multilayer process without manually pressing START after each layer. One way to accomplish this is:

```
IF:      PROCESS END ALL AND LAYER END ALL
THEN:    START
```

The PROCESS END ALL assures that when the process ends, it will not automatically repeat itself.

To enter this statement follow this procedure:

- 1** On the OPERATE screen, make sure the state is READY. If it is not, press STOP, then press RESET.
- 2** Press the F6 key (PROGRAM), to go to the PROGRAM display.
- 3** From the PROGRAM display, press the F3 key (I/O), to get to the I/O display.
- 4** From the I/O display, press the F1 key (LOGIC STATEMENT DIRECTORY).
- 5** Place the cursor on any blank logic statement, using the up and down cursor keys.
- 6** Press the F5 (EDIT LOGIC STATEMENT).
- 7** Press the F1 key (SELECT).
- 8** Cursor to LAYER END and press the F2 key (INSERT). The term "LAYER END ####" will appear after the "IF" in the upper left of the screen.
- 9** Cursor to PROCESS END, and press the F2 key (INSERT). "PROCESS END #### ccc LAYER END ####" will now appear after the "IF".
- 10** Press the F6 key (LOGIC STATEMENT).
- 11** Cursor down to THEN and press the F1 key (SELECT).
- 12** Cursor down to START and press the F2 key (INSERT). Then press the F6 key (LOGIC STATEMENT).
- 13** Cursor to "PROCESS END", and press the F2 key (NEGATE). A bar will appear above "PROCESS END".
- 14** Cursor to "####" and press 0, E (Enter). The #### will be replaced by ALL.
- 15** The cursor should now be on "ccc". Press the F1 key (SELECT) once to change the ccc to AND.
- 16** Cursor to "####" and press 0, E (Enter). The #### will be replaced by ALL.
- 17** Press the F6 key (Logic Statement Directory w/Save), to return to the Logic Directory. At this point the Logic Statement is entered into memory.
- 18** To return to the OPERATE display, press the F6 key three more times.

To run the multilayer process, press START once. As each layer ends, the IC/5 will automatically issue another START, until the LAST LAYER has completed.

6.6 I/O Map Directory

The I/O Map directory is selected by pressing the F3 key (I/O) in the Program display and then the F2 key (I/O MAP Directory). From the I/O Map directory, the desired I/O Board is chosen with the box cursor. Pressing the F5 key (I/O MAP) enters the I/O Map display for the designated board. The I/O Map display for board 1 is shown in Figure 6-5. Upon entry the cursor will be placed at the last referenced output or input number.

Figure 6-5 /O Map Board 1

I/O MAP BOARD 1			EDIT NAME	F1
RELAY OUTPUT		TTL INPUT	SAVE NAME	F2
NAME	TYPE	NAME	CANCEL NAME CHANGE	F3
1.	NO	1.	CLEAR NAME	F4
2.	NO	2.	TOGGLE TYPE	F5
3.	NO	3.	I/O MAP DIRECTORY	F6
4.	NO	4.		
5.	NO	5.		
6.	NO	6.		
7.	NO	7.		
8.	NO	8.		
		9.		
		10.		
		11.		
		12.		
		13.		
		14.		
0.0 A/sec 0.000 kA 0.0 %				

Table 6-3 Function Key Selection Choices for the I/O Map Display

Key	Function	Description
F1	EDIT NAME	Pressing this key will display a series of 10 underscores representing ten positions. The left and right arrow keys are used to move back and forth among the 10 positions. The up and down arrow keys are used to scroll through an alphanumeric listing, A through Z, 0 through 9, and the following characters: !, #, ±, %, & and -. Once the desired character is displayed, pressing the E key enters the character and advances the reverse video cursor box to the next position.
F2	SAVE NAME	Pressing this key saves the Name of the Input or Output. Once saved, this Name will be displayed whenever this Output (or Input) is chosen in the Edit Logic Statement Display.
F3	CANCEL NAME CHANGE	Pressing this key cancels any changes to the Name made after pressing the F1 KEY (EDIT NAME).

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Table 6-3 Function Key Selection Choices for the I/O Map Display

Key	Function	Description
F4	CLEAR NAME	Pressing this key clears the Name associated with the designated output (or input).
F5	TOGGLE TYPE	Pressing this key toggles the relay type from Normally Open (NO) to Normally Closed (NC).
F6	I/O MAP DIRECTORY	Pressing this key returns the display to the I/O Map Directory.

6.7 Define User Messages

Up to 10 user-defined messages can be created and up to 3 can be displayed at the same time. The messages are displayed in the lower right hand corner of the CRT. The messages are turned on and off with the Logic Statements using the MESSAGE ON/OFF Actions. If required to display IC/5 generated messages, these user-defined messages will be overwritten.

The User Messages display is entered by pressing the F3 key (I/O) panel from the Program display and then pressing F3 (DEFINE USER MESSAGES).

Figure 6-6 Define User Messages

USER MESSAGES			EDIT MESSAGE	— F1										
			SAVE MESSAGE	— F2										
<table border="0"> <tr><td>1.</td><td>6.</td></tr> <tr><td>2.</td><td>7.</td></tr> <tr><td>3.</td><td>8.</td></tr> <tr><td>4.</td><td>9.</td></tr> <tr><td>5.</td><td>10</td></tr> </table>			1.	6.	2.	7.	3.	8.	4.	9.	5.	10	CANCEL MESSAGE CHANGES	— F3
1.	6.													
2.	7.													
3.	8.													
4.	9.													
5.	10													
			CLEAR MESSAGE	— F4										
				— F5										
0.0 Å/sec 22.52 kÅ 0.0 %			I/O	— F6										

Table 6-4 Function Key Selection Choices for the Define User Messages Display

Key	Function	Description
F1	EDIT MESSAGE	Pressing this key will display a series of 20 underscores representing the positions of the 20 characters. The left and right arrow keys are used to move back and forth among the 20 positions. The up and down arrow keys are used to scroll through an alphanumeric listing, A through Z, 0 through 9, and the following characters: !, #, ±, %, & and -. Once the desired character is displayed, pressing the E key enters the character and advances the reverse video cursor box to the next position.
F2	SAVE MESSAGE	Pressing this key saves the Message. Once saved, this message will be displayed whenever this MESSAGE ON ### is chosen in the Edit Logic Statement Display.
F3	CANCEL MESSAGE CHANGE	Pressing this key cancels any changes to the Message made after pressing the EDIT MESSAGE panel.
F4	CLEAR MESSAGE	Pressing this key clears the selected Message from the Define User Messages display
F6	I/O	Pressing this key returns the display to the I/O display.

6.8 Floppy Disk

Parameters can be saved to and retrieved from the diskette by going to the FLOPPY DISK display. This screen is reached by going from the PROGRAM display to the I/O display (F3) to the FLOPPY DISK display (F4). For more information on the Floppy Disk option refer to [section 3.6.8 on page 3-39](#).

Upon entering this display a directory of all the IC/5 configuration files contained on the diskette is displayed and the following key selections are available. The box cursor can be positioned around any of the Configuration Files by moving the cursor arrows. Left and Right correspond to Page Up and Page Down. The Up and Down arrows will move the box cursor one position.

Figure 6-7 Floppy Disk

FLOPPY DISK		SAVE	— F1
CONFIG FILES, 2 file(s) found, 1243648 bytes free on diskette		RETRIEVE	— F2
ICSSYCN ISC	Stored at 16:57 on 11-22-1994, IC/5 Ver 0.10	DELETE	— F3
ICSSYCN2 ISC	Stored at 15:47 on 11-28-1994, IC/5 Ver 0.20		— F4
		ALL FILES	— F5
0.0 Å/sec	0.000 kÅ	0.0%	XTAL FAIL 1 2
		I/O	— F6

Table 6-5 Function Key Selection Choices for the Floppy Disk Display

Key	Function	Description
F1	SAVE	Pressing this key will select the Configuration File contained within the box cursor and prompt the user to "Save the file FILENAME.ISC?". At this time the filename may be changed. The filename is changed using the Up and Down arrow keys to scroll through the Alphanumeric listing A through Z, 0 through 9, and the characters: !, #, +, -, %, & and . at the reverse video box cursor position or using the Right and Left arrow keys to position the reverse video box cursor. The key choices are changed to CONTINUE and CANCEL. Selecting CONTINUE saves the file to the diskette. Selecting CANCEL returns the display to the Configuration Files display.
F2	RETRIEVE	?Pressing this key will select the Configuration File contained within the box cursor and prompt the user to "Load the file FILENAME.ISC?". The key choices are changed to CONTINUE and CANCEL. Selecting CONTINUE loads the contents of the file into the IC/5. Selecting CANCEL returns the display to the Configuration Files display.
F3	DELETE	Pressing this key will select the Configuration File contained within the box cursor and prompt the user to "Delete the file FILENAME.ISC?".
F5	ALL FILES	Pressing this key provides a directory of all the files contained on the diskette. From the ALL FILES display, function keys for DELETE, CONFIG FILES, and I/O are available.
F6	I/O	Pressing this key returns to the I/O display.



CAUTION

Do not remove the diskette during save or retrieve operations.

It is recommended that when doing a RETRIEVE operation, the instrument have the same hardware configuration, including optional Sensor Measurement Boards, as when the parameters were saved to diskette.

If the file retrieved from the floppy diskette contains parameters which are valid only with optional equipment installed, these parameter values will not be altered.

6.9 Error Messages in I/O Logic Statement Set-Up

CANNOT TOGGLE INPUT

Output types can be toggled between Normally Open and Normally Closed. An Input does not have a type function and cannot be toggled.

EDIT IN PROGRESS

The I/O Map or the User Messages display cannot be exited while an edit name or edit message operation is occurring.

ILLEGAL INPUT - VALUE TOO LARGE

ILLEGAL INPUT - VALUE TOO SMALL

Parameter entry is out of range. Allowable values will vary according to your unit configuration or the parameter being defined. Press Clear to delete the value and enter again.

INPUT IN USE

The input line in question has already been reserved for use.

INVALID EQUATION

Strings must have connectors and required numerics before exiting the Logic Statement

MAXIMUM TERMS

No more than five terms are allowed in any one Event or Action string.

MUST EDIT NAME FIRST

A save name or save message operation was requested without first having edited the name or message.

OUTPUT IN USE

Indicates the output in question is already reserved for use in Sensor or Source set-up or in one of the Logic Statements.

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Chapter 7

Remote Communications

7.1 Remote Communication Configuration Overview

There are two types of remote communication interfaces which can be used by a host computer to control or monitor the instrument. An RS-232C communications port is standard equipment. Additionally, an IEEE-GPIB interface may be installed. Device dependent information and protocol selection must be provided before an interface can be used

NOTE: Remote Communications operation is covered in detail in [section 7.4 on page 7-4](#) through [section 7.8 on page 7-41](#).

Figure 7-1 Display Tree for Remote Communications Set-Up



Configuration of the Remote Communications is initiated by pressing the F3 key (I/O) in the Program display and then selecting the REMOTE COMMUNICATIONS function (F5) in the I/O display. This will invoke the Remote Communications Display (see [Figure 7-2](#)). Upon entry, the cursor will be found at the last referenced communications parameter. The parameters are contained on a single page.

NOTE: Communication stops when entering 'Source Maintenance' and 'Cross Talk Calibrate' modes.

7.2 Remote Communication Parameters

A parameter is selected for entry by positioning the box cursor at the desired value following the parameter description. New values are input from the front panel and completed by pressing the **Enter** key. Values are cleared by pressing the **Clear** key.

Figure 7-2 Remote Communications Display

REMOTE COMMUNICATION		F1
Paths: 0=OFF, 1=RS-232, 2=IEEE-488, 4=FILE		F2
Remote Comm. Path	0 (Path: 0, 1 or 2)	F3
Data Logging Path	0 (Path: 0, 1, or 4)	F4
Print Screen Path	4 (Path: 4)	F5
RS-232 Baud Rate	2400 (2400, 4800, 9600, 19200)	F6
RS-232 Checksum	NO YES/NO	
IEEE-488 Address	3 (0-30)	
Data Log Format	0 (0=page, 1=comma delimited)	
Data Log XTAL History	NO YES/NO	
0.0 Å/sec	4.982 kÅ	0.0 %
XTAL FAIL 1 2		I/O

Table 7-1 Function Key Selection Choices for Remote Communications

Key	Function	Description
F6	I/O	Press this key to return to the I/O display.

Some parameters are applicable only for optional equipment. Parameters dealing with the optional IEEE-GPIB interface have a ✓ flag.

REMOTE COMM. PATH 0/1/2 ✓

This parameter selects between the two types of communications configurations available. Parameter values range from 0 to 2. RS-232C is selected by entering the value 1. A value of 2 selects GPIB (✓). A value of 0 turns the Remote Comm. Path off. The default is 0.

DATALOGGING PATH 0/1/2/4

This parameter determines the path for the Datalog output. A value of 0 turns datalogging off. A value of 1 outputs the Datalog string to the RS-232C port. A value of 4 outputs the Datalog string to the floppy disk. The default value is 0. Refer to [section 3.6.10 on page 3-40](#) for details on the Datalog string.

NOTE: If a configuration file from a unit with version 3.50 or earlier firmware is to be loaded into a unit with version 3.60 or later, verify that the path is **not** set to 3 as this will prevent the file from loading due to a "File Range Error".

PRINT SCREEN PATH 0/1/2/4

This parameter determines which path to output the print screen function.

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NOTE: If a configuration file from a unit with version 3.50 or earlier firmware is to be loaded into a unit with version 3.60 or later, verify that the path is **not** set to 3 as this will prevent the file from loading due to a "File Range Error".

RS-232C BAUD RATE 2400/4800/9600/19200

For RS-232C serial interfaces, this parameter sets the rate for data transfer. Permissible values are; 2400, 4800, 9600, and 19200. The default value is 2400.

RS-232C CHECKSUM YES/NO

This parameter provides the choice of having a Checksum when using RS-232C. For the INFICON format, the Checksum is an 8-bit unsigned sum of the command bytes. See [section 7.6 on page 7-8](#) for more information on message protocol. Permissible values for this parameter are YES and NO. The default value is NO.

IEEE488 ADDRESS ✓

For IEEE-GPIB interfaces, the GPIB address is a number which identifies an IC/5 to the Host Computer. Values range from 0 to 30. The default value is 3.

DATA LOG FORMAT 0 = page, 1 = comma delimited

This parameter allows a choice between a page format and a quotation mark/comma delimited format. The quotation mark/comma delimited format is to allow importation of the Data Log string from a floppy disk file into a spreadsheet program.

DATA LOG XTAL HISTORY YES/NO

This parameter selects whether to output the crystal use history. Refer to [section 3.6.10 on page 3-40](#).

7.3 Error Messages in Remote Communications Configuration

Illegal Baud Rate

The value you are attempting to enter is not one of the valid baud rates for serial communications. Valid rates are 2400, 4800, 9600 or 19200.

Illegal Input - Value Too Large

Illegal Input - Value Too Small

The value that you are attempting to enter is out of range. Allowable values will vary according to your unit's configuration or the parameter being defined. Press the **Clear** key to delete the value and enter again.

Port Conflict

This error message indicates you are trying to send two different outputs to the same path.

7.4 Remote Communications Overview

This instrument may be remotely controlled, programmed or interrogated. This is accomplished through remote communications and the use of a remote command set. The instrument will respond to messages that contain these commands. It will accept and operate on messages one at a time. It will respond to each command by carrying out valid operations and/or returning a message to the sender.

A host/server relationship is established in remote communications. The instrument, as server, responds to the remote host's commands. The responsiveness of this interaction may be affected by the instrument's operational state. It will be similar to that experienced by a user at the front panel.

NOTE: There are special commands which may be executed to establish a faster response time than is possible when operating normally. Specifically: 1) Screen lock; 2) battery backed RAM lock; and 3) service requests for IEEE488.

7.5 Physical Connections

You may choose to use one of two types of data communications hardware ports. Standard equipment includes a bit serial RS-232C port. Optionally, an IEEE488 parallel port may be added.

Selection and set-up of some general port and communication characteristics are handled in [section 7.1](#), [section 7.2](#) and [section 7.3](#). Generally speaking, both the host and server must have the same form of communications equipment and complementary set-up. For serial communications, baud rates must match and so must the data word format.

The word format for bit serial lines (RS-232C) is comprised of ten signal bits- eight data bits, one start bit, one stop bit and no parity. The eight data bits comprise a byte of information or character whose ASCII value ranges from 0 to 255.

7.5.1 RS-232C Serial Port

RS-232C serial communications are accomplished through an industry standard 9-pin female connector found on the rear panel of the instrument. A mating male connector is required for attachment of a host interface. The host and instrument can be separated by up to fifty feet using multiconductor shielded data cable.

The instrument is configured as DCE or Data Communication Equipment.

The following pin assignments should be used when constructing a cable:

Table 7-2 RS-232C Cable Pin Assignments

IC/5 (9-Pin D-sub)		Host	
Pin 1	(Not used)		The 760-406-P1 RS232 Loop-back connector provided in the ship kit connects the following pins: 2 to 3, 4 to 6 and 7 to 8.
Pin 2	TXD →	RXD	
Pin 3	RXD ←	TXD	
Pin 4	DSR ←	DTR	
Pin 5	GND	GND	
Pin 6	DTR →	DSR	
Pin 7	CTS ←	RTS	
Pin 8	RTS →	CTS	
Pin 9	GND (Shield)		

The port incorporates hardware flow control via Request to Send / Clear to Send (RTS/CTS) and Data Terminal Ready / Data Set Ready (DTR/DSR) signaling.

Request To Send (RTS) The instrument informs the host it is ready to receive a character by asserting the RTS signal. It lowers the signal when the receive buffer is full.

Clear to Send (CTS) The host informs the instrument it is ready to receive a character by asserting the CTS signal. The host should lower the signal if its received buffer becomes full and raise the signal when it can receive data again. This signal has an internal pull up in the instrument. Therefore, if left disconnected the instrument will assume the host is always capable of receiving data (no flow control).

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- Data Terminal Ready (DTR) The instrument informs the host that it is powered up and able to communicate by asserting this signal.

- Data Set Ready (DSR) The host informs the instrument that it is able to communicate. The instrument will ignore all incoming data if this signal is de-asserted. This signal has an internal pull up in the instrument. Therefore, if left disconnected the instrument will assume the host is always able to communicate.

7.5.2 IEEE488 Port

An IEEE488 circuit card may be purchased and installed into the IC/5, IPN 760-142-G1. The instrument appears on the IEEE488 bus as a device. A unique device address must be assigned. Refer to [section 7.2, Remote Communication Parameters, on page 7-2](#). A standard IEEE488 24-pin connector is provided on the circuit card.

The instrument makes use of the IEEE488 status byte.

Whenever there is message available (MAV) in the instrument, bit-4 of the status byte will be set. By enabling the automatic serial polling and checking the status byte, very reliable data transfer between the instrument and the host computer can be achieved. The timeouts for the device and the host should be set sufficiently long (at least 0.5 s).

Additionally, service requests are supported. A service request is 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 (2⁶) bit of the status byte. The following conditions of the instrument can be detected by examining the low 4 bits of the status byte in combination with the bit-4.

Table 7-3 Instrument Conditions

bit position:	7	6	5	4	3	2	1	0
MAV/Data ready:	-	-	-	1	-	-	-	-
Final thickness:	-	1	-	1	0	0	0	1
Stop:	-	1	-	1	0	0	1	0
End layer:	-	1	-	1	0	0	1	1
Power up:	-	1	-	1	0	1	0	0
End Process:	-	1	-	1	0	1	0	1

7.5.2.1 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 7-3 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 7-4 Device Characteristics

National Instruments	Device Characteristics	IBM AT, PS/2-25/30	
Board: IC5		SELECT (use right/left arrow keys):	
Access: GPIB0			
Primary GPIB Address.....	3	yes or no	
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

7.6 Message Protocols

There are multiple forms of message protocols to meet the needs of various users and network environments. The message protocol serves as a structure for the contained command or response information. It also can provide a level of acknowledgment between the host and server and a mechanism for verifying the information content.

A standard INFICON command structure has been established for use in its instruments. While some commands need to be instrument dependent, the basic structure and protocol is designed to be common among the products. It provides a comprehensive and reliable method for remote instrument communications.

7.6.1 INFICON Message Formats

There are two message formats for the serial ports and one for the IEEE488 port. All messages are comprised of byte serial information. The byte values represent command or response characters, control characters or numeric values. Mnemonics will be used to describe the portions of each message format.

NOTE: These mnemonics are not part of the message stream; they are used to represent specific ASCII codes, characters or numeric values that comprise the message stream.

Table 7-4 Mnemonics

Mnemonic	Meaning
<STX>	ASCII code 2 for Start of Transmission
<ACK>	ASCII code 6 for Positive Acknowledgment
<NAK>	ASCII code 21 for Negative Acknowledgment
<LF>	ASCII code 10 for Line Feed (EOT byte for IEEE488)
(command)	ASCII character codes representing the host's command as described in Section 7.7
(response)	ASCII character codes representing the instrument's response as described in Section 7.7
(nrc)	A negative response code; used for error responses to a host command. Section 7.7.7 lists the error codes and their meaning.
(checksum)	Numeric value from 0 to 255 (one byte) representing the modulo 256 remainder of the sum of the values of the ASCII codes that comprise the message or response including the ACK or NAK code.
(count)	Numeric value from 0 to 16,383 (two bytes) representing the number of characters in the command or response. Two byte values, high and low order, are required to represent this number. In order of transmission, the high byte will precede the low byte. For most commands, the number of characters will be less than 256. In this situation the low byte will contain the character count while the high byte will have zero value.

Serial With No Checksum Format

Host to Instrument Message

(command) <ACK>

Instrument to Host Message

(response) <ACK> or

(nrc) <NAK>

Serial With Checksum Format

Host to Instrument Message

<STX> (count) (command) (checksum)

Instrument to Host Message

<STX> (count) <ACK> (response) (checksum) or

<STX> (count) <NAK> (nrc) (checksum)

IEEE488 Message Format

Host to Instrument Message

(command) <LF>

Instrument to Host Message

(response) <LF> or

(nrc) <LF>

(See [section 7.7.7 on page 7-41](#) for a list of error codes.)

7.7 INFICON Standard Communication Commands

The standard command set is structured into six categories- **ECHO**, **HELLO**, **QUERY**, **UPDATE**, **STATUS** and **REMOTE**. Most commands require arguments. A space is used between commands and arguments and between multiple arguments.

The instrument uses a set of negative response codes (nrc) for commands resulting in an error.

7.7.1 ECHO Command

The format is:

E string

The **E**cho command returns the ASCII string argument back to the sender. This command is useful for set-up or troubleshooting.

7.7.2 HELLO Command

The format is:

H

The **H**ello command returns the model and version number in the ASCII format "**IC/5 VERSION x.xx**".

7.7.3 Query Commands

Query commands are used to request established parameter values. There is a specific query command for each parameter group. Depending on the actual hardware configuration, the response to some Query commands may be an 'E' nrc (negative response code) indicating there is no data to retrieve. Each command has one to three arguments. Each argument is separated by a space. The command variations include:

Table 7-5 Query Commands

command	parameter
QM	Query Material Parameters
QP	Query Process Parameters
QU	Query Utility Parameters
QS	Query Sensor Parameters
QC	Query Source Control Parameters
QL	Query Logic Statements
QT	Query Output Relay Type
QO	Query alphanumeric name of hardware output
QI	Query alphanumeric name of hardware input
QN	Query User Messages

7.7.3.1 Query Material Parameters

For each command format the symbol p represents a blank space. The format is:

QM p param# p material#

This command returns a material parameter or all material parameters for a specified material.

Table 7-6 Query Material Parameters

param#	Material Parameter
0	Compound Name (query only)
1	Density
2	Z-Ratio
3	Source
4	Control Loop
5	Process Gain
6	Primary Time Constant
7	System Dead Time
8	Recorder Output
9	Recorder Function
10	Master Tooling

Table 7-6 Query Material Parameters (continued)

param#	Material Parameter
11	Quality
12	Stability
13	Maximum Power
14	Soak Power 1
15	Rise Time 1
16	Soak Time 1
17	Soak Power 2
18	Rise Time 2
19	Soak Time 2
20	Auto Soak 2
21	Delay Option
22	Control Delay
23	Feed Power
24	Feed Ramp Time
25	Feed Time
26	Idle Power
27	Idle Ramp Time
28	Sensor 1 Option
29	Sensor 2 Option
30	Sensor 3 Option
31	Sensor 4 Option
32	Sensor 5 Option
33	Sensor 6 Option
34	Sensor 7 Option
35	Sensor 8 Option
36	Sensor 1 Weight
37	Sensor 2 Weight
38	Sensor 3 Weight
39	Sensor 4 Weight
40	Sensor 5 Weight
41	Sensor 6 Weight
42	Sensor 7 Weight
43	Sensor 8 Weight
44	Sensor 1 Tooling
45	Sensor 2 Tooling
46	Sensor 3 Tooling
47	Sensor 4 Tooling
48	Sensor 5 Tooling

Table 7-6 Query Material Parameters (continued)

param#	Material Parameter
49	Sensor 6 Tooling
50	Sensor 7 Tooling
51	Sensor 8 Tooling
52	Sensor 1 Cal Thick
53	Sensor 2 Cal Thick
54	Sensor 3 Cal Thick
55	Sensor 4 Cal Thick
56	Sensor 5 Cal Thick
57	Sensor 6 Cal Thick
58	Sensor 7 Cal Thick
59	Sensor 8 Cal Thick
60	Sensor 1 Crystal Position
61	Sensor 2 Crystal Position
62	Sensor 3 Crystal Position
63	Sensor 4 Crystal Position
64	Sensor 5 Crystal Position
65	Sensor 6 Crystal Position
66	Sensor 7 Crystal Position
67	Sensor 8 Crystal Position
99	All Parameters (QM only)

The QM 99 ## command returns a string of values, each separated by a space, in the order specified above for all operational parameters 0 - 67, inclusive.

7.7.3.2 Query Process Parameters

For each command format the symbol p represents a blank space. The format is:

QP p param# p process# p layer#

This command returns a process parameter or all process parameters for a specified process and layer.

Table 7-7 Query Process Parameters

param#	Process Parameter
0	Material Index
1	Rate
2	Final Thickness
3	Thickness Limit
4	Time Limit
5	Co-Deposition
6	Ratio Control
7	Rate Watch Time
8	Rate Watch Accuracy
9	Crucible
10	New Rate 1
11	Start Ramp 1
12	Ramp Time 1
13	New Rate 2
14	Start Ramp 2
15	Ramp Time 2
99	All Parameters; each separated by a space in the above order.

7.7.3.3 Query Utility Parameters

For each command format the symbol p represents a blank space.
The format is:

QU p param#

This command returns a utility or all utility parameters. The parameters marked * will return only a string of four X's (i.e., XXXX).

Table 7-8 Query Utility Parameters

param#	Utility Parameter
0	Active Process
1	Run Number
2	Layer To Start
3	Stop on Max. Power
4	Aggregate Multiplier
5	Analog Display
6	Analog Scan Rate
7	Test On
8	Time Compressed
9	Program Lock Code*
10	Sensor-I/O Lock Code*
11	Floppy Disk Access Code*
12	System Time
13	System Date
14	Audio Feedback
15	Co-Deposition Display
16	Rate Smoothing
99	All Parameters; each separated by a space in the order specified above.

7.7.3.4 Query Sensor Parameters

For each command format the symbol ρ represents a blank space. The format is:

QS ρ param# ρ sensor#

This command returns a sensor parameter or all sensor parameters.

Table 7-9 Query Sensor Parameters

param#	Sensor Parameter
0	Sensor Type
1	Xtal Switch Output
2	Xtal Shutter Output
3	Xtal Shutter Type
4	Z-Ratio Type
5	Recorder Output
6	Recorder Function
99	All Parameters; each separated by a space in the order specified above.

7.7.3.5 Query Source Parameters

For each command format the symbol ρ represents a blank space. The format is:

QC ρ param# ρ source#

This command returns a source control parameter or all source control parameters.

Table 7-10 Query Source Parameters

param#	Source Parameter
0	Voltage Range
1	Shutter Output
2	Shutter Output Type
3	Number of Crucibles
4	Crucible Output
5	Crucible Output Type
6	Turret Feedback
7	Turret Input
8	Turret Delay
9	DAC Output
99	All Parameters; each separated by a space in the order specified above.

7.7.3.6 Query Output Types

For each command format the symbol p represents a blank space.
The format is:

QT p output#

This command returns the type code for a specific relay. Type code values returned are 0 or 1, where 0 is Normally Open, 1 is Normally Closed.

7.7.3.7 Query Logic Statements

For each command format the symbol p represents a blank space.
The format is:

QL p logic statement#

This command returns the encoded conditional string assigned to a specific logic 'statement'. The string is represented in the form IF (event string) THEN (action string). Applicable codes and event names can be found with the descriptions for Update commands UL that follow. Multiple events are connected with AND, OR or ON. Parentheses show groupings. The symbol \sim is used to represent a negate. Certain events have a numeric qualifier. Event and Action descriptions can be found in [Chapter 6, I/O Logic Statement Set-Up](#).

7.7.3.8 Query Output Name

For each command format the symbol p represents a blank space.
The format is:

QO p output#

This command returns the alphanumeric name assigned to the designated output number.

7.7.3.9 Query Input Name

For each command format the symbol p represents a blank space.
The format is:

QI p input#

This command returns the alphanumeric name assigned to the designated input number.

7.7.3.10 Query User Messages

For each command format the symbol p represents a blank space.
The format is:

QN p user message#

This command returns the user defined alphanumeric name assigned to the designated message number.

7.7.4 UPDATE Commands

Update commands are used to change a specified parameter to a new value or condition. Some parameters are order dependent in that they cannot be updated prior to certain other parameters. For example, in the IC/5 two layers must be defined before specifying the codeposition of those layers.

There is a specific update command for each parameter group. Each command has one to four arguments starting with and separated by a space. The Update command variations include:

Table 7-11 Update Commands

command	parameter
UM	Update Material Parameters
UP	Update Process Parameters
UU	Update Utility Parameters
US	Update Sensor Parameters
UC	Update Source Control Parameters
UT	Update Output Relay Type
UL	Update Logic Statement
UO	Update alphanumeric name of hardware output
UI	Update alphanumeric name of hardware input
UN	Update user messages

7.7.4.1 Update Material Parameters

For each command format the symbol p represents a blank space. The format is:

UM p param# p material# p value

This command changes the value of a material parameter for a specified material. Refer to [Chapter 4, Material Set Up](#), for parameter value ranges.

Table 7-12 Update Material Parameters

param#	Material Parameter
1	Density
2	Z-Ratio
3	Source
4	Control Loop
5	Process Gain
6	Primary Time Constant
7	System Dead Time
8	Recorder Output
9	Recorder Function
10	Master Tooling

Table 7-12 Update Material Parameters (continued)

param#	Material Parameter
11	Quality
12	Stability
13	Maximum Power
14	Soak Power 1
15	Rise Time 1
16	Soak Time 1
17	Soak Power 2
18	Rise Time 2
19	Soak Time 2
20	Auto Soak 2 Value is upper or lower case YES or NO
21	Delay Option
22	Control Delay
23	Feed Power
24	Feed Ramp Time
25	Feed Time
26	Idle Power
27	Idle Ramp Time
28	Sensor 1 Option
29	Sensor 2 Option
30	Sensor 3 Option
31	Sensor 4 Option
32	Sensor 5 Option
33	Sensor 6 Option
34	Sensor 7 Option
35	Sensor 8 Option
36	Sensor 1 Weight
37	Sensor 2 Weight
38	Sensor 3 Weight
39	Sensor 4 Weight
40	Sensor 5 Weight
41	Sensor 6 Weight
42	Sensor 7 Weight
43	Sensor 8 Weight
44	Sensor 1 Tooling
45	Sensor 2 Tooling
46	Sensor 3 Tooling
47	Sensor 4 Tooling
48	Sensor 5 Tooling

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Table 7-12 Update Material Parameters (continued)

param#	Material Parameter
49	Sensor 6 Tooling
50	Sensor 7 Tooling
51	Sensor 8 Tooling
52	Sensor 1 Cal Thick
53	Sensor 2 Cal Thick
54	Sensor 3 Cal Thick
55	Sensor 4 Cal Thick
56	Sensor 5 Cal Thick
57	Sensor 6 Cal Thick
58	Sensor 7 Cal Thick
59	Sensor 8 Cal Thick
60	Sensor 1 Crystal Position
61	Sensor 2 Crystal Position
62	Sensor 3 Crystal Position
63	Sensor 4 Crystal Position
64	Sensor 5 Crystal Position
65	Sensor 6 Crystal Position
66	Sensor 7 Crystal Position
67	Sensor 8 Crystal Position

7.7.4.2 Update Process Parameters

For each command format the symbol p represents a blank space.
The format is:

UP p param# p process# p layer# p value

This command changes the value of a process parameter for a specific process and layer. Refer to [Chapter 5, Process Set-Up](#), for parameter value ranges.

NOTE: Rate, New Rate 1, New Rate 2 values can be input to the hundredth position via communications. Deposition will be controlled to the hundredth place, even though the front panel display and input only read to the tenth's place.

Table 7-13 Update Process Parameters

param#	Process Parameter
0	Material Index
1	Aggregate Rate
2	Final Thickness
3	Thickness Limit
4	Time Limit
5	Co-Deposition Value is upper or lower case YES or NO
6	Ratio Control
7	Rate Watch Time
8	Rate Watch Accuracy
9	Crucible
10	New Rate 1
11	Start Ramp 1
12	Ramp Time 1
13	New Rate 2
14	Start Ramp 2
15	Ramp Time 2

7.7.4.3 Update Utility Parameters

For each command format the symbol ρ represents a blank space.
The format is:

UU ρ param# ρ value

This command changes the value of a utility parameter. The parameters marked with a * cannot be updated. Refer to [Chapter 9, Utility Set-Up](#) for parameter value ranges. Non-numeric values are upper or lower case YES or NO.

Table 7-14 Update Utility Parameters

param#	Utility Parameter
0	Active Process
1	Run Number
2	Layer To Start
3	Stop on Max.Power
4	Aggregate Multiplier
5	Analog Display
6	Analog Scan Rate
7	Test On
8	Time Compressed
9	Program Lock Code*
10	Sensor-I/O Lock Code*
11	Floppy Disk Access Code*
12	System Time
13	System Date
14	Audio Feedback
15	Co-Deposition Display
16	Rate Smoothing

7.7.4.4 Update Sensor Parameters

For each command format the symbol p represents a blank space.
The format is:

US p param# p sensor# p value

This command changes the value of a sensor parameter. See [Chapter 8, Source/Sensor Set-Up](#), for parameter value ranges.

Table 7-15 Update Sensor Parameters

param#	Sensor Parameter
0	Type
1	Xtal Switch Output
2	Xtal Shutter Output
3	Xtal Shutter Type
4	Z-Ratio Type
5	Recorder Output
6	Recorder Function

7.7.4.5 Update Source Parameters

For each command format the symbol p represents a blank space.
The format is:

UC p param# p source# p value

This command changes the value of a source control parameter. See [Chapter 8, Source/Sensor Set-Up](#) for parameter value ranges.

Table 7-16 Update Source Parameters

param#	Source Parameter
0	Voltage Range
1	Shutter Output
2	Shutter Output Type
3	Number of Crucibles
4	Crucible Output
5	Crucible Output Type
6	Turret Feedback Value is upper or lower case YES or NO
7	Turret Input
8	Turret Delay
9	DAC Output

7.7.4.6 Update Output Types

For each command format the symbol p represents a blank space.
The format is:

UT p output# p [type code]

This command changes the type code for a specific relay. Type code values are 0 or 1, where 0 is Normally Open and 1 is Normally Closed.

7.7.4.7 Update Logic Statements

For each command format the symbol p represents a blank space.
The format is:

UL p logic statement# p IF p (event code) p THEN p (action code)

This command changes the encoded conditional string assigned to a specific logic 'device'. The string is represented in the form IF (event code) THEN (action code). Both IF and THEN portions are always required. An Event marked with a '#' requires a numeric qualifier. Codes are used to represent Events and Actions. Multiple Events are connected with AND, OR, or ON. Parentheses show groupings and the symbol '~' is used to represent a negate. Multiple Actions are connected with an AND.

For example, to enter into Logic Statement 24:

IF (Statement 7 or Statement 8) AND TIMR EXPIRED 14 and TIMR EXPIRED 1
THEN Message OFF 5 and Message ON 1

the command is:

UL 24 IF (43 7 OR 43 8) AND ~ 41 14 AND 41 1 THEN 22 5 AND 21 1

Table 7-17 Update Logic Statements - Output Event

event code	Output Event
0	Clear the event string
1	Source Switch State
2	Rise 1 State
3	Soak 1 State
4	Rise 2 State
5	Soak 2 State
6	Shutter Delay State
7	Rate Ramp 1 State
8	Rate Ramp 2 State
9	Feed Ramp State
10	Feed State
11	Idle Ramp State

Table 7-17 Update Logic Statements - Output Event (continued)

event code	Output Event
12	Idle State
13	Time Power
14	Pre-Deposit
15	Deposit
16	Post-Deposit
17	Manual
18	AutoTune
19	Thickness Limit
20	Final Thickness
21	Time Limit
22	Last Layer
23	Process End#
24	Layer End#
25	Material End#
26	Process#
27	Layer#
28	Material#
29	Source#
30	Sensor#
31	Stop
32	XTAL Fail #
33	Auto-Z Fail #
34	Max. Power
35	Shutter Error
36	Ready
37	Chopper Wheel
38	Computer Control
39	External Input #
40	Timer Active #
41	Timer Expired #
42	Counter Expired #
43	Statement #
44	Source Shutter
53	Rate < .1
54	Test

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Table 7-18 Update Logic Statements - Input Action

action code	Input Action
0	Clear the Input Assignments
1	Start
2	Stop
3	Reset
4	Select Process #
5	Zero Thickness
6	Zero Time
7	Trigger Final Thickness
8	Switch XTAL #
9	XTAL Fail Inhibit On
10	XTAL Fail Inhibit Off
11	Soak Hold 1 On #
12	Soak Hold 1 Off #
13	Soak Hold 2 On #
14	Soak Hold 2 Off #
15	RateWatcher Hold On
16	RateWatcher Hold Off
17	RateWatcher Hold Inhibit On
18	RateWatcher Hold Inhibit Off
19	External Output On #
20	External Output Off #
21	Message On #
22	Message Off #
23	Set Timer (seconds) # _p ## (two numeric qualifiers required; # represents the timer number and ## represents the timer value).
24	Set Timer (hours:minutes) # _p ## (two numeric qualifiers required; # represents the timer number and ## represents the timer value).
25	Cancel Timer #
26	Set Counter #
27	Decrement Counter #
28	Non Deposit Clock Hold On
29	Non Deposit Clock Hold Off
36	Start Inhibit On
37	Start Inhibit Off

7.7.4.8 Update Output Name

For each command format the symbol p represents a blank space.
The format is:

UO p output# p output string

This command will assign a user-defined string to the output # designated unless the output already has an IC/5-assigned name. The string can be no more than 10 characters long and must be comprised from the character set:

_____ ABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789!#~-%&

The output string may be cleared by sending the UO command with the output string left blank. The underscore is used to represent a blank space.

7.7.4.9 Update Input Name

For each command format the symbol p represents a blank space.
The format is:

UI p input# p input string

This command will assign a user-defined string to the input # designated unless the input already has an IC/5-assigned name. The string can be no more than 10 characters long and must be comprised from the character set:

_____ ABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789!#~-%&

The input string may be cleared by sending the UI command with the input string left blank. The underscore is used to represent a blank space.

7.7.4.10 Update User Message

For each command format the symbol p represents a blank space.
The format is:

UN p user_message# p user message string

This command will assign a user-defined string to the user message number designated. The string can be no more than 19 characters in length and must be comprised from the character set:

_____ ABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789!#~-%&

The user message string may be cleared by sending the UN command with the user message string left blank. The underscore is used to represent a blank space.

7.7.5 STATUS Commands

Status commands return pertinent information based on a specific request made. Commands are provided to determine global information which is system level or channel information which is layer oriented. A status code is required for each command. The command and the code are separated by a space. The command variations include:

SG Status of system or instrument level conditions.

SL Status of an active layer.

For each command format the symbol *p* represents a blank space. The format is:

SG_pglobal_status_code

This command can be used to determine system or instrument level conditions. For the Response Formats: *x* represents a number (if the value being returned does not occupy the entire width, blanks are added to the left); *s* represents the sign (only a negative sign is displayed, a blank is returned in this position if the value is positive); *p* represents a blank.

Table 7-19 Status Command **SG_pglobal_status_code**

Code#	Global Condition	Response Format
0	Active Process - Returns an ASCII value of 1 through 50	xx
1	Number of Layers In Progress - The first returned value indicates the number of layers in progress, returning an ASCII 0, 1, or 2. The second and third values (if present) indicate the current layers in progress.	0 or 1bx or 2 _p xx _p xx
2	Output Status - Returns 38 ASCII bytes, one per output with a value of "0" or "1." A "1" indicates the output is active.	xxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxx
3	Input Status: Returns 28 ASCII bytes, one per input, with a value of "0" or "1." A "1" indicates the input is active.	xxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxx
4	Logic Statements - Returns 100 ASCII bytes, one per logic statement, depending on the condition of the logic string. A "1" indicates the equation evaluates to a true condition. For command 4: xxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxx xxxxxxxxxxxxxxxxxxxx	

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Table 7-19 Status Command SG_pglobal_status_code

Code#	Global Condition	Response Format	
5	System Messages - Returns a variable length string listing message numbers corresponding to the status messages on the instrument. (This sequence may be repeated if there is more than one message code returned.) See Section 13.1 for error message descriptions.	p ^{xx} p	
	Response codes to SG 05 Command:		
	Message #		System Messages
	0		NO SYSTEM MESSAGES
	30		XTAL FAIL
	31		MAX. POWER REACHED
	33		XTAL SWITCHING
	34		SWITCHER FAIL
	35		AUTOTUNE FAILURE
	36		AUTOTUNE TIMEOUT
	37		AUTOTUNE SUCCESSFUL
	38		UNABLE TO AUTO Z
	41		SAMPLE
	42		HOLD
	43		DELAY
44	AUTOTUNE MAX. POWER		
45	RATE ABOVE MAX.		
46	SPEED TEST		
47	FAST SYSTEM		
48	SLOW SYSTEM		

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Table 7-19 Status Command `SGpglobal_status_code`

Code#	Global Condition	Response Format
49	QUICK BUMP	
50	HALF RATE	
51	COMPLETE BUMP	
52	END OF PROCESS	
53	NO DISK OPTION	
54	NO DISK IN DRIVE	
55	DISK IS FULL	
56	DISK WR PROTECTED	
57	DISK MEDIA ERROR	
58	FILE NOT FOUND	
59	FILE IS READ ONLY	
60	FILE CHKSUM ERROR	
61	FILE FORMAT ERROR	
62	FILE READ ERROR	
63	FILE RANGE ERROR	
64	PARAMS DEFAULTED	
65	DATA LOG FAILURE	
69	RS-232C TIME OUT	
70	IEEE488 TIME OUT	
71	MEM ALLOC FAIL	
72	CO-DEP UNCALIBRATED	
73	CALIBRATION TIMEOUT	
74	XTAL FAIL IN CAL	
200	User Message 1	

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Table 7-19 Status Command SG_pglobal_status_code

Code#	Global Condition	Response Format																								
	201 User Message 2																									
	202 User Message 3																									
	203 User Message 4																									
	204 User Message 5																									
	205 User Message 6																									
	206 User Message 7																									
	207 User Message 8																									
	208 User Message 9																									
	209 User Message 10																									
6	<p>Stop Status - Returns the stop status as an ASCII number, 0 if the system is not in STOP or returns an ASCII code indicating what caused the stop. Causes marked with an * have numeric designators on the front panel which do not return when the SG 06 request is sent. See Chapter 13 for error message descriptions.</p> <p>Response Codes to SG 06 Command.</p> <table border="1"> <thead> <tr> <th>Stop#</th> <th>Stop Cause</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>SHUTTER DELAY</td> </tr> <tr> <td>2</td> <td>FRONT PANEL</td> </tr> <tr> <td>3</td> <td>TIME POWER</td> </tr> <tr> <td>4</td> <td>MAX. POWER</td> </tr> <tr> <td>5</td> <td>XTAL FAIL*</td> </tr> <tr> <td>6</td> <td>SOURCE CONFLICT</td> </tr> <tr> <td>7</td> <td>SENSOR CONFLICT</td> </tr> <tr> <td>8</td> <td>POWER LOSS</td> </tr> <tr> <td>9</td> <td>SOURCE SWITCH</td> </tr> <tr> <td>10</td> <td>SWITCHER FAIL</td> </tr> <tr> <td>11</td> <td>MAX. POWER < 5%</td> </tr> </tbody> </table>		Stop#	Stop Cause	1	SHUTTER DELAY	2	FRONT PANEL	3	TIME POWER	4	MAX. POWER	5	XTAL FAIL*	6	SOURCE CONFLICT	7	SENSOR CONFLICT	8	POWER LOSS	9	SOURCE SWITCH	10	SWITCHER FAIL	11	MAX. POWER < 5%
Stop#	Stop Cause																									
1	SHUTTER DELAY																									
2	FRONT PANEL																									
3	TIME POWER																									
4	MAX. POWER																									
5	XTAL FAIL*																									
6	SOURCE CONFLICT																									
7	SENSOR CONFLICT																									
8	POWER LOSS																									
9	SOURCE SWITCH																									
10	SWITCHER FAIL																									
11	MAX. POWER < 5%																									

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Table 7-19 Status Command `SGpglobal_status_code`

Code#	Global Condition	Response Format
	12 RATE TOO LOW	
	13 QUICK TUNE FAIL	
	14 HALF RATE FAIL	
	15 COMPLETE TUNE FAIL	
	16 MAX. POWER ERROR	
	17 COMMUNICATIONS	
	18 LOGIC STATEMENT	
	19 HAND HELD	
	20 NO SOURCE DAC	
7	<p>Sensor Status - Returns the sensor status for all sensors.</p> <p>The status format is shown below; separating each sensor information field is the CR character (ASCII 13).</p> <p>Sensor # GOOD A Sensor is good and actively in use for a current film.</p> <p>Sensor # FAIL A Sensor has failed and the current film needs to use this sensor.</p> <p>Sensor # GOOD N Sensor is good and turned off for the current film.</p> <p>Sensor # FAIL N Sensor has failed and turned off for the current film.</p>	
8	Layers in current process. The value returned indicates the number of layers in the current process.	<code>pp^x to xxx</code>
9	End of Process. The value returned indicates whether the IC/5 has reached the end of a process. A value of 1 indicates the end of process has been reached. A value of 0 indicates the end of process has not been reached.	<code>x</code>
10	Process Layer Information. This command returns a variable length string in the format <code>NNxxx...xxx</code> . The value <code>NN</code> indicates the number of defined processes. The following values indicate the number of layers defined for each of the <code>NN</code> processes.	<code>NN_pxxx</code> The <code>p_{xxx}</code> sequence is repeated for each defined process.

Table 7-19 Status Command **SG_pglobal_status_code**

Code#	Global Condition	Response Format
11	Defined Material Count The value returned indicates the number of materials that are defined.	xx
12	Timer Tick and the delta fundamental frequency for all eight sensors. 1-9 returned for a positive change. A-I returned for a negative change. 0 returned for no change.	ttttxxxxxxxx

SL_player_status_code_pLayer #

These commands are used to determine the condition of started layers. For example: SL 1 1 will return the current Rate for Layer 1.

For the Response Formats: x represents a number (if the value being returned does not occupy the entire width, blanks are added to the left); s represents the sign (only a negative sign is displayed, a blank is returned in this position if the value is positive); t represents the timer tick value; w represents the sensor status byte and _p represents a blank.

Table 7-20 Status Command **SL_player_status_code_pLayer #**

Code	Channel Condition	Response Format
0	Process information. All the information for codes 1 to 9	
1	Rate (Å/s) currently read. (Raw reading) sx.xxx _b to sxxx.b	sx.xxx _p to sxxx. _p
2	Power (%) currently read.	_p xx.xxx _p
3	Thickness (KÅ) currently accumulated	sxxx.xxx _p
4	State currently in progress.	_p xx _p
	Response Codes to SL 04 Layer # Command.	
	State#	State in Process
	0	READY
	1	SOURCE SWITCH
	2	RISE 1
	3	SOAK 1
	4	RISE 2
	5	SOAK 2
	6	SHUTTER DELAY
	7	DEPOSIT (before any rate ramps)

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Table 7-20 Status Command `SLplayer_status_codepLayer #`

Code	Channel Condition	Response Format
10	Crystal position. The value of w will be a "G" for a good crystal, an "F" for a failed crystal, an "I" for an invalid frequency reading and an "x" indicates the sensor is not in use. When using a CrystalSix sensor, the value of P indicates the current crystal position. If a single or dual sensor head is in use the value of P will be a one.	
	<code>wwwwwwww_pP_pP_pP_pP_pP_pP_p</code>	
11	Datalog string. This command will return the datalog string for the layer specified. This string will be returned in the comma delimited format. Data is available for the last two layers completed	
12	Rate that is displayed on the Operate screen.	
	The rate field may vary from <code>sx.xxx_p</code> to <code>sxxxx._p</code> .	
20	Rate deviation/power output trend. Average values from the operational screen graph. Format of each data point, response length varies depending on number of data points.	<code>xxx.xxx_p</code>
21	Timer tick, Sensor Status, Fundamental frequency of active sensors. Eight bytes are returned for the sensor status. Each byte represents the status of one sensor. A "G" indicates the sensor reading is valid, an "F" indicates the crystal is failed, an "I" indicates the frequency reading is invalid, and an "x" indicates the sensor is not selected.	
	<code>ttt_pwwwwwwww_psxxxxxxx.xx_p</code>	
22	Timer tick, Sensor Status, Anharmonic frequency of active sensors. Eight bytes are returned for the sensor status. Each byte represents the status repeated for each active sensor of one sensor. A "G" indicates the sensor reading is valid, an "F" indicates the crystal is failed, an "I" indicates the frequency reading is invalid, and an "x" indicates the sensor is not selected.	
	<code>ttt_pwwwwwwww_psxxxxxxx.xx_p</code> The <code>sxxxxxxx.xx_p</code> sequence is repeated for each active sensor.	

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Table 7-20 Status Command `SLplayer_status_codepLayer #`

Code	Channel Condition	Response Format
23	<p>Timer tick, Sensor Status, Fundamental, and Anharmonic frequencies of active sensors. A negative value of the last valid frequency reading is returned when a crystal fail occurs. Eight bytes are returned for the sensor status. Each byte represents the status of one sensor. A “G” indicates the sensor reading is valid, an “F” indicates the crystal is failed, an “I” indicates the sensor reading is invalid and an “x” indicates the sensor is not selected.</p>	
	<p><code>t_pwwwwwww_psxxxxxx.x_psxxxxxx.x_p</code> The <code>sxxxxxx.x_psxxxxxx.x_p</code> sequence is repeated for each active sensor.</p>	
24	<p>Sensor Z-value of active sensors. The value of w will be a “G” for a good crystal, an “F” for a failed crystal, an “I” for an invalid reading and an “x” indicates the sensor is not in use.</p>	
	<p><code>wwwwwww_pxxx.x_p</code> The <code>xxx.x_p</code> sequence is repeated for each active sensor.</p>	
25	<p>Timer tick, Sensor Status, Fundamental frequency, Anharmonic frequency, Fundamental activity. Eight bytes are returned for the sensor status. Each byte represents the status of one sensor. A “G” indicates the sensor reading is valid, an “F” indicates the crystal is failed, an “I” indicates the frequency reading is invalid and an “x” indicates the sensor is not selected.</p>	
	<p><code>t_pwwwwwww_psxxxxxx.x_psxxxxxx.x_pxxx_p</code> The sequence <code>sxxxxxx.x_psxxxxxx.x_pxxx_p</code> is repeated for each active sensor.</p>	
26	<p>Timer tick, Sensor Status, Fundamental frequency, individual sensor rate of active sensors. Eight bytes are returned for the sensor status. Each byte represents the status of one sensor. A “G” indicates the sensor reading is valid, an “F” indicates the crystal is failed an “I” indicates the frequency reading is invalid and an “x” indicates the sensor is not selected.</p>	
	<p><code>t_pwwwwwww_psxxxxxx.x_psx.x_p</code> The rate field may vary from <code>sx.x_p</code> to <code>sxxxx._p</code>. The sequence <code>sxxxxxx.x_psx.x_p</code> is repeated for each active sensor.</p>	

Table 7-20 Status Command $SL_p layer_status_code_p Layer \#$

Code	Channel Condition	Response Format
27	<p>Timer tick, Sensor Status, Sensor thickness. Eight bytes are returned for the sensor status. Each byte represents the status of one sensor. A "G" indicates the sensor reading is valid, an "F" indicates the crystal is failed an "I" indicates the frequency reading is invalid and an "x" indicates the sensor is not selected.</p>	<p>$t t b w w w w w w w w p s x x x . x x x p$ The sequence $s x x x . x x x p$ is repeated for each active sensor.</p>
30	<p>Timer tick, Sensor Status, Fundamental frequency, Fundamental activity, individual sensor rate and sensor thickness of active sensors. Eight bytes are returned for the sensor status. Each byte represents the status of one sensor. A "G" indicates the sensor reading is valid, an "F" indicates the crystal is failed an "I" indicates the frequency reading is invalid and an "x" indicates the sensor is not selected.</p>	
31	<p>Timer tick, Sensor Status, Average Sensor Rate. Eight bytes are returned for the sensor status. Each byte represents the status of one sensor. A "G" indicates the sensor reading is valid, an "F" indicates the crystal is failed an "I" indicates the frequency reading is invalid and an "x" indicates the sensor is not selected.</p>	<p>$t t p w w w w w w w w p s x x x x$ The rate field may vary from $s x . x x x p$ to $s x x x x . p$.</p>
<p>NOTE: Timer Tick is a counter that increments from 0 to 999 and repeats. Every 100 msec the IC/5 controller processes frequency information from each measurement board and the Timer Tick counter is incremented. Keeping track of the counter value informs the operator whether the currently returned frequency has been updated since the last request for this information.</p>		

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7.7.6 REMOTE Commands

Remote commands perform an action based on the specific command given. Commands are provided to affect global features which are system level oriented (RG commands) or channel information which is layer oriented (RL commands). Every command requires a remote code and may require a value. Commands, codes and values are separated by a space. Command variations include:

RG Affects a system or instrument level condition.

RL Affects conditions of the specified layer.

For each command format the symbol *p* represents a blank space. The format is:

RG_pglobal_remote_code#_pvalue

This command can be used to affect system or instrument level features. A value may be required.

Table 7-21 REMOTE Commands—Global

code#	Global Action
NOTE: Codes 0,1, and 2 need to be separated by one tenth of a second.	
0	Start - equivalent to hitting a start key.
1	Stop - equivalent to hitting a stop key.
2	Reset - equivalent to hitting a reset key.
3	Remote Lock On - prohibits any parameter from being entered via front panel.
4	Remote Lock Off - clears remote lock condition. Also clears Display Lock.
5	Set Logic vvv - sets the Logic number indicated. NOTE: this will happen only if in the Logic Statement the Event is set as computer controlled. Otherwise, this command will be ignored.
6	Clear Logic vvv - clears the Logic number indicated. NOTE: this will happen only if in the Logic Statement the Event is set as computer controlled. Otherwise, this command will be ignored.
7	Crystal Fail Inhibit On - prohibits the crystal fail Event from being true.
8	Crystal Fail Inhibit Off - allows the crystal fail Event to be true.
9	Display Lock On - locks front panel display and keyboard. Used to speed response time via communications. (Cleared by issuing RG 4 command.) Display Lock is automatically cleared on a power failure.

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Table 7-21 REMOTE Commands—Global (continued)

code#	Global Action
10	Battery Backed RAM Lock On -prevents saving of parameters to the nonvolatile RAM. Useful to speed communications when consecutively updating a large number of parameters. It has no effect on the speed of communications when querying parameters. If the instrument loses power while the battery-backed RAM is locked, any parameters updated during the time the battery-backed RAM was locked will not be retained.
11	Battery Backed RAM Lock Off - Unlocks the battery-backed RAM lock and resumes normal operation.
12	Non-Deposit Clock Hold on. “Holds” the state timer during any non-Deposit state. See Section 6.5.
13	Non-Deposit Clock Hold off. Removes the state timer “Hold” and resumes normal operation. See Section 6.5
14	Soak Hold 1 on s - Turns on Soak Hold 1 for source s.
15	Soak Hold 1 off s - Turns off Soak Hold 1 for source s.
16	Soak Hold 2 on s - Turns on Soak Hold 2 for source s.
17	Soak Hold 2 off s - Turns off Soak Hold 2 for source s.
18	User Message on mm - Turns on User Message mm.
19	User Message off mm - Turns off User Message mm.
20	Delete material vv. Removes material vv from the material directory. This command is valid only if the material being deleted is not used in any process.
21	Name Material vvv uuu. Give material number vvv the name corresponding to material library entry uuu. Library entries range from 0 (Ag) to 255 (USER), with numbers corresponding to the alphabetical listing in the library. The density and z-ratio will be changed accordingly. This command can be used to change the name of any defined material or can be used to define the first undefined material in the Material Directory. After its definition the material can have its parameter values changed and may be called out in a process’ layer definition using the UM and UP series of commands. See Appendix A for Material Table.
22	Add layer vvv. Will define the next undefined layer in process vvv, giving it all default parameters.
23	Insert layer uuu vvv. Will insert a layer immediately before layer vvv of process uuu.
24	Delete layer uuu vvv. Will delete layer vvv of process uuu.

Table 7-21 REMOTE Commands—Global (continued)

code#	Global Action
25	Copy layer uuu_pfff_p ttt. Copies layer fff of process uuu to the position preceding layer ttt.
26	Switch crystal s_px . Crystal switches sensor s to crystal position x. If $x = 0$, the IC/5 will choose the “next” crystal. If the sensor is not used in a layer currently running, the next crystal will be the next one in sequence. If the sensor is being used in a layer that is running, the next crystal will be the next one from the list in the XL Position material parameter. If a sensor is used in a layer that is running, or if the sensor is a dual head the value of “x” must be zero, otherwise an error will occur.
27	Default Parameters will set all of the IC/5 parameters to the default values except for the communications parameters. The communications parameters will remain unchanged.

$RL_pchannel_remote_code#_pIII\#_pvalue$

These commands are used to affect actions associated with started layers. Single or multiple values may be required for some commands. If the layer designated is not currently active, an “F” (cannot change value now) error code will be returned. III# is the number of the active layer.

Table 7-22 REMOTE Commands—Channel

code#	Channel Action
0	Manual On III - Places layer III into manual power control
1	Manual Off III - Removes layer III from manual power control and places layer III into deposit.
2	Set Power Level III uu.uuu - Sets the power level for layer III to uu.uuu % (only while in Manual).
3	Zero Thickness III - Zeros the thickness for layer III.
4	Final Thickness Trigger III - Triggers final thickness for layer III.

7.7.7 Negative Response Error Codes

An error code in the form of a single ASCII character is returned when a command results in an error. The error code is followed by a NAK character.

Table 7-23 Negative Response Error Codes

error code	Command Error
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
O	Data Overrun Error

7.8 Sample INFICON Messages and Host Programs

The following illustrate examples of typical message streams and host programs. The message streams are shown with decimal byte values representing ASCII codes or numeric sums. The programs are in BASIC and were implemented on an AT class PC.

7.8.1 Sample INFICON Messages

Serial Communications Forms (RS-232C)

Command Message - No Checksum

Description- Query state of Stop On Max Power
 Command- QU 3
 Message Form- (command)<ACK>
 Message Stream- 81 85 32 51 06

Command Message - With Checksum

Description- Update Maximum power of Material 20 to 60 %
 Command- UM 13 20 60
 Message Form- <STX>(count)(command)(checksum)
 Message Stream- 02 00 11 85 77 32 49 51 32 50 48 32 54 48 46

Response Message - No Checksum

Description- Process 1 is active
 Response- 1
 Message Form- (response)<ACK>
 Message Stream- 49 06

Description- Command was illegal; nrc is A.
 Response- A
 Message Form- (nrc)<NAK>
 Message Stream- 65 21

Response Message - With Checksum

Description- SOAK 1 power is 42%
 Response- 42
 Message Form- <STX>(count)<ACK>(response)(checksum)
 Message Stream- 02 00 05 06 52 50 46 48 202

Description- There is no data to retrieve; nrc is E.
 Response- E
 Message Form- <STX>(count)<NAK>(nrc)(checksum)
 Message Stream- 02 00 02 21 69 90

Parallel Communications Forms (IEEE488)

Command Message

Description- Hello
 Command- H
 Message Form- (command)<LF>
 Message Stream- 72 10

Response Message

Description- Instrument Identification
 Response- IC/5 VERSION 2.20
 Message Form- (response)<LF>
 Message Stream- 73 67 47 53 32 86 69 82 83 73 79 78 32 49 46 48 48 10

Description- Illegal command format; nrc is D.
 Response- D
 Message Form- (nrc)<LF>
 Message Stream- 68 10

7.8.2 Sample Host Programs

The following BASIC programs illustrate host processing that could be used to remotely communicate with the IC/5. They accept commands from the keyboard, and display the response received from the IC/5.

7.8.2.1 Serial Communications - No Checksum

```
5 `—IC/5 RS-232C COMMUNICATIONS / NO CHECKSUM—
10 OPEN "COM1:2400,N,8,1,CS,DS" FOR RANDOM AS #1
20 NAK$ = CHR$(21) : ACK$ = CHR$(6)
22 CMD$ = "RG 01"
23 GOSUB 80
24 CMD$ ="RG 02"
25 GOSUB 80
30 INPUT "ENTER COMMAND"; CMD$
40 GOSUB 80
50 PRINT RESPONSE$
60 GOTO 30
70 `
80 `—TRANSMIT COMMAND AND RECEIVE RESPONSE SUBROUTINE—
90 `
100 `—SEND COMMAND—
101 FOR V = 1 TO 200
102 NEXT V
110 PRINT #1, CMD$ + ACK$;
120 `
130 `—RECEIVE RESPONSE—
140 RESPONSE$ = ""
150 TOUT = 8: GOSUB 190
155 IF I$ = ACK$ THEN RETURN
160 IF I$ = NAK$ THEN RETURN
165 RESPONSE$ = RESPONSE$ + I$
170 GOTO 150
180 `
190 `—READ CHARACTER FROM INSTRUMENT TO I$—
200 ON TIMER (TOUT) GOSUB 230: TIMER ON
210 IF LOC(1) < 1 THEN 210 ELSE TIMER OFF: I$ = INPUT$(1,#1)
220 RETURN
230 TIMER OFF: RESPONSE$ = "RECEIVE TIMEOUT": I$ = NAK$: RETURN 220
```

7.8.2.2 Serial Communication with Checksum

```

5  `—IC/5 RS-232C COMMUNICATIONS PROGRAM WITH CHECKSUM—
10 OPEN "COM1:2400,N,8,1" FOR RANDOM AS #1
20 STX$ = CHR$(2) : NAK$ = CHR$(21) : ACK$ = CHR$(6)
22 CMD$ = "RG 01"
23 GOSUB 80
24 CMD$ = "RG 02"
25 GOSUB 80
30 INPUT "ENTER COMMAND"; CMD$
40 GOSUB 80
41 IF RESPONSE$ = "RECEIVE TIMEOUT" THEN 50
42 L = LEN(RESPONSE$) : L = L - 1
44 RESPONSE$ = RIGHT$(RESPONSE$,L)
50 PRINT RESPONSE$
60 GOTO 30
70 `
80 `—TRANSMIT COMMAND AND RECEIVE RESPONSE SUBROUTINE—
90 `
100 `—SEND COMMAND—
110 SIZEM$ = CHR$(LEN(CMD$) / 256)
120 SIZEL$ = CHR$(LEN(CMD$) MOD 256)
130 CHECKSUM = 0
140 FOR X = 1 TO LEN(CMD$)
150 CHECKSUM = CHECKSUM + ASC(MID$(CMD$,X,1))
160 NEXT X
170 CHECKSUM$ = CHR$(CHECKSUM AND 255)
180 PRINT #1, STX$ + SIZEM$ + SIZEL$ + CMD$ + CHECKSUM$
190 `
200 `—RECEIVE RESPONSE—
210 TOUT = 4: GOSUB 390
220 IF I$ <> STX$ THEN 180
230 TOUT = 3: GOSUB 390
240 SIZE = 256 * ASC(I$)
250 TOUT = 3: GOSUB 390
260 SIZE = SIZE + ASC(I$)
270 CHECKSUM = 0
280 RESPONSE$ = ""
290 FOR I = 1 TO SIZE
300 TOUT = 3: GOSUB 390
310 RESPONSE$ = RESPONSE$ + I$
320 CHECKSUM = CHECKSUM + ASC(I$)
330 NEXT I
340 TOUT = 3: GOSUB 390
350 N = ASC(I$)
360 IF N <> (CHECKSUM AND 255) THEN PRINT "RESPONSE CHECKSUM ERROR"
370 RETURN
380 `
390 `—READ CHARACTER FROM INSTRUMENT TO I$—
400 ON TIMER (TOUT) GOSUB 430: TIMER ON
410 IF LOC(1) < 1 THEN 410 ELSE TIMER OFF: I$ = INPUT$(1,#1)
420 RETURN
430 TIMER OFF: RESPONSE$ = "RECEIVE TIMEOUT": RETURN 440
440 RETURN 370

```

7.8.2.3 IEEE Sample Host Program

This program demonstrates IEEE488 communications with an IC/5. This example program was written using QuickBasic version 4.0 and used a national instruments PCIIA IEEE488 card and drivers.

Below is a listing of the program's variables:

bd0% unit descriptor identifying the GPIB

bd1% unit descriptor identifying the IC/5

CNT% size of command or maximum size of response

IBCNT% number of bytes read

CMD\$ command string entered by user to be sent to IC/5

status% status returned by national Instrument drivers

```
'<<<<<<<<<<  INITIALIZATION  >>>>>>>>>>>>
REM $INCLUDE: 'QBDECL4.BAS' 'National Instruments include library

'<<<<<<<<<<  OPEN DEVICES  >>>>>>>>>>>>
begin:
  bd0% = ILFIND("gpib0") 'Open the GPIB.
  bd1% = ILFIND("ic5") 'Open the IC/5.

'<<<<<<<<<<  CLEAR DEVICES  >>>>>>>>>>>>
  CALL IBCLR(bd0%) 'Clear the GPIB.
  CLS 'Clear screen.

lup:
  '<<<<<<<<<<  SEND COMMAND  >>>>>>>>>>>>
  PRINT
  CALL IBCLR(bd1%) 'Clear the IC/5.
  INPUT "ENTER COMMAND STRING "; CMD$
  CMD$ = CMD$ + CHR$(&HA) 'Add EOS character to command.
  CNT% = LEN(CMD$) 'Find length of command.
  status% = ILWRT(bd1%, CMD$, CNT%) 'Write command.

  '<<<<<<<<<<  READ RESPONSE  >>>>>>>>>>>>
  msg$ = SPACE$(2000) 'Make room for largest response.
  CNT% = LEN(msg$)
  status% = ILRD(bd1%, msg$, CNT%) 'Read response.

  '<<<<<<<<<<  PRINT RESPONSE  >>>>>>>>>>>>
  msg$ = LEFT$(msg$, IBCNT%)
  PRINT msg$;

GOTO lup 'Get next command

END
```

To implement serial polling of the message available (MAV) bit the following lines may be added to the IEEE488 program listed above. These lines would be added immediately before the line:

```
'<<<<<<<<< READ RESPONSE >>>>>>>>>'

'<<<<<<<<< WAIT FOR MESSAGE AVAILABLE BIT >>>>>>>>>'
WAITMAV:

CALL IBRSP (bd1%, SPR%)
B = SPR%/16
B = INT(B)
IF B = 1 THEN GOTO RESPONSE ELSE GOTO WAITMAV

RESPONSE:
```

After sending a command to the IC/5 the status byte is polled. The response to the command is retrieved only after the MAV bit is set ($2^4 = 16$).

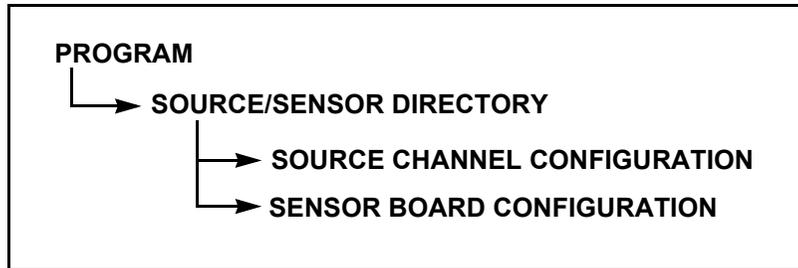
Chapter 8

Source/Sensor Set-Up

8.1 Source/Sensor Set-Up Overview

The IC/5 provides the capability to configure the instrument's source control and measurement sensor channels. The basic unit has up to six source control channels and two measurement sensors. Optionally, it will support up to eight sensors. Each source control channel is treated as an individual device. The sensors, however, are treated in pairs.

Figure 8-1 Display tree for Source/Sensor set-up



Source/Sensor Set-Up is initiated by selecting the Source/Sensor function (F4) in the Program display. This will invoke the Source/Sensor Directory (see Figure 8-1). Upon entry, the cursor will be found at the last referenced source channel or sensor pair. You may return to the Program display by selecting the F6 key (PROGRAM).

Figure 8-2 Source/Sensor Directory

SOURCE/SENSOR DIRECTORY					F1
1. SOURCE 1	1. SENSOR BOARD 1				F2
2. SOURCE 2	2. SENSOR BOARD 2				F3
3. SOURCE 3	3. SENSOR BOARD 3				F4
4. SOURCE 4	4. SENSOR BOARD 4				F5
5. SOURCE 5				EDIT SOURCE/SENSOR	F6
6. SOURCE 6				PROGRAM	
0.0 Å/sec	0.000 kÅ	0.0 %	XTAL FAIL 1 2		

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8.2 Source/Sensor Navigation

Once you are in the Source/Sensor Directory, you may select for configuration a source channel or sensor pair by positioning the box cursor at the desired source or sensor device and then pressing the F5 key (EDIT SOURCE/SENSOR). The displays that follow are sensitive to the type of device selected and the presence of optional hardware. Certain parameters may be displayed or inhibited depending on the actual hardware configuration or the values entered. The parameters for each channel or board are contained on a single display page. New values are input from the front panel followed by pressing the **Enter** key. Values are cleared by pressing the **Clear** key.

Figure 8-3 Source Parameter Editing

SOURCE 1			F1
DAC OUTPUT	1	(1-6, 0=None)	F2
Voltage Range	3	(0=+10V, 1=+5V, 2=+2.5V 3= 10V, 4= 5V, 5= 2.5V)	F3
Shutter Output	<input type="text" value="0"/>	(0, 1-38)	F4
Shutter Output Type	0	(0=NO, 1=NC)	F5
Number of Crucibles	4	(1, 4, 8, 16, 32, 64)	F6
Crucible Output	0	(0, 1-37)	
Crucible Output Type	0	(0=NO, 1=NC)	
Turret Feedback	NO	YES/NO	
Turret Delay	5	SECONDS	
0.0 Å/sec 0.000 kÅ 0.0 %			SOURCE/SENSOR

Table 8-1 Function Key Selection Choices for Source/Sensor Editing

Key	Function	Description
F6	SOURCE/SENSOR	Select this key to return to the SOURCE/SENSOR Directory and save the current parameters.

8.3 Source Parameters

The following parameters can be displayed for each of the source control channels.

DAC OUTPUT

This parameter designates which of the DAC outputs is to be used as a source output. Values range from 0 to 6, with 0 indicating there is no DAC identified with this particular source. Values 1 through 6 correspond to the 6 DAC outputs on the back of the instrument.

VOLTAGE RANGE 0/1/2/3/4/5

This parameter selects the control voltage range for the source being edited. Permissible values are 0, 1, 2, 3, 4 and 5 for maximum output voltages of 10, 5, 2.5, -10, -5, and -2.5 Volts respectively. The default value is 3, for a control voltage output of 0 to -10 Volts.

SHUTTER OUTPUT 0 to 38

This parameter designates which of the 38 outputs is to be used as the Source Shutter relay. Values range from 0 through 38. 0 indicates that a Shutter is not used and the values 1 through 38 correspond to the appropriate relay or open collector type output. The default value is 0. If a value other than 0 is entered the relay chosen as the Source Shutter relay is designated as such in the I/O Map Display. When running a Layer containing the Source for which the Shutter Output parameter is programmed, the logic condition is set to be true when the Layer is in DEPOSIT or MANUAL. The condition remains true until the end of DEPOSIT or until a STOP command is received.

SHUTTER OUTPUT TYPE 0/1

This parameter designates the normal state of the relay contacts for the Shutter Output relay. Permissible values are 0 and 1. 0 indicates an Normally Open relay, 1 indicates a Normally Closed relay. The default value is 0.

NUMBER OF CRUCIBLES 1,4,8,16,32,64

Refer to Section 3.6.2.1 for an example of programming Turret source crucible selection. This parameter can be used to automatically index the turret position when using a multiple pocket turret source. Permissible values are 1, 4, 8, 16, 32 and 64. The value selected denotes the number of pockets in the turret source. The default value is 1 and indicates a single pocket source. If a 1 is chosen, the parameters- Crucible Output, Crucible Output Type, Turret Feedback and Turret Delay or Turret Input are removed from the Display. The number of crucibles determines the number of relays needed for the crucible output. As the relays are binary encoded (actual coding is binary - 1, with 000 representing position 1 and 111 representing position 8), 2 relays are needed for 4 crucibles, 3 for 8, 4 for 16, 5 for 32 and 6 for 64.

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CRUCIBLE OUTPUT 0 to 37

This parameter designates which of the output relays are to be used as Crucible Output relays. Values range from 0 to 37. The default is 0 and indicates the Crucible Output is inactive. The value entered into this parameter indicates which of the output relays begins the sequence of outputs used as crucible control outputs. For example, a 4 entered into the Number of Crucibles parameter and a 1 entered into the Crucible Output parameter will designate output relays 1 and 2 as crucible control outputs with the least significant bit of the binary coding in relay output 1. An 8 entered into the Number of Crucibles parameter and a 1 entered into the Crucible Output parameter will designate output relays 1, 2, and 3 as crucible control outputs with the least significant bit of the binary coding in relay output 1.

CRUCIBLE OUTPUT TYPE 0/1

This parameter designates the normal state of the relay contacts for the Crucible Output relays. Permissible values are 0 and 1. 0 indicates an Normally Open relay, 1 indicates a Normally Closed relay.

TURRET FEEDBACK YES/NO

Some turret source indexers provide feedback to signify when the turret is in the proper position. This parameter allows the IC/5 to accept this input and respond accordingly. Parameter entry may be either YES or NO. A YES indicates that Turret Feedback is expected and the Turret Input parameter is displayed on the screen. A NO indicates there is no Turret Feedback forthcoming and the Turret Delay parameter is displayed. The default value is NO. See the Turret Input and Turret Delay descriptions below.

NOTE: If the turret feedback is set to YES and the Process is STARTed, the IC/5 will proceed to the source switch state. If the turret input is not received within 60 seconds the IC/5 will enter the STOP state.

TURRET INPUT 0 to 28

This parameter designates which of the 28 inputs is to be the Turret Feedback input. Values range from 0 to 28. Values 1 through 28 correspond to the appropriate input. Value 0 indicates that an input for turret feedback is not used. The default value is 0. However, an input must be assigned, or the process will never proceed past the source switching phase of the process. If a value other than 0 is entered, then the input chosen as the Turret Input is designated as such on the I/O Map display. Input lines are activated with a contact closure to ground.

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TURRET DELAY 1 to 60 sec

If Turret Feedback is not used a timer will be set to allow the source crucible time to rotate into position. This parameter sets the amount of time the Process will remain in the Source Switch state waiting for the crucible to rotate before proceeding to the Rise 1 state. Permissible values are 1 to 60 seconds. The default value is 5 seconds.



CAUTION

The IC/5 will proceed to the Rise 1 state after the Turret Delay time expires. This could result in damage to your equipment if the crucible is not in position after expiration of the Turret Delay time.

Figure 8-4 Sensor Parameter Editing

SENSOR BOARD 1		Sensor 1	Sensor 2	
Type	(1=Single, 2=Dual, 6=Multi)	1	1	F1
Xtal Shutter				F2
Output	(0, 1-38)	0	0	
Type	(0=NO, 1=NC)	0	0	F3
Z-Ratio				
Type	(0=Auto, 1=Material)	1	1	F4
Sensor	MATERIAL MATERIAL	1.000	1.000	
Recorder				F5
Output	(1-60,0=None)	0	0	
Function	(0=Rate 100Å/S, 1=Rate 1000Å/S, 2=Thick 100 Å, 3=Thick 1000Å, 4=Rate Dev ±50Å/S)	0	0	F6
0.0 Å/sec 0.000 kÅ 0.0 %		XTAL FAIL 1 2		SOURCE/ SENSOR

8.4 Sensor Parameters

The following entries represent the parameters possible with the standard two sensors. Each sensor is configured separately. If the unit has optional sensors, each additional pair of sensors will have an identical parameter set.

TYPE 1/2/6/7

This parameter provides selection among the single (1), dual (2), CrystalSix (6) and Rotary (7) sensor heads. It enables the Crystal Switch feature for the multi-position heads and enables the crystal indexing feature on the hand held power controller. Allowable values are 1, 2, 6, and 7. The default value is 1. If a value of 1 is entered the Xtal Switch Output parameter is removed from the display. If a value of 2 is entered, then Sensor 2 Type is automatically set to a value of 2. This parameter cannot be changed while executing a process.

XTAL SWITCH OUTPUT 0 to 38

This parameter designates which of the 38 outputs is to be used as the Crystal Switch relay for Sensor 1. Values range from 0 to 38. Values 1 through 38 correspond to the appropriate output. Value 0 indicates that the Crystal Switch Output is not used. The default value is 0. *A nonzero value must be entered if a Sensor Type value of 2, 6, or 7 is chosen.* If a value other than 0 is entered, the relay chosen as the Crystal Switch relay is designated as such on the I/O Map Display. The contact closure on this relay is always Normally Open.

If a dual head is chosen for Type, the output relay will close upon initiating a Crystal Switch and then open upon initiating a second Crystal Switch. If CrystalSix is chosen for the Type, then upon initiating a Crystal Switch, the output relay will first close for one second, then open for one second, then close for one second and then open (i.e., two pulses to move one position). If a “rotary” sensor is chosen for the Type (Type 7), then upon initiating a crystal switch, the output relay will first close for one second and then open (i.e., one pulse to move one position). When Type 7 is chosen the XTAL position selection feature (section 3.6.1.1 on page 3-33) is not available. The Type 7 sensor head is assumed to have six crystal positions. Refer to section 3.6 on page 3-32 for additional information.

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XTAL SHUTTER OUTPUT 0 to 38

This parameter designates which of the 38 outputs is to be used to activate the Crystal Shutter for Sensor 1. Values range from 0 to 38. Values 1 through 38 correspond to the appropriate output. Value 0 indicates that a shutter is not used. The default value is 0. If a value other than 0 is entered then the relay chosen as the Crystal Shutter output relay is designated as such on the I/O Map Display. The logic condition is set to be true as long as the Layer containing Sensor 1 is in CONTROL DELAY, SHUTTER DELAY, DEPOSIT, MANUAL, or in the Sample period of the RateWatcher function. The condition remains true until the end of DEPOSIT, until a STOP command is received, or during the Hold period of the RateWatcher function.

XTAL SHUTTER TYPE 0/1

This parameter designates the normal state of the relay contact closure for the Crystal Shutter relay. Permissible values are 0 and 1. 0 indicates an Normally Open relay, 1 indicates a Normally Closed relay. The default value is 0 for Normally Open.

Z-RATIO 0/1

This parameter designates the method in which the Z-ratio value will be obtained for use in computing thickness with this sensor. Permissible values are 0 and 1. 0 indicates that the Auto Z calculation feature of the system is used. Auto Z cannot be enabled on a crystal which is “unable to Auto Z.” Refer to [section 3.6.3 on page 3-36](#) for details on why a crystal may be “unable to Auto Z.” 1 indicates that the Z-ratio established in Material Definition is used. The default value is 1 for the Material Z-ratio.

SENSOR Z (display only)

The value found here is the most recently calculated Auto Z-ratio associated with this sensor. It is entered by the instrument automatically. When the Z-ratio parameter (above) is set to 0, this value is updated once every second. In the event of an Auto Z failure, the most recently calculated Z value is entered and held constant until the crystal is replaced.

RECORDER OUTPUT

This parameter designates which of the DAC outputs is to be used as a Sensor’s recorder output. Values range from 0 to 6, with 0 indicating there is no DAC identified with this sensor. Values 1 through 6 correspond to the 6 DAC outputs on the back of the instrument.

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RECORDER FUNCTION

This parameter determines the function of the Sensor's recorder output. Values range from 0 to 4, 6 to 9.

- 0 indicates the function is Sensor Rate in the range of 0 to 100 Å/s.
- 1 is for Sensor Rate in the range of 0 to 1000 Å/s.
- 2 is for Sensor Thickness in the range of 0 to 100 Å.
- 3 is for Sensor Thickness in the range of 0 to 1000 Å.
- 4 is for rate deviation on a scale of +/- 50 Å/s.
- 6 is for Sensor Rate in the range of 0 to 10 Å/s.
- 7 is for Sensor Rate in the range of 0 to 50 Å/s.
- 8 is for Sensor Thickness in the range of 0 to 5000 Å.
- 9 is for Sensor Rate in the range of 0 to 1 Å/s.

8.5 DAC Output Selection Rules

The six DAC outputs located on the back of the IC/5 may be used for either Source Control Outputs, Sensor Recorder Outputs, or Aggregate Rate Recorder Output. Since these outputs can be set-up for different functions certain rules apply.

- 1** No DAC output can be set-up as both a recorder output and a source output. If this is attempted the error message *Set as Source Out* or *Set as Recorder Out* will be displayed.
- 2** A DAC output cannot be set-up for more than one source. If this is attempted the error message *Set as Source Out* will be displayed.
- 3** A DAC output can be set-up for more than one recorder output including any combination of Aggregate Rate/Thickness or Sensor Rate/Thickness.
- 4** If a DAC output is set-up for multiple recorder outputs that are required to be operative at the same time the error message *Recorder Conflict* will appear. This is a non-fatal error (i.e., it will not cause the IC/5 to STOP) and the message will remain until the conflict is resolved or a STOP takes place. The priority of a recorder output that is in conflict is:
 - a. Aggregate Rate/Thickness on the Primary Layer (the first of two co-deposited layers).
 - b. Aggregate Rate/Thickness on the Secondary Layer (the second of two co-deposited layers).
 - c. Sensor Rate/Thickness on the Primary Layer (from sensors 1 to 8).
 - d. Sensor Rate/Thickness on the Secondary Layer (from sensors 1 to 8).
- 5** A STOP will occur if a Layer is started and the Source designated for that Layer does not have a DAC output defined (i.e., the Source DAC OUTPUT parameter is 0). The error message "STOP—No source DAC" will be displayed.
- 6** For a Sensor's Recorder Output to be active it must be associated with an active Material.

8.6 Error Messages in Source/Sensor Set-Up

BOTH SNSR ON IN MATL

Shown when attempting to change the Sensor type parameter to a Dual sensor head while both sensors are turned on in a Material Set-Up display.

ILLEGAL INPUT - VALUE TOO LARGE

ILLEGAL INPUT - VALUE TOO SMALL

Parameter entry is out of range. Allowable values will vary according to your unit configuration or the parameter being defined. Press Clear to delete the value and enter again.

ILLEGAL SENSOR TYPE

Sensor type may only be 1, 2, or 6.

INPUT IN USE

The input in question has already been reserved for use.

OUTPUT IN USE

Indicates the output in question is already reserved for use in Sensor or Source Set-Up or in one of the Logic Statements.

SET AT RECORDER OUT

The value you are attempting to enter has been previously defined as a recorder output in either the Material Set-Up display or one of the Sensor Set-Up displays.

SET AS SOURCE OUT

The value you are attempting to enter has been previously defined as a Source DAC output in one of the Source Set-Up displays.

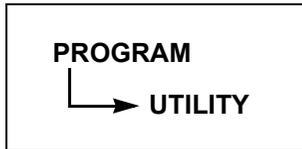
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Chapter 9 Utility Set-Up

9.1 Utility Set-Up Overview

The IC/5 provides the capability to modify a series of top level parameters that define the controller's method of handling system level activities. Some of the parameters are automatically incremented by the instrument.

Figure 9-1 Display Tree For Utility Set-Up



Initiate Utility Set-Up by selecting the F5 key (UTILITY) in the Program display. This will invoke the Utility Display (see Figure 9-2). Upon entry, the cursor will be found at the last referenced utility parameter. The parameters are contained on two display pages.

Figure 9-2 Utility Display (Page 1)

UTILITY			PAGE FORWARD	
Active Process	<input type="text" value="1"/>	(1-50)		F1
Run Number	1			F2
Layer to Start	1			F3
Stop on Max Power	YES	YES/NO		F4
Aggregate Multiplier	YES	YES/NO (Used on a sensor fail)		F5
Analog Display	2	(0=±10Å/S, 1=±20Å/S, 2=POWER)		F6
Analog Scan Rate	0	(0=AUTO, 1=SLOW, 2=MEDIUM, 3=FAST)		
Test On	YES	YES/NO		
Time Compressed	NO	YES/NO		
4.0 Å/sec 0.049 kÅ 0.0 %			PROGRAM	

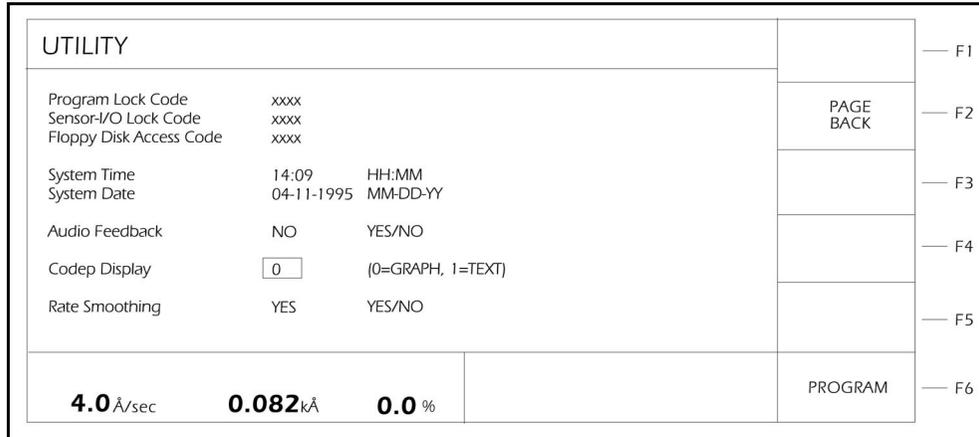
9.2 Utility Navigation

Select a parameter for entry by positioning the box cursor at the desired value following the parameter description. New values are input from the front panel followed by pressing the **Enter** key. Values are cleared by pressing the **Clear** key.

Table 9-1 Function Key Selection Choices for Utility Parameters

Key	Function	Description
F1	PAGE FORWARD	Select this key to access the second page of parameters.
F2	PAGE BACK	Select this key to return to the first page of parameters.
F6	PROGRAM	Select this key to return to the PROGRAM display.

Figure 9-3 Utility Display (Page 2)



9.3 Utility Parameters

ACTIVE PROCESS 1 to 50

This parameter selects which sequence of Layers, as defined in Process Set-Up, is to be executed. Values are 1 to 50. The default value is 1. This parameter cannot be changed while executing a process.

RUN NUMBER 1 to 999

This is a counter which increments by one at each start of a Process. Any arbitrary value may be entered as a starting point. Values range from 1 to 999. The default value is 1.

LAYER TO START 1 to 250

This selects the starting Layer from the sequence of Layers defined in the Active Process. The upper limit to the range of values is determined by the number of Layers defined for a given Process. Values range from 1 to a maximum of 250. This value cannot be changed while executing a process.

STOP ON MAX POWER YES/NO

This parameter provides a safety feature. If the parameter is set to YES and the IC/5 is at maximum power for 5 continuous seconds, the IC/5 will enter the STOP State. When in the STOP State, all source control voltage will be set to zero. The default value is YES.

AGGREGATE MULTIPLIER (YES / NO)

For multiple sensor deposition control applications the Utility parameter AGGREGATE MULTIPLIER (YES/NO) determines whether a multiplier is calculated for a crystal's rate information if this crystal fail occurs during deposition. This multiplier is used only during the layer in which the crystal failure occurs. After this layer is finished, the multiplier is cleared. Use of the AGGREGATE MULTIPLIER affects calculation of the aggregate rate as follows: (Assume all Sensor Weights are the same):

Table 9-2 Aggregate Multiplier Effect

Condition of the deposition	Sensor #1 Rate (Å)	Sensor #2 Rate (Å)	Sensor #3 Rate (Å)	Sensor #4 Rate (Å)	Aggregate Rate (Å)	Aggregate Multiplier
Start	10	10	10	10	10	1
Later in the Deposition	16	10	10	4	10	1
If #1 fails, notice what happens to the aggregate rate if we do not calculate an aggregate multiplier	Xtal Fail	10	10	4	8	1
An AGGREGATE MULTIPLIER is calculated as the ratio of the aggregate rate before the sensor failure (using an average rate for the failed sensor prior to failure) divided by the aggregate rate after the sensor failure (without the failed sensor's rate information).	With: 10 Without: 8 Ratio 1.25					
Applying the multiplier to all future aggregate rate results:	Xtal Fail	10	10	4	10	1.25
If during the deposition the use of the aggregate multiplier is turned off, the aggregate rate reverts back to:	Xtal Fail	10	10	4	8	not used

If the layer has not finished, the use of the AGGREGATE MULTIPLIER may be turned back on and the previously calculated multiplier (in this case 1.25) will continue to be used.

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ANALOG DISPLAY 0/1/2

This determines the vertical scale for the graphics display when in the OPERATE display. Permissible values are 0, 1, and 2. A zero sets the vertical scale to $\pm 10 \text{ \AA/s}$, a 1 sets the vertical scale to $\pm 20 \text{ \AA/s}$, and a 2 sets the scale to % Power. The default value is 0.

ANALOG SCAN RATE 0/1/2/3

This determines the horizontal axis for the graphics area when in the OPERATE display. Permissible values are 0, 1, 2 and 3. A zero places the scan rate into Auto mode. A 3 sets the scale to 3 measurements per horizontal pixel, a 2 sets the scale to 10 measurements per horizontal pixel, and a 1 sets the scale to 40 measurements per horizontal pixel. The default value is 0. When in the Auto mode, the scan rate starts in “fast”; after reaching the end of the display the graph collapses to half size and continues in “medium”; again at the end of the display the graph will collapse to half size and continue in “slow”.

TEST ON YES/NO

This feature provides a constant rate signal which can be varied by altering the density and tooling parameters (see Section 3.6.7). It is designed to allow testing of a Process without actually running a deposition. YES turns the test signal on. The default value is NO. This parameter cannot be changed while executing a process.

TIME COMPRESSED YES/NO

When in TEST mode, this feature allows a faster than real time execution of the Process. This is useful when testing a long Process. A value of YES increases the speed of execution 10 to 1. The default value is NO.

PROGRAM LOCK CODE 1 to 9999, 0

The Program Lock Code restricts access to programming and modifying the instrument. All parameters, including the SENSOR parameters and Logic Statements, can be reviewed but none can be changed unless the correct lock code is entered. Values range from 1 to 9999.

Before entering a new lock code, the current code must be entered.

Entering a value of zero erases the lock code and provides open access. The default condition is unlocked or open access. If a nonzero lock code is programmed, the lock code can be reset to the unlocked condition by pressing the **Clear** key while powering up the instrument.



CAUTION

If a lock code is not set, that is, if it is set to zero, then powering up and pressing the Clear key will default all the instrument's parameters.

When a Program Lock Code is entered, that code must be entered in the Program Display in order to change any of the set-up parameters in the instrument.

SENSOR-I/O LOCK CODE 1 to 9999, 0

The Sensor-I/O lock code provides privileged access to programming the SENSORS and I/O devices. Parameters for these devices can be reviewed but cannot be changed unless the correct lock code is entered. Values range from 1 to 9999.

Before changing the sensor I/O lock code, the current code must be entered. Entering a new value of zero erases the lock code and provides open access. The default condition is unlocked for open access. If a nonzero lock code is programmed, the lock code can be reset to the unlocked condition by pressing the Clear key while powering up the instrument.



CAUTION

If one or both lock codes are nonzero, powering up the instrument while pressing the Clear key will erase the lock code(s). If the lock codes are set to zero, then holding in the Clear key while powering up the instrument will set all the instrument's parameters to their default values.

When a Sensor-I/O Lock Code is entered in UTILITY Set-Up, that code must be entered prior to Sensor or I/O Set-Up in order to change any of the Sensor or I/O parameters.

FLOPPY DISK ACCESS CODE . . . 1 to 9999, 0

The Floppy Disk Access Code allows configuration file retrieval from a floppy disk when the Program Lock Code is locked. This allows a process recipe to be entered into the IC/5 from a floppy disk without “unlocking” the Program Lock Code. Otherwise floppy disk retrieval is not allowed when a Program Lock Code is present. This parameter has no effect if there are no lock codes, or the access code is set to zero.

NOTE: When pressing the Clear key on power-up, the Floppy Disk Access Code is cleared when the parameters are cleared; not when the lock codes are cleared. The Floppy Disk Access Code is not stored on nor retrieved from a floppy disk. Program and I/O lock codes are stored on and retrieved from a floppy disk.

SYSTEM TIME 00:00 to 23:59 mins:secs

Twenty-four-hour clock for current time of day. Values range from 00:00 to 23:59.

SYSTEM DATE mm-dd-yyyy

Current date. Increments automatically. Values range from 01-01-0000 to 12-31-9999.

AUDIO FEEDBACK YES/NO

Activates Audio Feedback; signifying data entry. The default value is Yes which activates the audio signal.

CODEP DISPLAY 0/1

This value determines whether the Operate Display for a co-deposition provides text-only or a text/graphic display. The default is 0 for a text/graphic display.

RATE SMOOTHING YES/NO

This parameter provides an averaging of the instantaneous rate measurement. The default value is YES. When set to YES, the Rate displayed in the graphics area of the OPERATE display and the rate output to the analog output is a 5 point box car average. When set to NO, the rate displayed in the graphics area of the OPERATE display and the rate output to the analog output is the instantaneous rate measurement. The measurement rate is 10 Hz.

9.4 Error Messages in Utility Set-Up

ILLEGAL DATE

The month or day entry is invalid. The month number must be 01-12; days should be in the correct range for the month specified.

ILLEGAL INPUT - VALUE TOO LARGE

ILLEGAL INPUT - VALUE TOO SMALL

Parameter entry is out of range. Allowable values will vary according to your unit configuration or the parameter being defined. Press **Clear** to delete the value and enter again.

ILLEGAL LOCK CODE

The correct lock code is necessary to unlock parameters.

ILLEGAL TIME

Time is invalid. The hour number must be in the 00 to 23 range; the minute number must be in the 00 to 59 range.

LAYER UNDEFINED

The "Layer to Start" defined in Utility Set-Up must correspond to a defined layer in the active process.

MUST ENTER OLD CODE

Utility Set-Up requires the old Program or I/O Lock Code to be entered before updating to a new Program or I/O Lock Code.

NOW ENTER NEW CODE

After you verify the old Program or I/O Lock Code, this message will prompt you to enter a new Lock Code.

PROCESS UNDEFINED

The Active Process defined in Utility Set-Up must correspond to a defined Process. A defined Process is one which contains Layers.

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Chapter 10 Applications

10.1 Multiple Sensor Deposition Control

The conventional method of controlling thin film depositions is to use one crystal sensor for each material source. In addition to this conventional method, the IC/5 can make use of multiple sensors for control of each material source.

To use multiple sensor deposition control, elect the appropriate Sensor Option for as many sensors as desired (up to 8). The Sensor Option parameter is located on page 3 of each Material Set-Up display (refer to [section 4.3 on page 4-5](#)). For conventional deposition control (one sensor per material source) simply select one sensor.

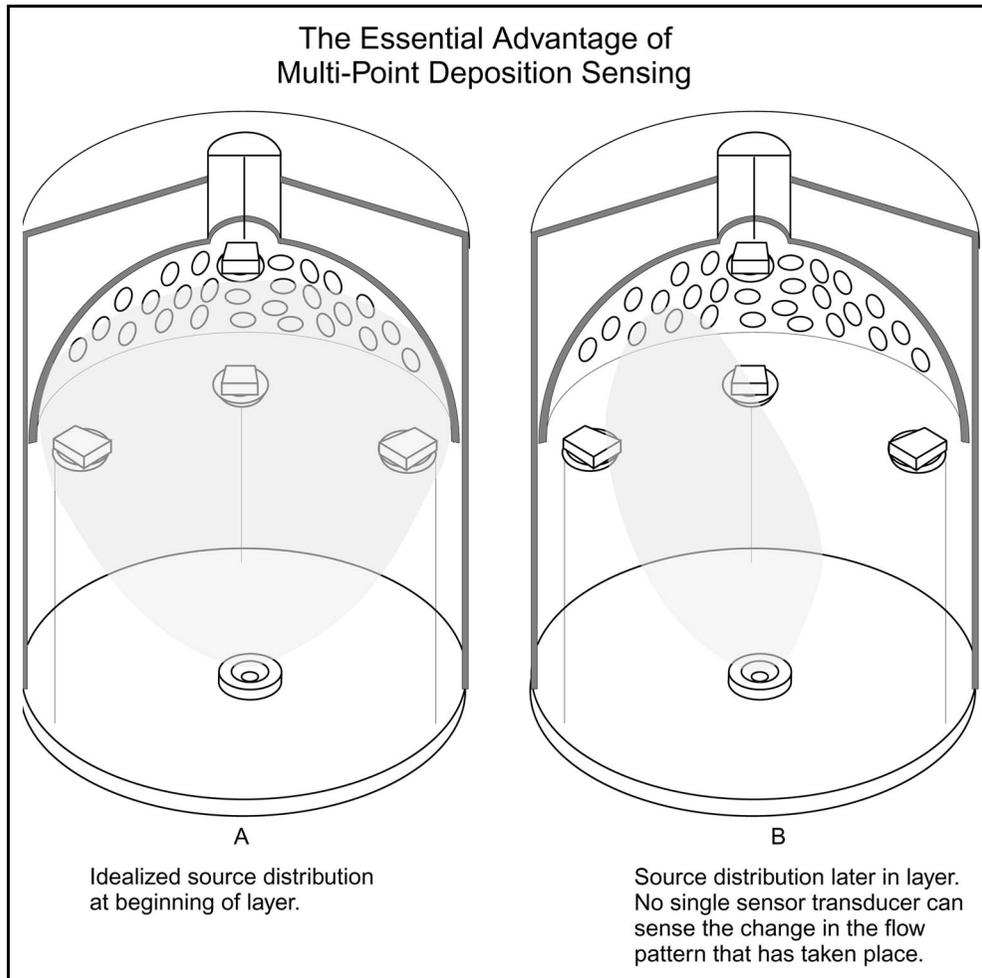
The multiple sensor deposition control feature is designed to monitor a source's flux distribution using many sensors. Multiple point sensing improves thickness reproducibility by controlling an aggregate (averaged) deposition rate. Two important elements of a deposition process contribute to layer-to-layer thickness variances and cannot be addressed by a single point controller. First, a deposition source never has the idealized (cosine) flux distribution. Also, the flux distribution is dynamic, changing as the deposition progresses.

The IC/5, when using more than one sensor for each material, calculates an aggregate rate and uses it for rate control and thickness termination. This aggregate rate is comprised of rate information from up to 8 sensors, each sensor having its own weighting and tooling factors.

As the source distribution changes, any individual sensor may detect more (or less) of the source flux. However, the aggregate rate is held constant. Each substrate, contained in a rotating planetary substrate holder, is then exposed to the constant aggregate rate, eliminating thickness variations due to a change in the source's flux distribution.

This concept is illustrated in [Figure 10-1](#), which also shows the preferred placement of the Quartz Crystal sensors relative to the deposition source and substrates.

Figure 10-1 The Essential Advantage of Multi-Point Deposition Sensing



10.1.1 Instrument Parameters and Corrections for Multiple Sensor Operation

AGGREGATE RATE

The Aggregate Rate calculation is based on:

- ◆ The rate information acquired by each sensor in use.
- ◆ A weighting factor that reflects the relative importance of each sensor's information.
- ◆ A sensor tooling factor that corrects for any relative difference in flux distribution reaching the sensors.

The aggregate rate is calculated from a combination of the above information into a weighted average.

If a sensor fails during deposition, a sudden change in the aggregate rate may occur due to this sensor's rate information being lost. An aggregate multiplier is calculated to correct for this sudden change. The aggregate multiplier is based on the last 2.5 seconds of the deposition prior to sensor failure, excluding the last 0.5 second. An average aggregate rate is calculated both with and without the newly failed sensor. The ratio of the two is used as a multiplier for the rest of this layer's deposition. This removes any sudden jump in the aggregate rate at the time of sensor failure. After this layer finishes, the aggregate multiplier is removed. (See section 9.3 on page 9-2 for additional information)

AGGREGATE MULTIPLIER

The parameter AGGREGATE MULTIPLIER (YES/NO) determines whether an aggregate multiplier is calculated for this crystal's rate information if a crystal fail occurs during deposition. This parameter is located on the Utility Parameters display. This multiplier is used only during the layer in which the crystal failure occurs. After this layer is finished, the multiplier is cleared.

SENSOR WEIGHT 1.0 to 400.0 %

The Sensor Weight parameter is used to gauge the relative importance of an individual sensor's measured rate in calculating the weighted average, "aggregate", rate. This parameter is located on page 3 of the Material Set-Up display.

SENSOR OPTION 0 to 4

The sensor option parameter on page 3 of the Material Set-Up display provides for each sensor the ability to:

- 0) Turn off the use of this sensor
- 1) STOP if this is the last sensor to fail during deposition
- 2) Go to TIME POWER if this is the last sensor to fail during deposition
- 3) STOP when this sensor fails
- 4) Go to TIME POWER if this sensor fails.

NOTE: When using the double start or codeposition features a sensor may not be used by two layers if both are in DEPOSIT at the same time. If attempted, a "sensor conflict" error will occur and the instrument will enter the STOP state. If one layer is in either a pre-Deposit or post-Deposit state, and the other layer in DEPOSIT, the layer in DEPOSIT has use of the sensor. Once both layers are started, a sensor cannot be enabled if it is used by the other material.

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TOOLING: MASTER & SENSOR

The tooling factor is now broken into two parts. The MASTER TOOLING located on the first page of the Material Set-Up display, is used to scale the aggregate rate and thickness to the substrate. SENSOR TOOLING is used to account for the geometric tooling factor of each sensor. The Sensor Tooling parameter is located on page 3 of the Material Set-Up display.

MASTER TOOLING 10.0 to 400.0 %

The MASTER TOOLING is used as a global tooling factor. This parameter is used to affect all the sensors' tooling together and calibrate the aggregate rate and thickness to the thickness measured on the substrate.

SENSOR TOOLING 10.0 to 400.0 %

SENSOR TOOLING is used to account for the geometric tooling factor of each sensor. The default value is 100%. The calibration procedure for the Master Tooling can also be applied to the SENSOR TOOLING parameter. Alternatively each SENSOR's TOOLING factor can be adjusted relative to a particular sensor.

10.2 Trend Analysis

Along with multiple sensor monitoring and control of the deposition process the IC/5 allows rate and thickness information from individual quartz crystal sensors to be output to the Digital-to-Analog (DAC) outputs. The function of each of the 6 DAC outputs can be selected among the following functions: (refer to [section 8.3 on page 8-3](#), [section 8.4 on page 8-6](#), [section 8.5 on page 8-8](#), and [section 4.3 on page 4-5](#).)

- ◆ Source Control voltage
- ◆ Recorder Output for Sensor Rate or Sensor Thickness
- ◆ Recorder Output for Aggregate Rate or Aggregate Thickness
- ◆ Power Level

This enables mapping of an individual sensor's information, useful in monitoring the change in source flux distribution during the deposition process.

10.2.1 Instrument Parameters Associated with the Trend Analysis Feature

SOURCE DAC OUTPUT

This parameter designates which of the DAC outputs is to be used as a source output. Values range from 0 to 6, with 0 indicating there is not a DAC identified with this particular source. Values 1 through 6 correspond to the 6 DAC outputs on the back of the instrument. (Refer to [section 8.3 on page 8-3.](#))

RECORDER OUTPUT (sensor or aggregate)

This parameter designates which of the DAC outputs is to be used as a Sensor recorder output. (Refer to [section 8.4 on page 8-6.](#)) There is also a parameter to designate which of the DAC outputs is to be used as a recorder output for Aggregate Rate. (Refer to [section 4.3 on page 4-5.](#))

NOTE: A recorder output cannot be associated with a DAC that is configured as a Source output. An error message will be displayed if this is attempted.

RECORDER FUNCTION (sensor or aggregate)

This parameter determines the function of the sensor recorder output between Sensor Rate, Thickness or Rate Deviation. (Refer to [section 8.4 on page 8-6.](#)) There is also a parameter to determine the function of the aggregate recorder output. (Refer to [section 4.3 on page 4-5.](#))

10.3 Use as a System Controller Example

Refer to [Chapter 6](#) of this manual for more detailed information on the IC/5 I/O functions.



CAUTION

The following actions are all level outputs and will remain active until turned off. This is true even if the logic string is cleared. For example, the action External Output ON 1 will activate relay number 1. Relay number 1 will remain active until an External Output OFF 1 action is executed:

CRYSTAL FAIL INHIBIT (ON/OFF)
 RW HOLD (ON/OFF)
 RW HOLD INHIBIT (ON/OFF)
 SOAK HOLD 1 (ON/OFF)
 SOAK HOLD 2 (ON/OFF)
 NON-DEPOSIT CLOCK HOLD (ON/OFF)
 EXTERNAL OUTPUT (ON/OFF)
 MESSAGE (ON/OFF) ##

The I/O capability of the IC/5 can be used to control an entire vacuum deposition system including pump down sequencing. The following discussion details the implementation of an IC/5 to control the entire process cycle of a deposition system. The discussion is divided into two sections. The first section is a list of equipment used in this application, and is provided only as a reference to the type of equipment required. The second section provides a detailed example listing the I/O Configuration and Logic Statements used to control the vacuum deposition system. These logic statements are one possible set of statements which will control the system properly and are meant as a guideline only.



WARNING

Automated control of a vacuum deposition system must provide for fail safe conditions to prevent personal injury or damage to the vacuum system. These fail safe conditions must account for power loss or inadvertent manual actuation of valves, pumps, gauges or other hardware connected to the system.



WARNING - Risk Of Electric Shock

Extreme care must be taken when applying power to the electron beam gun or other high voltage equipment. Be certain you do not provide power when inappropriate. Death or personal injury may result.



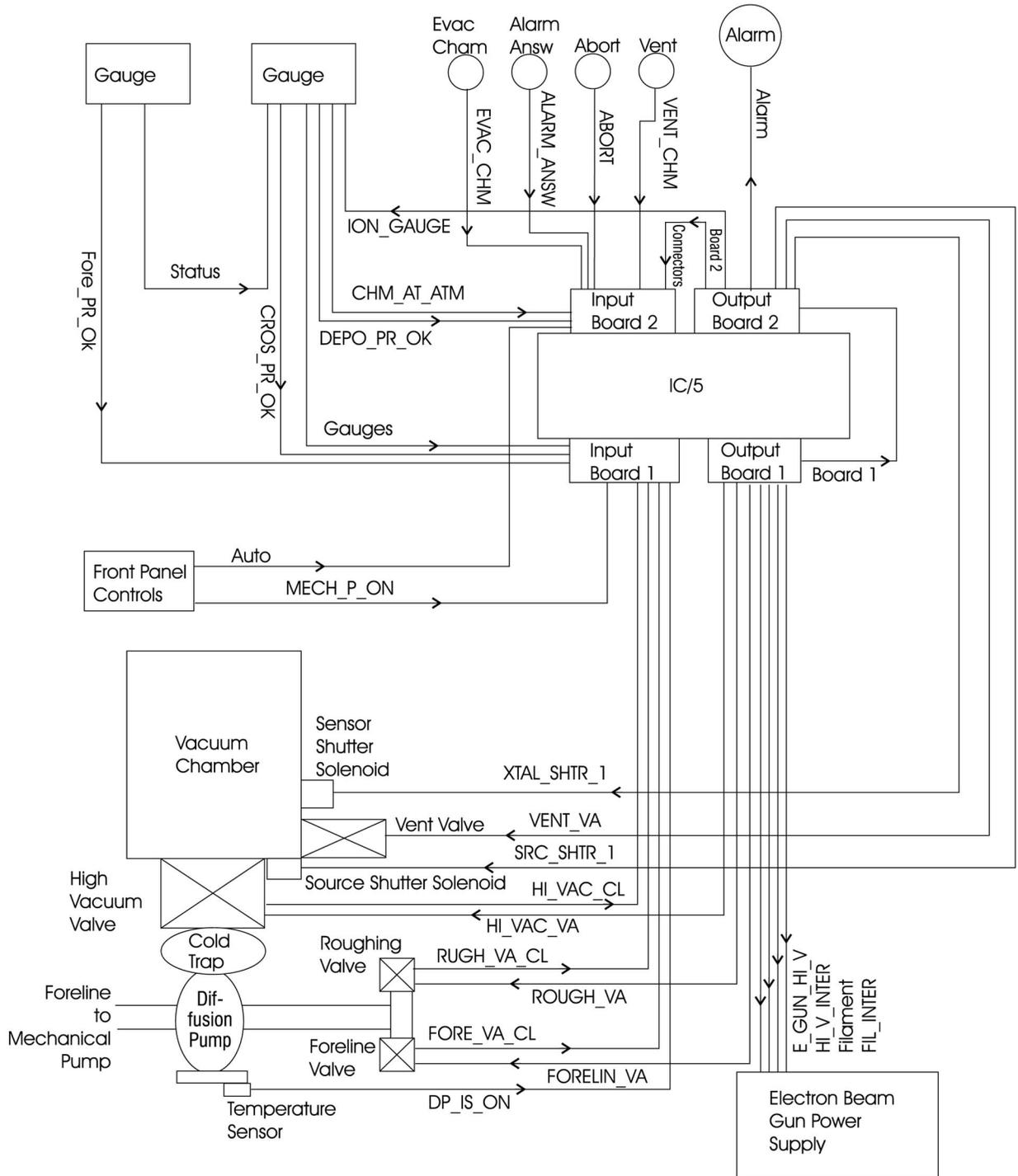
WARNING

It is strongly recommended that you verify operation of the system controller functions, including all valving and I/O logic statements prior to applying power to the vacuum system.

A block diagram of the example system configuration is shown in [Figure 10-2](#). In this figure, inputs to and outputs from the IC/5 are labeled with the mnemonics shown on the I/O Map Display for Board 1 and Board 2 in [section 10.3.2 on page 10-10](#). Arrows pointing to the IC/5 indicate inputs to the IC/5. Arrows pointing away from the IC/5 indicate output relay connections to the various system equipment.

NOTE: This example of the IC/5 automatically controlling the Pump Down, Deposition, and Vent cycle does not contain automatic filling/refilling of the Liquid Nitrogen cold trap. This example is for a single sensor, single source deposition.

Figure 10-2 Example System Configuration



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10.3.1 System Equipment List

10.3.1.1 Valves

- Foreline** An electro-pneumatically controlled valve which also contains a position indicator switch. This switch is closed when the valve is closed.

- Roughing** An electro-pneumatically controlled valve which also contains a position indicator switch. This switch is closed when the valve is closed.

- High Vacuum** An electro-pneumatically controlled valve which also contains a position indicator switch. This switch is closed when the valve is closed.

- Vent Valve** An electro-pneumatically controlled valve.

10.3.1.2 Switches

Auto/Manual

A key switch that switches power from the manually operated system control switches to the Automatic position. In the Automatic position power is applied to one side of the Relays used to control the Foreline, Roughing, Vent, and High Vacuum valves.

Abort

A momentary contact switch which is Normally Open. This provides contact closure for the Abort input.

Alarm Answered

A momentary contact switch which is Normally Open. This provides contact closure for the Alarm Answered input.

Evacuate Chamber

A momentary contact switch which is Normally Open. This provides contact closure for the Evacuate Chamber input.

Vent Chamber

A momentary contact switch which is Normally Open. This provides contact closure for the Vent Chamber input.

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10.3.1.3 Solenoid Valves

Source Shutter

An electro-pneumatically operated valve which controls the source shutter.

Sensor Shutter

An electro-pneumatically operated valve which controls the sensor shutter.

10.3.1.4 Electron Beam Gun Power Supply

This provides power to the electron beam gun with the ability to remotely enable the filament voltage and 10 KV electron beam acceleration voltage. The supply used in this example has 4 inputs to remotely control these voltages. These inputs are Filament On, Filament Off, Remote High Voltage On, Remote High Voltage Off. In this example, each input is wired in series with an IC/5 relay. In this example these four relays are numbered 5, 6, 7, and 8 and are named E-GUN-HI-V, HI-V-INTER, FILAMENT, and FIL-INTER.

10.3.1.5 Vacuum Gauges and Controllers

Two vacuum gauge controllers are used. These 2 gauges provide 3 pressure sensors, 2 of which are Pirani gauges and the third is an ION gauge. One of the Pirani gauges is used to sense the foreline pressure, the second is used to sense the chamber pressure and the Ion Gauge is used to sense the chamber pressure when under high vacuum. The Ion Gauge controller has a remote emission on input which is wired in series to the ION-GAUGE relay in the IC/5.

The Gauge controllers have 4 relays programmed to monitor the vacuum system pressure and are wired to be Normally Open. One of these relays is programmed to close when the Crossover pressure is reached and provides the contact closure for the CROS - PR - OK input. A second relay is programmed to close when the foreline pressure is below a specified set point and provides the contact closure for the FORE - PR - OK input. The third relay is programmed to close when the chamber is at atmospheric pressure and provides the contact closure for the CHM-AT-ATM input. The fourth relay is programmed to close when the Ion Gauge reaches the desired deposition pressure and provides contact closure for the DEPO-PR-OK input.

The Gauge controllers also have status relays to indicate whether the gauge is operating normally. These status relays are wired to be Normally Closed. The status relay of the first gauge controller is wired in series to the status relay of the second gauge controller which in turn is wired in series to the GAUGES input on the IC/5.

10.3.1.6 Temperature Sensor

This sensor provides a contact closure if the sensor's temperature exceeds a specific value. The Temperature Sensor is mounted to the bottom of the diffusion pump and is used to indicate when the diffusion pump has reached operating temperature. This contact closure provides the DP-IS-ON input.

10.3.1.7 Lamps

A lamp is used for the Alarm indication. Power to this lamp is applied with closure of the ALARM relay. This maybe an audible alarm if desired.

10.3.2 I/O Set-Up

The IC/5 logic statements in this example make use of various inputs from gauges, valves, vacuum system panel controls and a series of switches to control the operation of valves, shutters, power to the electron beam gun and an alarm. The system configuration is such that automatic operation of the pump down and deposition process cycle is controlled with the series of momentary switches labeled EVAC Cham, ALARM ANSW, ABORT, and VENT. (See [Figure 10-2](#)) The STOP, START, and RESET switches on the IC/5 front panel are not used unless an interruption of the deposition process only is desired. The ABORT switch is used if an interruption of the pump down cycle and an interruption of the deposition process is desired. Whenever the control system requires operator attention the ALARM relay is set. Whenever the ALARM relay is set, the ALARM ANSW button must be pressed to indicate the situation has been resolved, otherwise further automatic processing is not allowed.

The ALARM relay is set whenever any one of four conditions occurs. These are:

- ◆ When all the conditions required for the system to operate under automatic control are realized.
- ◆ Whenever there is an Abort input received.
- ◆ Whenever the IC/5 is in the STOP state.
- ◆ When the pump down, deposition process cycle has completed and the vacuum system is at atmospheric pressure.

Once the Alarm relay is set, further automatic processing cannot proceed unless the Alarm Answered input is activated.



WARNING - Risk Of Electric Shock

This example of automated vacuum system and deposition control uses an electron beam gun. The power to this electron beam gun is remotely activated in these example logic statements. Extreme care must be used whenever working with the high voltage present when using an electron beam gun. Be certain you understand completely how to operate the IC/5 and how the logic functions work before automating your vacuum system.

NOTE: In this example there are a number of conditions which must be satisfied in order for the electron beam gun high voltage and filament voltage to be turned on. One of these conditions is that the IC/5 must be in the READY state. When an Abort input is activated the electron beam gun high voltage and filament voltage are turned off. Therefore, if an Abort input is activated after the deposition is started the electron beam gun high voltage and filament voltage will not be turned on automatically unless the deposition process is restarted from the READY state.

Since the logic statements are evaluated once every 100 milliseconds, timers are used in some cases to “latch” a condition or series of conditions. This is done by making a Statement conditional on the expiration state of a particular timer. Consideration must be given as to when this timer should be canceled. Other timers in this example are used as delays between the occurrence of an event and the execution of an action.



WARNING

When switching from the manually operated to the automatically operated states, be careful of the status of the high vacuum, roughing, foreline, and vent valves.

For this example, the foreline valve should be open and all other valves closed when switching between manual and automatic control.

Figure 10-3 User Messages

USER MESSAGES		EDIT MESSAGE
1. START_PUMP_CYCLE	6. VENTING_CHAMBER	SAVE MESSAGE
2. UNDER_HIGH_VACUUM	7.	CANCEL MESSAGE CHANGE
3. PROCESS_STARTED	8.	CLEAR MESSAGE
4. COOL_DOWN_CYCLE	9.	
5. CHAMBER_VENTED	10.	
0.0 A/SEC -0.000 KA 0.0%		I/O

These User Messages alert the operator to the status of the Process Cycle. Logic Statements can be written to display these messages in the lower right hand message area on the IC/5 CRT.

Figure 10-4 I/O Map Board 1

I/O MAP BOARD 1		EDIT NAME
RELAY OUTPUT	TTL INPUT	SAVE NAME
1. NAME BOARD_1	1. NAME DP_IS_ON	CANCEL NAME CHANGE
2. FORELIN_VA	2. MECH_P_ON	CLEAR NAME
3. HI_VAC_VA	3. FORE_PR_OK	
4. ROUGH_VA	4. FORE_VA_CL	TOGGLE TYPE
5. E_GUN_HI_V	5. RUGH_VA_CL	
6. HI_V_INTER	6. HI_VAC_CL	
7. FILAMENT	7. CRDS_PR_OK	
8. FIL_INTER	8. GAUGES	
	9.	
	10.	
	11.	
	12.	
	13.	
	14.	
0.0 A/SEC 0.641 KA 0.0%		I/O MAP DIRECTORY

This display is used to assign alphanumeric names to the various Outputs and Inputs connected to I/O Board 1. This is to help the design and understanding of the Logic Statements. For this example the TTL Inputs monitored are:

- 1 A temperature sensor mounted onto the bottom of the diffusion pump to indicate when the pump is at operating temperature.
- 2 An input connected to one side of the Double Pole Double Throw switch used to turn on the mechanical pump. One half of this switch carries power to the Mechanical Pump. The second half of the switch does not carry power but provides a contact closure to indicate the switch is in the ON position.
- 3 This input monitors the Foreline Pressure relay from the Gauge.
- 4 This input monitors whether the Foreline Valve is closed.

- 5 This input monitors whether the Roughing Valve is closed.
- 6 This input monitors whether the High Vacuum Valve is closed.
- 7 An input to monitor the Cross Over Pressure relay from the Gauge.
- 8 An input to monitor the Gauges' Status relays. This indicates if the gauges are operating properly.

10.3.2.1 Outputs Connected to I/O Board 1

- 1 The Board 1 Relay is wired in series with the Board 2 Relay. These relays are programmed to be Normally Closed; all other relays are programmed to be Normally Open. Both of these relays are in turn wired in series with the Connectors input on Board 2. This combination of relays and an input monitor the hardware connections to the I/O boards. This ensures the connectors are attached to the IC/5 in order for the logic processing to proceed.
- 2 The Foreline Valve relay controls opening and closing of the Foreline Valve.
- 3 The High Vacuum Valve relay controls opening and closing of the High Vacuum Valve.
- 4 The Roughing Valve relay controls opening and closing of the Roughing Valve.
- 5 The Electron Beam Gun High Voltage relay is one of two relays required to remotely turn the electron beam gun high voltage on.
- 6 The Electron Beam Gun High Voltage Interlock relay is the second of two relays required to remotely turn the electron beam gun high voltage on.
- 7 The Electron Beam Gun Filament relay is one of two relays required to remotely turn on the electron beam gun filament voltage.
- 8 The Electron Beam Gun Filament Interlock relay is the second of two relays required to remotely turn the electron beam gun filament voltage on.

Figure 10-5 I/O Map Board 2

I/O MAP BOARD 2			EDIT NAME
RELAY OUTPUT		TTL INPUT	SAVE NAME
NAME	TYPE	NAME	
9. BOARD_2	NC	15. DEPO_PR_OK	CANCEL NAME CHANGE
10. ALARM	NO	16. EVAC_CHM	
11. ION_GAUGE	NO	17. VENT_CHM	CLEAR NAME
12. VENT_VA	NO	18. AUTO	
13.	NO	19. CHM_AT_ATM	TOGGLE TYPE
14. SRC SHTR 1	NO	20. ALARM_ANSW	
15.	NO	21. CONNECTORS	I/O MAP DIRECTORY
16.	NO	22. ABORT	
		23.	
		24.	
		25.	
		26.	
		27.	
		28.	

0. 0 A/SEC 0. 641 KA 0. 0 %

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This display is used to assign alphanumeric names to the various Outputs and Inputs connected to I/O Board 2. This is to help the design and understanding of the Logic Statements. For this example the TTL Inputs monitored are:

- 1** This input monitors the Deposition Pressure relay from the gauge.
- 2** The Evacuate Chamber input initiates the automatic process cycle. The logic statements are designed so that the Alarm Answered input (if the Alarm is ON) must be triggered prior to the Evacuate Chamber input in order for automatic pump down to begin.
- 3** The Vent Chamber input is used to manually vent the vacuum chamber.
- 4** The Auto input indicates to the IC/5 that the Vacuum system is ready to be controlled automatically by the IC/5.
- 5** This input monitors the atmospheric pressure relay from the gauge.
- 6** The Alarm Answered input indicates to the IC/5 that the Operator or Process Engineer has responded to the Alarm.
- 7** The Connectors input is wired in series to the Board 1 and Board 2 relays to indicate the output connectors for I/O Boards 1 and 2 are properly connected. See also the explanation for relay number 1 under I/O Board 1.
- 8** This input is used to abort automatic processing.

10.3.2.2 Outputs Connected to I/O Board 2

- 1** The Board 2 relay is wired in series with the Board 1 relay and the Connectors input to indicate the I/O Board connectors for boards 1 and 2 are properly connected. See also the explanation for relay number 1 under I/O Board 1.
- 2** The Alarm relay is used to indicate the vacuum system requires attention by the Operator or Process Engineer. This relay is wired to apply power to a visual (or audible) alarm when closed.
- 3** The Ion Gauge relay is wired in series with the remote emission input on the Ion Gauge. It is used to turn the Ion Gauge On and Off.
- 4** The Vent Valve relay turns the vent valve on and off.
- 5** The Crystal Shutter 1 relay controls the crystal shutter for sensor 1. This relay is programmed in the Source/Sensors series of IC/5 displays.
- 6** The Source Shutter 1 relay controls the opening and closing of the shutter for source 1. This relay is programmed in the Source/Sensors series of IC/5 displays.

10.3.2.3 Logic Statement Directory

The Logic Statements are broken down into 3 sections. The first section, comprised of statements 1 through 23, deals primarily with the pump down sequence during automatic processing (i.e. when the key switch is in the Auto position). These Statements also contain some fail safe conditions to stop the automatic process if something goes wrong and to prevent, for example, the Foreline Valve and Roughing Valve from being open at the same time.

The second section is comprised of statements 24 through 29. These statements place the User-Defined Messages onto the IC/5 display at appropriate times during the pump down cycle. The third section, statements 30 through 43, controls the actual deposition process. This involves turning the electron beam gun high voltage on and off, monitoring the chamber pressure to determine when to begin the deposition and issuing START commands to begin the process and step through the layer sequence. This section also contains statements for venting the chamber at the end of the deposition process, after the cool down period has expired. Messages indicating the status of the deposition process are also managed in this section.

NOTE: Statements 1 Through 23 Control the Automatic Pump Down Cycle.

Figure 10-6 Statement 1

```

1 IF CONNECTORS and MECH_P_ON and
    AUTO and GAUGES
    THEN TMR-SECS 1 1.0 and ALARM ON
    
```

Statement 1 is designed to identify to the IC/5 that the vacuum system is ready for automatic process control. This is indicated by setting Timer 1. Other Logic Statements will evaluate true only if Timer 1 has expired. Statement 2 which is the antithesis of Statement 1, cancels Timer 1 to prevent automatic processing. The Alarm Relay is also turned ON to indicate to the Operator or Process Engineer that the vacuum system requires attention. This relay may be connected to an Audio or Visual Alarm. The Connectors, Mechanical Pump On, Auto, and Gauges inputs must be activated in order for Timer 1 to be started and for the Alarm Relay to be closed.

Figure 10-7 Statement 2

```

2 IF CONNECTORS or MECH_P_ON or
    AUTO or GAUGES
    *** THEN FORELIN_VA OFF and ROUGH_VA OFF and
    
```

Statement 2 is designed to detect whether the system is not ready for automatic process control or whether something goes wrong during the process. The action taken is to stop the pump down or venting process by closing the foreline, roughing and vent valves and canceling Timer 1.

Figure 10-8 Statement 3

```

3  IF  TIMR EXPIRED  1  and  RUGH_VA_CL  and
    TIMER ACTIVE  4
    THEN FORELIN_VA ON
    
```

Statement 3 monitors if Timer 1 is expired and if the Roughing Valve is closed. Timer 4 is used as a delay between closing of the roughing valve and opening of the foreline valve. (Timer 4 is set in Statement 20) This delay is used to prevent a burst of pressure through the foreline. Statements 1, 2, and 3 are used to identify the status of the vacuum system. Many of the remaining Logic Statements are dependent on one of these three Statements.

Figure 10-9 Statement 4

```

4  IF  FORE_VA_CL  and TIMR EXPIRED  1
    THEN HI_VAC_VA OFF
    
```

This statement is used to ensure the High Vacuum Valve is closed whenever the Foreline valve is closed. (When the system is set for automatic process control, i.e. Timer 1 expired). It is detrimental to the vacuum system to have the high vacuum valve open when the foreline valve is closed.

Figure 10-10 Statement 5

```

5  IF  FORE_VA_CL  and TIMR EXPIRED  1
    THEN ROUGH_VA OFF
    
```

Statement 5 ensures the roughing valve is closed whenever the foreline valve is open (when the system is set for automatic process control, i.e., Timer 1 expired). It is detrimental to the vacuum system to have the roughing valve open when the foreline valve is open.

Figure 10-11 Statement 6

```

6  IF  DP_IS_ON  or  VENT_CHM  or
    STATEMENT  2
    ***THEN HI_VAC_VA OFF  and  ION_GAUGE OFF  and
    CANCEL TIMER  5 and  CANCEL TIMER  6 and  CANCEL TIMER  7
    
```

Statement 6 prevents the process from proceeding if the Diffusion pump is not at operating temperature or if Statement 2 is true. It will also prevent the Diffusion pump from being dumped to atmosphere if the Vent Chamber input is activated while the High Vacuum Valve is open. This Statement, in conjunction with Statement 17, ensures the high vacuum valve is closed prior to opening the vent valve.

Timers 5, and 6 are used as delays between opening the Foreline Valve and opening the High Vacuum Valve. Timer 7 is the delay between opening the High Vacuum Valve and turning on the Ion Gauge. By canceling timers 5, 6, and 7 automatic processing cannot proceed as Statements 12 and 13, which open the high vacuum valve and turn on the Ion Gauge, are dependent on these timers.

Figure 10-12 Statement 7

```

7 IF EVAC_CHM and STATEMENT 3 and
   CROS_PR_OK and DP_IS_ON and TIMR EXPIRED 8
   THEN FORELIN_VA OFF and HI_VAC_VA OFF and
   TMR-SECS 2 1.0 and TMR-SECS 3 1.0 and CANCEL TIMER 8
    
```

This statement monitors the Evacuate Chamber input and the status of Timer 8. Timer 8 is set in Statement 23 to indicate the Alarm Answered input has been activated (i.e., the alarm has been answered). Therefore, automatic processing cannot proceed unless the Evacuate Chamber and the Alarm Answered inputs are initiated and the conditions of Statement 3 are satisfied. Statements 7 and 8 are very similar however they differ by monitoring the status of the Crossover pressure input. If the Crossover pressure has not been achieved, the foreline and high vacuum valves are closed and timers 2 and 3 are set. These timers are used in Statements 9 and 10 to delay the opening and closing of the roughing valve. This is done to prevent a pressure burst through the diffusion pump and foreline. Timer 8 is immediately canceled so that Statement 7 is always dependent on the Alarm Answered input being initiated.

Figure 10-13 Statement 8

```

8 IF EVAC_CHM and STATEMENT 3 and
   CROS_PR_OK and DP_IS_ON and TIMR EXPIRED 8
   THEN TMR-SECS 5 20.0 and CANCEL TIMER 8
    
```

Statement 8 differs from Statement 7 in the status of the Crossover pressure input. If the chamber Crossover pressure is reached, timer 5 is set for 20 seconds. The vacuum system at this point has the Roughing, High Vacuum, and Vent Valves closed and the Foreline Valve open. Timer 5 is used as a delay prior to opening the High Vacuum Valve.

Figure 10-14 Statement 9

```

9 IF TIMR EXPIRED 2 and FORE_VA_CL
   THEN ROUGH_VA ON and CANCEL TIMER 2
    
```

By its dependency on Timer 2, Statement 9 is tied to Statement 7. If the chamber is not at the Crossover pressure the roughing valve will be open to pump down to the Crossover pressure. The dependency on the Foreline Valve closed input is to insure the foreline valve is closed prior to opening the Roughing valve. Timer 2 is immediately canceled so that Statement 9 is evaluated true only once each time Statement 7 is true.

Figure 10-15 Statement 10

```

10 IF TIMR EXPIRED 3 and CROS_PR_OK
   THEN ROUGH_VA OFF and TMR-SECS 9 5.0
    
```

Statement 10 is also tied to Statement 7 by its dependency on Timer 3. This is done to ensure that Statement 10 cannot be true unless Statement 7 is true. Since the status of the Crossover pressure in Statement 10 is the same as in Statement 8 this is needed to differentiate between the two conditions (i.e. how we arrive at the cross overpressure, via Statement 7 or Statement 8). Timer 9 is used as a delay between closing the roughing valve and opening the foreline valve in Statement 11.

Figure 10-16 Statement 11

```

11 IF STATEMENT 10 and RUGH_VA_CL and
    TIMR EXPIRED 9
    THEN FORELIN_VA ON and TMR-SECS 6 20.0 and
    CANCEL TIMER 3 and CANCEL TIMER 9
    
```

A branch in the logic processing occurs at Statements 7 and 8. Which progression the logic processing takes is dependent on the condition of the Crossover pressure. If the chamber pressure is at or below the Crossover pressure the logic progression will go from Statement 6 to Statement 8 to Statement 12. If the chamber pressure is above the cross over pressure the logic progression will go from Statement 6 to Statement 7 to Statements 9 though 11. Statement 11 completes the branch, opening the foreline valve and setting a 20 second timer which acts as a delay prior to opening the high vacuum valve. Timers 5 and 6 serve the same purpose. Which timer is set is dependent on the logic branch taken. Timers 3 and 9 are canceled so that Statement 11 can be true only once each time Statements 7 and 10 are true.

Figure 10-17 Statement 12

```

12 IF TIMR EXPIRED 5 or TIMR EXPIRED 6
    THEN HI_VAC_VA ON and TMR-SECS 7 20.0 and
    CANCEL TIMER 5 and CANCEL TIMER 6
    
```

Statement 12 monitors the delay timers 5 or 6 and opens the High Vacuum Valve when the delay time is expired. Timer 7 is set in order to delay turning on the Ion Gauge after opening the High Vacuum Valve. Timers 5 and 6 are immediately canceled so that Statement 12 can be true only once during each process cycle.

Figure 10-18 Statement 13

```

13 IF TIMR EXPIRED 7
    THEN ION_GAUGE ON
    
```

Statement 13 turns on the Ion Gauge when the 20 second time delay defined by Timer 7 expires.

Figure 10-19 Statements 14 and 15

```

14 IF   DEPO_PR_OK      and   HI_VAC_CL      and
      STATEMENT 3 and TIMR EXPIRED 7
      THEN ION_GAUGE OFF      and   TMR-SECS 15 1.0

15 IF TIMR EXPIRED 15
      THEN ION_GAUGE ON      and   CANCEL TIMER 15
    
```

Statements 14 and 15 are designed to keep the Ion Gauge emission turned on in the event an electron beam gun arc or other electrical noise turns off the Ion Gauge emission.

Figure 10-20 Statement 16

```

16 IF   HI_VAC_CL
      THEN ION_GAUGE OFF      and   CANCEL TIMER 7
    
```

Statement 16 ensures the Ion Gauge emission is turned off whenever the High Vacuum Valve is closed. Timer 7 is canceled to ensure that Statement 13 (i.e. turning on the Ion Gauge) can not be evaluated true after Statement 16 is evaluated true.

Figure 10-21 Statement 17

```

17 IF   VENT_CHM
      STATEMENT 3 and   HI_VAC_CL      and
      THEN VENT_VA ON
    
```

This Statement activates the Vent Valve Relay only if the High Vacuum Valve is closed. The intention is to prevent an accidental venting of the Vacuum Chamber while under high vacuum. If the high vacuum valve is open, Statement 6 will close the valve and Statement 17 will not be evaluated true. Therefore, if the high vacuum valve is open it will take 2 Vent Chamber inputs to activate the vent valve. The dependence on Statement 3 prevents the Vent Chamber input from being evaluated unless the system is ready for automatic process control.

Figure 10-22 Statement 18

```

18 IF   CHM_AT_ATM
      THEN VENT_VA OFF
    
```

Statement 18 monitors the Chamber at Atmosphere input from the Gauge and turns off the Vent Valve when the chamber reaches atmospheric pressure.

Figure 10-23 Statement 19

```

19 IF   ABORT      and   TIMR EXPIRED 1
      THEN HI_VAC_VA OFF      and   ROUGH_VA OFF      and
      VENT_VA OFF      and   ALARM ON      and   CANCEL TIMER 2
    
```

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Statement 19 allows intervention to Abort automatic process control if desired. By its dependence on Timer 1, the Abort input will be acted on only if the system is in the automatic process control state. When evaluated true, Statement 19 places the vacuum system into a specific condition. The High Vacuum Valve, Roughing Valve, and Vent Valve relays will all be closed (the foreline valve will remain open if it is in the open state at the time of the Abort input). Timer 2 is canceled to prevent Statement 9, which turns on the Roughing Valve, from being evaluated true after an Abort input. The Alarm relay is activated to alert the operator that the system requires attention.

Figure 10-24 Statement 20

20	IF	ABORT	and	TIMR EXPIRED	1
	THEN	TMR-SECS	4	2.5 and	CANCEL TIMER 13

Statement 19 does not modify the condition of the Foreline Valve. Statements 3, 20, and 21 are used to open the Foreline Valve if the Foreline Valve was closed at the time of the Abort input. The action taken is to set timer 4 and cancel timer 13. Timer 4 is the delay timer to prevent the Foreline Valve from opening too soon after closing the Roughing valve. Timer 4 is canceled in Statement 21 which then allows Statement 3 to be evaluated true and the Foreline Valve relay activated. Timer 13 is used in Statements 31, 32, 33, and 34 to indicate the four relays associated with the electron beam gun high voltage are activated. Timer 13 is canceled here to prevent further processing of the deposition cycle after receiving an Abort input.

Figure 10-25 Statement 21

21	IF	RUGH_VA_CL	and	TIMR EXPIRED	4
	THEN	CANCEL TIMER	4		

Statement 21 works in conjunction with Statements 3 and 20. Timer 4, which is the delay timer between closing the Roughing valve and opening the Foreline valve, is no longer needed once the Roughing valve is closed.

Figure 10-26 Statement 22

22	IF	ABORT	and	TIMR EXPIRED	1
	THEN	CANCEL TIMER	3 and	CANCEL TIMER	5 and
		CANCEL TIMER	6 and	CANCEL TIMER	7 and
				CANCEL TIMER	9

Statement 22 cancels timers 3, 5, 6, 7, and 9 to prevent further processing of the pump down cycle after receiving an Abort input. Timer 3 is monitored in Statement 10 and Timers 5 and 6 are used in Statement 12 to delay the opening of the High Vacuum Valve after opening the Foreline Valve. Timer 7 is used in Statement 13 to delay turning on the Ion Gauge emission after opening the High Vacuum Valve and Timer 9 is used as a delay between Statements 10 and 11 to prevent the Foreline Valve from opening too soon after closing the Roughing Valve.

Figure 10-27 Statement 23

```

23 IF ALARM_ANSW
    THEN TMR-SECS 8 0.1 and ALARM OFF and
    CANCEL TIMER 14
    
```

This Statement monitors the Alarm Answered input. Once the Abort input is activated, the Alarm Answered and Evacuate Chamber inputs must both be triggered in order for automatic processing of the pump down cycle and deposition process to continue. This is done by setting Timer 8 and having Statements 7 and 8 dependent on Timer 8. The Deposition process may be interrupted without disturbing the pump down cycle by pressing the STOP key on the IC/5 front panel. Statement 35 sets Timer 14 to indicate a STOP command has been initiated from the IC/5 front panel. Timer 14 is also used to prevent Statements 30 and 31, which turn on the electron beam gun high voltage and filament voltage, from being evaluated true after the STOP command.

NOTE: Statements 24 through 29 are used to turn the user messages on and off at various stages of the pump down cycle.

Figure 10-28 Statement 24

```

24 IF ( STATEMENT 7 or STATEMENT 8 ) and
    TIMR EXPIRED 14 and TIMR EXPIRED 1
    THEN MESSAGE OFF 5 and MESSAGE ON 1
    
```

This statement turns on the START PUMP CYCLE message and turns off the CHAMBER -VENTED message. The dependence on Timer 14 is so that the message is not displayed a second time if a STOP/START sequence is given through the IC/5. The dependence on Timer 1 ensures the message is displayed only when the system is set for automatic process control.

Figure 10-29 Statement 25

```

25 IF STATEMENT 12 and TIMR EXPIRED 14
    THEN MESSAGE OFF 1 and MESSAGE ON 2
    
```

Statement 12 opens the High Vacuum Valve. The START PUMP CYCLE message is turned off and the UNDER HIGH VACUUM message is turned on.

Figure 10-30 Statement 26

```

26 IF HI_VAC_CL
    THEN MESSAGE OFF 2
    
```

This Statement cancels the UNDER HIGH VACUUM message whenever the high vacuum valve is closed.

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Figure 10-31 Statement 27

```

27 IF      STATEMENT 36
      THEN MESSAGE ON      6
    
```

Statement 36 monitors the same conditions as Statement 17. Whereas Statement 17 opens the Vent valve, Statement 36 cancels all previous messages, places the IC/5 into the STOP state and Statement 27 puts up the VENTING- CHAMBER message.

Figure 10-32 Statement 28

```

28 IF      CHM_AT_ATM      and      GAUGES      and
      TIMR EXPIRED 1
      THEN MESSAGE OFF      6 and MESSAGE ON      5
    
```

Statement 28 monitors the Chamber at Atmosphere input. It also monitors the Gauges input to ensure the Gauges are functioning properly before canceling the “VENTING- CHAMBER” message and displaying the “CHAMBER- VENTED” message.

Figure 10-33 Statement 29

```

29 IF      STATEMENT 19 or STATEMENT 2
      *** THEN MESSAGE OFF      1 and MESSAGE OFF      2 and
      MESSAGE OFF      5 and MESSAGE OFF      6
    
```

Statement 29 cancels the “START PUMP-CYCLE”, “UNDER-HIGH- VACUUM”, “CHAMBER VENTED”, and “VENTING- CHAMBER” messages when either the pump down cycle and deposition process is aborted, Statement 19, or the system is not ready for the automatic process cycle, Statement 2.

NOTE: Statements 30 Through 43 Control the Deposition Process and Post Deposition Process Venting.

Figure 10-34 Statement 30

```

30 IF      DEPO_PR_OK      and      HI_VAC_CC      and
      READY      and TIMR EXPIRED 14 and TIMR EXPIRED 1
      THEN FIL_INTER ON      and FILAMENT ON      and
      TMR-SECS 10 3.0
    
```

Statement 30 monitors the Deposition Pressure OK input, makes sure that the IC/5 is in the READY state, the high vacuum valve is open and the instrument is ready for automatic process control. Once these conditions are met, the electron beam gun filament is turned on by activating the Filament Interlock On and Filament On relays. This statement can be true only if these conditions are met and Timer 14 has not expired. The dependence on Timer 14 is so a STOP/ RESET command sequence on the IC/5 can be allowed without Statements 30, 31, and 32 being evaluated true causing an unwanted START command. Timer 10 is set to allow a

delay between turning the electron beam gun filament voltage on and turning the electron beam gun high voltage on. This delay allows the filament to warm up prior to applying high voltage.

Figure 10-35 Statement 31

```
31 IF STATEMENT 30 and TIMR EXPIRED 10
    THEN HI_V_INTER ON and E_GUN_HI_V ON and
    TMR-SECS 13 0.1 and CANCEL TIMER 10
```

Statement 31 turns on the electron beam gun high voltage by activating the high voltage interlock and electron beam gun high voltage relays after a 3 second delay. Timer 13 is used in Statement 32 to indicate that Statement 31 has occurred. Timer 10 is canceled so that this statement can be true only once.

Figure 10-36 Statement 32

```
32 IF ( LAYER END ALL and PROCESS END ALL and
    TIMR EXPIRED 13 ) or STATEMENT 31 and TIMR EXPIRED 14
    THEN START
```

Statement 32 gives the IC/5 a START command to begin the Deposition process. This statement will give the IC/5 another START command at the end of every Layer to automatically sequence through every Layer in the Process. The “Not Process End All” condition prevents an unwanted START command at the end of the process. After the first START command, the IC/5 will no longer be in the READY state and therefore Statements 30 and 31 can not be evaluated true a second time. The portion of the condition statement that says, “Statement 31 and Not Timer Expired 14” gives the first START command to the IC/5 (making sure it was not in the READY state from a STOP/RESET sequence). The “Layer End All and Not Process End All and Timer Expired 13” portion of the condition statement gives subsequent START commands to the IC/5 as desired. Timer 13 is used to effectively indicate that the “Statement 31 and Not Timer Expired 14” condition has already been met and the first START command already given.

Figure 10-37 Statement 33

```
33 IF PROCESS END ALL and TIMR EXPIRED 13
    THEN TMR-HH:MM 11 0:20 and MESSAGE OFF 3 and
    MESSAGE ON 4
```

Statement 33 monitors for the End of Process condition. Again the dependence on Timer 13 indicates that the End of Process condition occurred after the Process was Started during this automatic pump down/deposition cycle and was not from an earlier Process completion. Once the End of Process condition occurs the cool down timer (Timer 11) is started. The PROCESS STARTED message is canceled and the COOL-DOWN CYCLE message is displayed.

Figure 10-38 Statement 34

```

34 IF PROCESS END ALL and TIMR EXPIRED 13
    THEN E_GUN_HI_V OFF and HI_V_INTER OFF and
        FILAMENT OFF and FIL_INTER OFF and CANCEL TIMER 13
    
```

Statement 34 monitors for the same conditions as Statement 35 and turns off the 4 Relays associated with the electron beam gun filament voltage and electron beam gun high voltage. Timer 13 is canceled at this point to signify the end of the deposition process.

Figure 10-39 Statement 35

```

35 IF STOP and TIMR EXPIRED 1
    THEN ALARM ON and CANCEL TIMER 7 and
        TMR-SECS 14 0.1
    
```

Timer 14 is set in Statement 35 to indicate a STOP command has been initiated from the IC/5 front panel. The intention in using Timer 14 is to preserve the STOP/START feature of the IC/5. In this manner the STOP button on the IC15 can be used to “pause” the deposition cycle leaving the vacuum system under high vacuum. The deposition process may be restarted at the point of interruption by pressing START or may be restarted by pressing RESET then START in the normal manner. (Timer 14 is used to indicate that a STOP has occurred after the process was STARTed and before the process was completed).

Figure 10-40 Statement 36

```

36 IF VENT_CHM and HI_VAC_CL and
    STATEMENT 3
    THEN MESSAGE OFF 1 and MESSAGE OFF 2 and
        MESSAGE OFF 3 and MESSAGE OFF 4 and STOP
    
```

This statement monitors the same condition as Statement 17 in the event that the Vent Chamber input is activated while the deposition process is underway. The “START PUMP CYCLE”, “UNDER HIGH VACUUM”, “PROCESS STARTED”, and “COOL-DOWN CYCLE” messages are canceled and the IC/5 is placed in the STOP state to prevent further process execution and ensure all source DAC outputs are set to zero.

Figure 10-41 Statement 37

```

37 IF ABORT or AUTO
    *** THEN CANCEL TIMER 10 and CANCEL TIMER 11 and
        CANCEL TIMER 12 and MESSAGE OFF 3 and MESSAGE OFF 4
    
```

This statement monitors the Abort and Auto inputs. If the Abort input is activated or the Auto input is not activated this statement takes down the messages associated with the deposition process and cancels timers 10, 11, and 12. Where Timer 10 is the delay between turning on the electron beam gun filament voltage and turning on the electron beam gun high voltage. Timer 11 is the cool down period, and Timer 12 is the delay between closing the High Vacuum Valve and opening the Vent

valve. Canceling these timers ensures those statements dependent on these timers will not evaluate true if the Abort input were to take place after the timers were started but prior to their expiring.

Figure 10-42 Statement 38

```

38 IF      HI_VAC_CL
      THEN HI_V_INTER OFF      and FIL_INTER OFF      and
      E_GUN_HI_V OFF      and FILAMENT OFF
    
```

Statement 38 ensures that the electron beam gun filament voltage and electron beam gun high voltage relays are deactivated whenever the High Vacuum Valve is closed.

Figure 10-43 Statement 39

```

39 IF TIMR EXPIRED 11
      THEN HI_VAC_VA OFF      and MESSAGE OFF      4 and
      MESSAGE ON      6 and TMR-SECS 12 5.0 and CANCEL TIMER 11
    
```

Statement 39 is dependent on the cool down timer, Timer 11. When the cool down period expires the High Vacuum valve is closed, the “COOL - DOWN CYCLE” message is removed from the display and replaced with the “VENTING CHAMBER. message. Also a 5-second delay timer is set and the cool down timer is canceled.

Figure 10-44 Statement 40

```

40 IF TIMR EXPIRED 12
      THEN VENT_VA ON      and CANCEL TIMER 12
    
```

After the high vacuum valve is closed and a 5-second delay timer expires the Vent valve is turned on.

Figure 10-45 Statement 41

```

41 IF CHM_AT_ATM      and TIMR EXPIRED 1
      THEN VENT_VA OFF      and ALARM ON
    
```

If the chamber is at atmospheric pressure and the system is set for automatic process control, the Vent valve is turned off and the Alarm relay is activated. The Alarm relay is activated to indicate to the operator that the vacuum system requires attention.

Figure 10-46 Statement 42

```

42 IF STATEMENT 30
      THEN MESSAGE OFF      2 and MESSAGE ON      3
    
```

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Statement 30 monitors the Deposition Pressure OK input, makes sure that the IC/5 is in the READY state, the high vacuum valve is open and the instrument is ready for automatic process control. Once these conditions are met, the electron beam gun filament is turned on by activating the Filament Interlock and Filament relays. When Statement 30's conditions are met, Statement 42 cancels the "UNDER HIGH VACUUM" message and displays the "PROCESS STARTED" message.

Figure 10-47 Statement 43

```
43 IF      STATEMENT  2
*** THEN STOP
```

Statement 43 places the IC/5 into the STOP state if Statement 2 evaluates to be true. Statement 2 is designed to detect if the system is not ready for automatic process control or if something goes wrong during the process.

Chapter 11

Installation and Interfaces

11.1 Location Guidelines

Before you permanently install this controller, we recommend that you read this entire section on Installation and Interfaces and follow its recommendations as closely as possible. INFICON has taken numerous steps to ensure its equipment will operate in a variety of harsh situations. Failure to adhere to these simple practices may adversely affect the performance and longevity of this controller, or controllers made by any manufacturer.

11.1.1 Sensor Types

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, [Table 11-1](#). For specific recommendations, consult your INFICON representative.

Table 11-1 Sensor Selection Table

	Max. Bakeout Temperature*	Water Tube & Size (Max. Envelope)	Coax Length	Body & Holder	IPN
CrystalSix Sensor	130 °C	3.5" dia. x 2.0" high (8.9cm x 5.1cm)	30" (76 cm)	304 SS (plate, holders & material shield)**	750-446-G1
Standard Sensor	130 °C	1.063" x 1.33" x .69" high (2.7cm x 3.4cm x 1.75cm)	30" (76 cm)	304 SS	750-211-G1
Standard Sensor w/Shutter	130 °C	1.06" x 2.24" x .69" (2.7cm x 5.7cm x 1.75cm)	30" (76 cm)	304 SS	750-211-G2
Sputtering Sensor	105 °C	1.36 x .47" (3.45cm x 1.18cm)	30" (76 cm)	Au-plated BeCu	007-031
Compact Sensor	130 °C	1.11" x 1.06" x 1.06" (2.8cm x 2.7cm x 2.7cm)	30" (76 cm)	304 SS	750-213-G1
Compact Sensor w/Shutter	130 °C	2.08" x 1.62" x 1.83" (5.3cm x 4.1cm x 4.6cm)	30" (76 cm)	304 SS	750-213-G2
UHV Bakeable Sensor	450 °C	1.35" x 1.38" x .94" (5.3cm x 4.1cm x 4.6cm)	12" (30.5cm) 20" (50.8cm) 30" (76.2cm)	304 SS	007-219 007-220 007-221
UHV Bakeable Sensor w/Shutter	400 °C	1.46" x 1.37" x 1.21" (3.7cm x 3.5cm x 3.1cm)	12" (30.5cm) 20" (50.8cm) 30" (76.2cm)	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; water flow is required for actual deposition monitoring. These temperatures are conservative maximum device temperatures, limited by the properties of Teflon (PTFE) at higher temperatures. In usage, the water cooling allows operation in environments that are significantly elevated, without deleterious affects.

** Aluminum body for heat transfer.

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. For best operation, maintain the input water temperature at less than 30°C. 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.



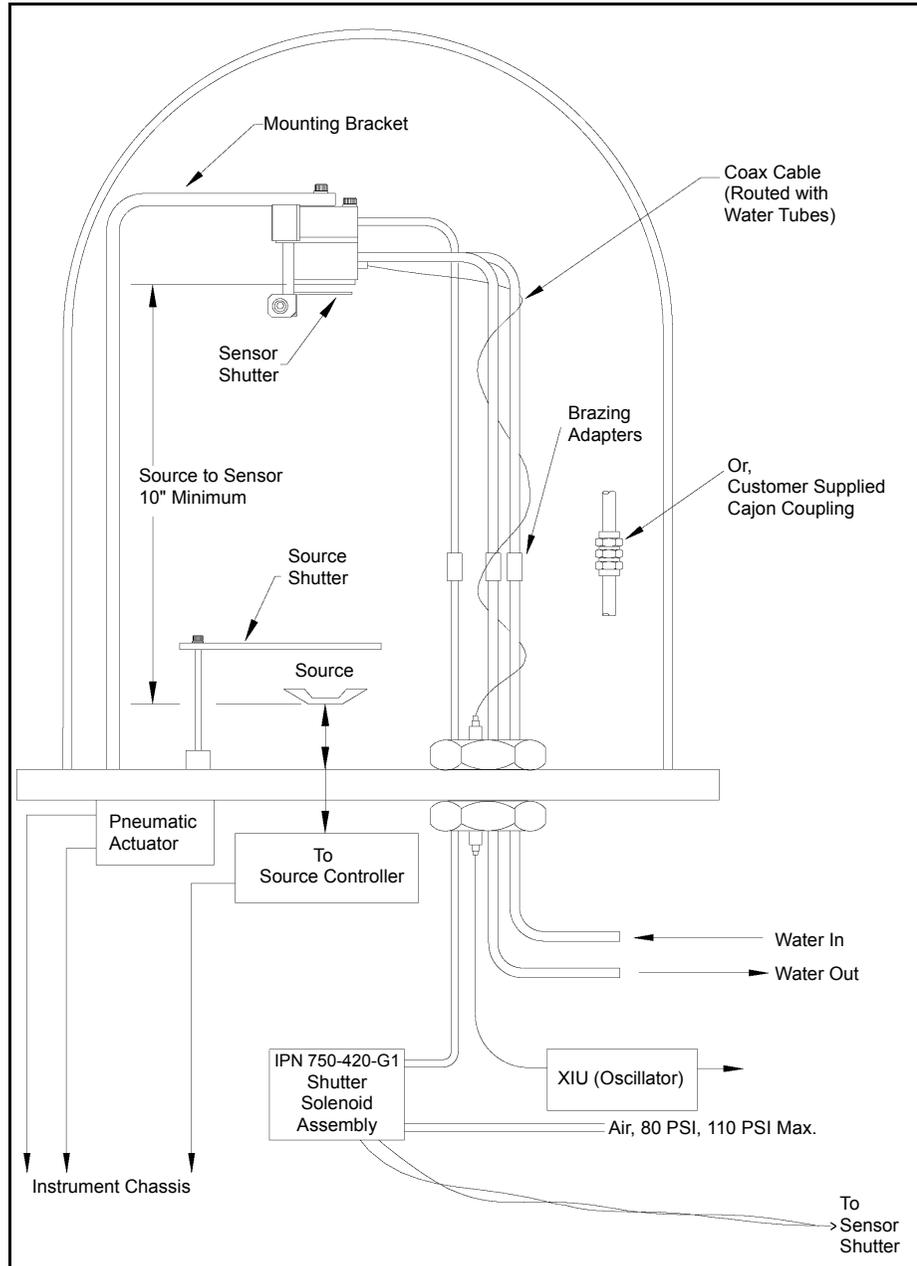
CAUTION

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.

11.1.2 Sensor Installation

Figure 11-1 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.

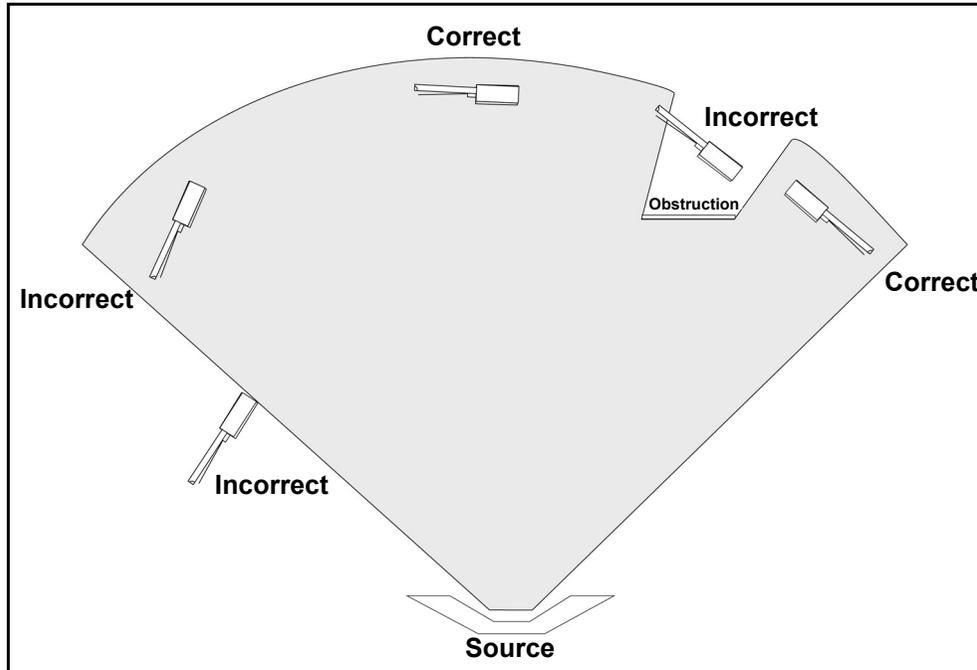
Figure 11-1 Typical Installation



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Generally, install the sensor as far as possible from the evaporation source (a minimum of 10" [25.4 cm] is recommended) while still being in a position to accumulate thickness at a rate proportional to accumulation on the substrate. Figure 11-2 shows proper and improper methods of installing sensors.

Figure 11-2 Sensor Installation Guidelines



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. Follow these precautions:

- ◆ 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 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-deposition), try to locate the sensors so the evaporant from each source is flowing to only one sensor. It is not generally possible to do this without special shielding or optional "material directors".

11.1.3 Control Unit Installation

The control unit is designed to be rack mounted. It may be also used on a table. The controller is forced-air cooled, with the air flow exiting the rear of the unit for clean room convenience.

It is generally advisable to centrally locate the controller, minimizing the length of external cabling. The cable supplied from the Sensor card to the XIU is fifteen feet. Thirty, fifty and one- hundred-foot cables are available.

11.2 Avoiding Electrical Interference

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

To maintain the required shielding and internal grounding and ensure safe and proper operation, the instrument must be operated with all enclosure covers, sub-panels and braces in place and fully secured with the screws and fasteners provided.

NOTE: When using the IC/5 with an RF sputtering system, the cable between the IC/5 and oscillator should be kept as far away from the RF transmission cable as possible. Interference from the RF transmission cable may cause an erroneous crystal fail.

11.2.1 Verifying/Establishing Earth Ground

If a ground must be established, 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 a salt solution around to improve the ground's conduction. A near zero resistance measurement indicates earth ground is achieved.
- ♦ Keep connections to this grounding network as short as possible.

11.2.2 Connections to Earth Ground

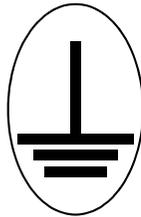
There are two earth connectors:

- ◆ The ground connection on the controller is a threaded stud with a hex nut. One suggestion is to connect a ring terminal to the ground strap, thus allowing a good connection, and easy removal and installation. See Figure 11.3 for the suggested method of grounding.
- ◆ This instrument is also connected to earth via a sealed three-core 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 - Risk Of Electric Shock

Never interrupt the protective earthing intentionally. 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.



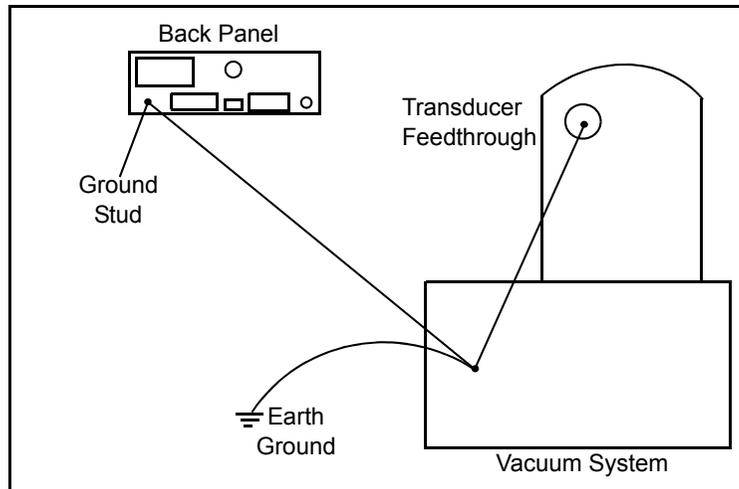
CAUTION

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

When used with RF powered sputtering systems, the grounding method may have to be modified to 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.

In many cases, a braided ground strap is sufficient. However, there are cases when a solid copper strap (0.030" thick x 1" wide) is required because of its lower RF impedance.

Figure 11-3 System Grounding Diagram



11.2.3 Minimizing Noise Pickup From External Cabling

When a controller is fully integrated into a deposition system, there are many wire connections, each a potential path for noise to reach the inside of the control unit. The likelihood of these wires causing a problem can be greatly diminished by adhering to the following guidelines.

- ◆ Use shielded coax cable or twisted pairs for all connections.
- ◆ Minimize cable lengths.
- ◆ Avoid routing cables near areas that have the potential to generate high levels of interference. For example, large power supplies such as those used for electron beam guns or sputtering sources can be a source of large, rapidly changing electromagnetic fields. Placing cables as little as one foot away from these problem areas can significantly reduce noise pickup.
- ◆ Be sure that a good ground system and straps are in place per the recommendations in [section 11.2.2 on page 11-6](#).
- ◆ Ensure that all instrument covers and option panels are in place and tightly secured with the provided fasteners.

NOTE: Always use shielded cables when making connections to the IC/5 rear panel to minimize electrical noise pickup.

11.3 Connecting the Controller

The operation of the controller depends on the proper connection of power and signal interfaces to owner equipment and sources.

11.3.1 Verifying the Correct Input Voltage



WARNING - Risk Of Electric Shock

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

Never remove the covers from the instrument during normal operation.

There are no operator serviceable items within this instrument.

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

In order to comply with accepted safety standards, this instrument must be installed into a rack or system which contains a mains switch. This switch must break both sides of the line when it is open and it must not interfere with the safety ground.

The controller is initially powered by AC line current. The four supported nominal voltage settings and their acceptable voltage input ranges are shown in [Table 11-2](#).

Table 11-2 Supported Nominal Voltage Settings

Nominal Setting	Acceptable Input Range
100 V(ac)	85 to 110 V(ac)
120 V(ac)	108 to 132 V(ac)
230 V(ac)	207 to 253 V(ac)
240 V(ac)	204 to 264 V(ac)

One of these nominal voltages has been factory set and that number shows through the window in the power input module. The line voltage provided in your facility must be within the voltage range indicated in [Table 11-2](#) for the nominal setting.

If the nominal line voltage is 230 V(ac), use the 240 V(ac) nominal setting whose input range includes 230 V(ac) $\pm 10\%$.



WARNING

Verify that the correct fuse is in place by first unplugging the unit, then pull the fuse extractor and visually inspect the fuse for the proper rating. Use of an improper fuse may create a safety hazard.

**For 100 or 120 V(ac) operation, use a 4 amp Type T fuse.
For 230 or 240 V(ac) operation, use a 2 amp Type T fuse.**

Also, visually verify that the voltage selector drum has been oriented to the proper position.

11.3.2 Voltage Selection

If necessary, the power supply voltage range can be checked or changed on site by a knowledgeable technician using extreme caution.



CAUTION

Damage to the unit and/or its interfaces will result by operating the unit in the incorrect voltage range.



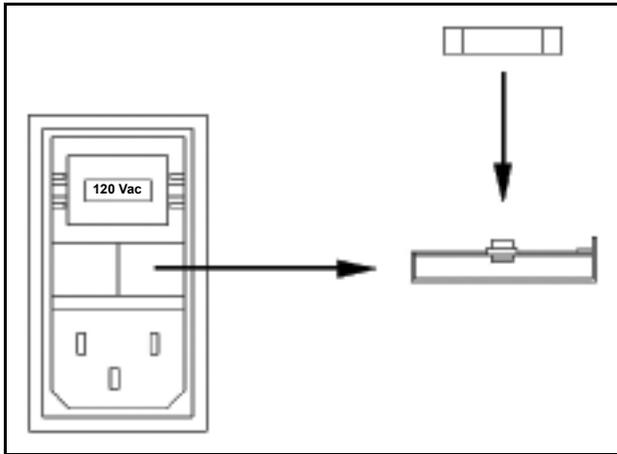
WARNING - Risk Of Electric Shock

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

If the voltage selector drum needs to be changed to match your nominal line voltage, it is required that the power cord be removed. Pry open the hinged door that covers the voltage select drum and fuse. Pull out the drum. Reorient the selector to the desired nominal line voltage. Reinsert the drum.

Pull out the fuse holder and check the fuse type and rating. The fuse must be a 4 amp Type T for either the 100 V(ac) or 120 V(ac) settings, or a 2 amp Type T for either the 230 V(ac) or 240 V(ac) settings. Install the proper fuse, push the holder firmly into place, and close the hinged door over the fuse and selector drum. The selected nominal voltage will show through the window. See [Figure 11-4](#)

Figure 11-4 Voltage Selector Drum and Fuse



11.3.3 Routing XIU Cables

XIU cables, IPN 600-1039-Gxx, are available in lengths of 15 ft. (4.6m), 30 ft. (9.1m), 50 ft. (15.3m), and 100 ft (30.5m). The signals traveling on this cable are both analog and digital. It is suggested that it not be routed near areas with high levels of electromagnetic interference, even if its length must be somewhat increased.

11.3.4 Interface Cable Fabrication and Pin-Out

It is necessary to fabricate several cables in order to interface the controller to the deposition system. Refer to [section 11.2.3, Minimizing Noise Pickup From External Cabling](#), on page 11-7.

11.3.4.1 Source Control Connection

A digital to analog conversion (DAC) module, IPN 760-1112-G1, is included as standard equipment with the controller. It provides 6 conversion channels. These 6 channels may be programmed for source control or chart recorder functions as desired. The 6 connectors are BNC.

11.3.4.2 Input/Relay Module Connections

The Input/Relay module, IPN 760-162-G1, is included as standard equipment with the controller and is used to interface with other machinery of the vacuum system. It can control components such as heaters, rotators or shutters through its 8 relays. It can respond to external instructions through its 14 isolated input lines. Standard equipment provides 8 relays and 14 input lines. Optionally, this can be expanded to 24 relays, 28 TTL inputs, and 14 open collector type outputs with the addition of 2 optional I/O cards.

The module provides separate connectors for relay outputs and input lines. A 25-pin D-sub, male connector is used for the eight high voltage relays. A 15-pin D-sub, male connector is used for the input lines. Mating connectors are provided in ship kits IPN 760-020 and 760-024. Refer to [Figure 3-2 on page 3-3](#) for connector locations. Relay connections are rated at 30 V(dc) or 30 V(ac) RMS or 42 V(peak) maximum; 2.5 A maximum.

Inputs are activated by pulling the specific Input terminal to ground (<0.8 V) through a contact closure to common (GND) or with TTL/CMOS Logic having current sink capability of 2 mA (1 low power TTL load).



WARNING - Risk Of Electric Shock

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.

Table 11-3 Input/Relay Pin Connections

I/O Board #1				I/O Board #2			
Relay #	Pins	TTL Input #	Pin	Relay #	Pins	TTL Input #	Pin
1	7, 6	1	15	9	7, 6	15	15
2	9, 8	2	14	10	9, 8	16	14
3	11, 10	3	13	11	11, 10	17	13
4	13, 12	4	12	12	13, 12	18	12
5	5, 4	5	11	13	5, 4	19	11
6	3, 2	6	10	14	3, 2	20	10
7	1, 14	7	9	15	1, 14	21	9
8	15, 16	8	8	16	15, 16	22	8
		9	7			23	7
		10	6			24	6
		11	5			25	5
		12	4			26	4
		13	3			27	3
		14	2			28	2
		GND	1			GND	1

I/O Board #3			
Relay #	Pins	TTL Output #	Pin
17	7, 6	25	9
18	9, 8	26	10
19	11, 10	27	11
20	13, 12	28	12
21	5, 4	29	13
22	3, 2	30	14
23	1, 14	31	15
24	15, 16	32	1
		33	2
		34	3
		35	4
		36	5
		37	6
		38	7
		GND	8

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11.3.4.3 RS-232C Communications

RS-232C serial communications is included in the controller as standard equipment. It is used to remotely control or monitor the IC/5. An industry standard 9-pin D-Sub connector is required for the host computer side connection. Depending on the computer source, all connections may not be necessary. The length of the cable is limited to fifty feet according to published standards. The controller interface operates as DTE (Data Terminal Equipment). Pin assignments are for the IC/5's connector.

Table 11-4 RS-232C Pin Connections

Signal Name		Pin	EIA Name
TX	Transmit Data	2	BA
RX	Receive Data	3	BB
RTS	Request To Send	8	CA
CTS	Clear To Send	7	CB
DSR	Data Set ready	4	CC
SG	Signal Ground	5	AB
	(Not Used)	1	
DTR	Data Terminal Ready	6	CD
GND	Shield Ground	9	

11.3.4.4 Isolated +24 V(dc) Supply

An isolated +24 V(dc) power supply is available on a 9-pin D-Sub connector on the IC/5 back panel. This supply is rated for 1.75 Amps maximum.

The pin assignments for this connector are:

Table 11-5 +24 V(dc) Pin Connections

Pin	Function
1	Return
2	Return
3	Return
4	Not Connected
5	Not Connected
6	+24 Volts
7	+24 Volts
8	+24 Volts
9	Not Connected



CAUTION

Both the isolated 24 V(dc) supply and the RS-232C remote communications port use a 9-pin D-sub connector. Care must be taken not to inadvertently connect the RS-232C remote communications cable to the 24-volt supply connector. Also, care must be taken not to inadvertently connect the 24 V(dc) supply cable to the RS-232C remote communications connector.

Chapter 12

Calibration Procedures

12.1 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 in the 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 12.2](#).

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 in the tooling parameter in Material Set-Up. The tooling factor can be experimentally established by following the guidelines in [section 12.3 on page 12-2](#).

In the IC/5 if the Z-ratio is not known, it could be estimated from the procedures outlined in [section 12.4 on page 12-3](#), or, typically, the Auto Z function can be used to determine the Z-ratio.

12.2 Determining Density

NOTE: The bulk density values retrieved from the Material Library are sufficiently accurate for most applications.

Follow the steps below to determine density value:

- 1 Place a substrate (with proper masking for film thickness measurement) adjacent to the sensor, so that the same thickness will be accumulated on the crystal and this substrate.
- 2 Set density to the bulk value of the film material or to an approximate value.
- 3 Set Z-ratio to 1.000 and tooling to 100%.
- 4 Place a new crystal in the sensor and make a short deposition (1000-5000 Å), using manual control.
- 5 After deposition, remove the test substrate and measure the film thickness with either a multiple beam interferometer or a stylus-type profilometer.
- 6 Determine the new density value with the following equation:

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

where:

D_1 = Initial density setting

T_x = Thickness reading on IC/5

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 $T_x = T_m$.

12.3 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 in the IC/5

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.

12.4 Laboratory Determination of Z-ratio

NOTE: On the IC/5, the Auto Z function is available to automatically calculate the Z-ratio. Especially when precise Z-ratio values are significant, Auto Z is recommended. Refer to [section 2.1.6 on page 2-9](#) for a description of Auto Z theory.

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

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

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

where:

d_f = density (g/cm³) of deposited film

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

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

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

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

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

- 1** Establish the correct density value as described in [section 12.2 on page 12-1](#).
- 2** Install a new crystal and record its starting frequency F_{co} . It will be necessary to send the SC 12 n command to get this information (see [section 7.7.5, STATUS Commands, on page 7-28](#)).
- 3** Make a deposition on a test substrate 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.
- 4** Stop the deposition and record the ending crystal frequency F_c using the SC 12 n command.
- 5** Remove the test substrate and measure the film thickness with either a multiple beam interferometer or a stylus-type profilometer.

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

$$T_f = \frac{Z_q \times 10^4}{2\pi zp} \left\{ \left(\frac{1}{F_{co}} \right) A \tan \left(z \tan \left(\frac{\pi F_{co}}{F_q} \right) \right) - \left(\frac{1}{F_c} \right) A \tan \left(z \tan \left(\frac{\pi F_c}{F_q} \right) \right) \right\} \quad [5]$$

where:

T_f = thickness of deposited film (kÅ)

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

F_c = Final frequency of the sensor crystal (Hz)

F_q = Nominal blank frequency = 6045000 (Hz)

z = Z-Ratio of deposited film material

Z_q = Specific acoustic impedance of quartz = 8765000 (MKS units)

p = density of deposited film (g/cc)

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 Z-value for both layers.
- ♦ If the thickness of layer 1 is thin compared to layer 2, use material 2 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.

12.5 Determining Cross Talk Calibration For Co-Deposition

The automatic Cross Talk Calibration feature of the IC/5 is beneficial to applications involving the simultaneous deposition of two materials. When depositing two materials, it is not always possible to isolate each crystal so that it samples material from a single source. The Cross Talk Calibration feature is used to eliminate interference from the second source's material being deposited onto sensors intended to control the deposition rate from the first source.

Calibration Thickness (CALThick) values must be determined for each sensor, for each material used in the co-deposition, otherwise a co-deposition uncalibrated message will be displayed. The Process cannot be STARTed until the Cal Thick values are entered. These values may be manually entered on page 3 of the Material Definition display or may be automatically calculated using the Cross Talk Calibration series of displays. If Automatic Cross Talk Calibration is chosen the CAL Thick values calculated will be displayed on page 3 of the Material Definition display.

The CAL Thick values are then used to calculate the percent cross talk (Cross Talk %) values shown on the Layer definition display. EVERY sensor used on BOTH materials of a codeposition MUST be calibrated for each material.

Example: Materials A and B are to be co-deposited

Material A uses Sensors 1 and 2 which control the aggregate rate for Source 1. Material B uses Sensors 3 and 4 which control the aggregate rate for Source 2.

Enter CAL Thick values for Material A (either automatically or manually):

	Sens 1	Sens 2	Sens 3	Sens 4
CAL Thick	2.500 kA	2.200 kA	0.250 kA	1.000 kA

The percent Cross Talk for the Layer having Material A is:

$$\left(\frac{\text{CAL Thick Sens 3} + \text{CAL Thick Sens 4}}{\text{CAL Thick Sens 1} + \text{CAL Thick Sens 2}} \right) \times 100\% = 26.6\% \quad [6]$$

Enter CAL Thick values for material B (either automatically or manually)

	Sens 1	Sens 2	Sens 3	Sens 4
CAL Thick	0.100 kA	0.050 kA	0.125 kA	0.500 kA

The percent Cross Talk for the Layer having Material B is:

$$\left(\frac{\text{CAL Thick Sens 1} + \text{CAL Thick Sens 2}}{\text{CAL Thick Sens 3} + \text{CAL Thick Sens 4}} \right) \times 100\% = 24.0\% \quad [7]$$

If two Layers to be co-deposited have Cross Talk percentages greater than 100%, the Process will STOP and the error message **Cross Talk > 100%** will be displayed.

For the above example the calculated Cross Talk percentages are both below 100% and the two co-deposited Layers can be STARTed. If a sensor were to fail during deposition, the IC/5 will calculate new Cross Talk percentages for the "new" sensor configuration. For example, if Sensor 4 fails the new Cross Talk percentage for Material A will be 5.3% which is acceptable, however, Material B's new Cross Talk percentage will now be 120%. If this occurs the Process will STOP and the error message **Cross Talk > 100%** will be displayed. This error condition must be rectified before the Process can continue.

12.5.1 Procedure Set-Up

The Cross Talk Calibration feature will automatically calculate the Cal Thickness values that appear on Material Page 3. These values in turn are used in co-deposition to determine rates adjusted for the interference of one source with the other. Calibration is done for each Material to be used in a Co-deposition. Note that EVERY sensor used on BOTH Materials of a co-deposition MUST be calibrated for EACH Material calibrated. Each material to be co-deposited is calibrated separately. If a material is used in more than one co-deposition application, for example, materials A and B co-deposited then materials A and C co-deposited, Material A needs to be calibrated only once. A review of the Procedural Notes is recommended, see [section 12.5.5 on page 12-10](#). This is especially important if using Dual Sensor Heads.

To do a calibration, go to the Cross Talk Calibration display. This display is entered from the Maintenance/Diagnostics Display by pressing the F5 function key. The display is shown below in [Figure 12-1](#). SETUP is shown in the lower left hand corner of the display.

Figure 12-1 Cross Talk Calibration

CROSS TALK CALIBRATION										
Material Index	1		(1-24)	Al						
Desired Rate	10.0		A/Sec							
Maximum Power	90.0		%							
Calibrate YES/NO	Sens1 YES	Sens2 YES	Sens3 <input type="checkbox"/> NO	Sens4 NO	Sens5 NO	Sens6 NO	Sens7 NO	Sens8 NO		
Rate	A/SEC									
Cal Thick	KA									
									START MANUAL	
SETUP										
A/SEC		KA		%						MAINT/ DIAG

12.5.1.1 Cross Talk Calibrate Parameters

MATERIAL INDEX 1 to 24

This parameter is used to select the Material (from the Material Directory) to be calibrated. Values range from 1 to 24. The default value is 1. The name of the material is displayed to the right of the selection.

DESIRED RATE 0.1 to 999 A/s

This parameter determines the aggregate rate at which to control the deposition source while a Cross Talk Calibration is being done. This aggregate rate is comprised of the sensors chosen to be ON in the Material Set-Up display. Values range from 0.1 to 999 A/s. The default value is 10 A/s. It is recommended this rate be identical to the aggregate rate desired during deposition.

MAXIMUM POWER 0.0 to 99.9

This parameter is identical in function to the Maximum Power parameter found in Material Set-Up. The default value is 90.0 %a.

CALIBRATE Yes/No

This entry selects which sensors are to be calibrated.

NOTE: Every Sensor used for both of the co-deposited materials must be turned on (set to YES) during calibration of each Material in order for the Cross Talk Correction to work properly. The aggregate rate, however, is determined only from those sensors turned on in the Material Set-Up display for each Material.

Any sensor for which there is a crystal fail will default to NO.

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12.5.1.1.1 Function Key Selection Choices for Cross Talk Calibration Setup

Key	Function	Description
F5	START MANUAL	Press this key to place the IC/5 into the MANUAL state. This allows manipulation of the source power using the Hand Held Controller. Upon entering the MANUAL state, Source and Sensor shutters will activate. Rates and Thicknesses for each of the sensors being calibrated will also be displayed. The Aggregate Rate, Thickness, and % Power are also displayed.
F6	MAIN/DIAG	Press this key to return to the Maintenance/Diagnostics display.

12.5.2 Cross Talk Calibration MANUAL display

Upon pressing the START MANUAL function key from the SETUP display, the IC/5 enters the Manual state, allowing manipulation of the source power level using the Hand-Held Controller. This is used to prepare the source for calibration. Bring the source power level to a point where the deposition rate is stable and approximately the rate at which you wish to calibrate.

12.5.2.1 Function Key Selection Choices for Cross Talk Calibration Manual

Key	Function	Description
F5	START CALIBRATION	When the power level and rates are stable press the F5 key (START CALIBRATION) to enter the automatic calibration portion of Cross Talk Calibration.
F6	LEAVE MANUAL	Press this key to leave the Cross Talk Calibration Manual display and return to the Cross Talk Calibration Setup display.

12.5.3 Cross Talk Calibration CALIBRATE display

Upon entering this display the thickness values are zeroed and the aggregate rate will be controlled to the desired rate. Thickness will accumulate on each of the sensors set for calibrate YES. Calibration will continue until a 300 Hz frequency shift has taken place on the sensors selected in the Material Set-Up display (i.e., the sensors used to calculate the Aggregate Rate). The instrument will stay in the automatic calibration mode for a minimum of 1 minute. The estimated time to complete calibration is displayed in the lower left hand side message area.

If the desired 300 Hz frequency shift has not taken place within 15 minutes, automatic calibration will time out and an error message will be given. When automatic calibration is completed the IC/5 will enter a RAMP Power Down state in which the source control power is ramped to Zero over the time period designated by this material's Idle Ramp Time.

12.5.3.1 Function Key Selection Choices for Cross Talk Calibration Calibrate

Key	Function	Description
F6	STOP CALIBRATION	Press this key to leave the CALIBRATE display and return to the SETUP display.

12.5.4 Cross Talk Calibration SELECT display

After the RAMP down state the IC/5 enters the SELECT display, from which the user can accept or reject the calibration thickness values, as desired. If the values are accepted they are stored on page 3 of the Material Set-Up display.

12.5.4.1 Function Key Selection Choices for Cross Talk Calibration Select

Key	Function	Description
F3	RECALIBRATE	Press this key to recalibrate the Calibration Thickness values starting at Cross Talk Calibration MANUAL, rejecting the calculated calibration thickness values.
F4	ACCEPT	Press this key to accept the Calibration Thickness values and returns to the Cross Talk Calibration SETUP display. The accepted Calibration Thickness values are entered into page 3 of the Material Set-Up display.
F5	REJECT	Press this key to reject the Calibration Thickness values and return to the Cross Talk Calibration SETUP display.
F6	STOP CALIBRATION	Press this key to stop the calibration procedure and return to the Cross Talk Calibration SETUP display.

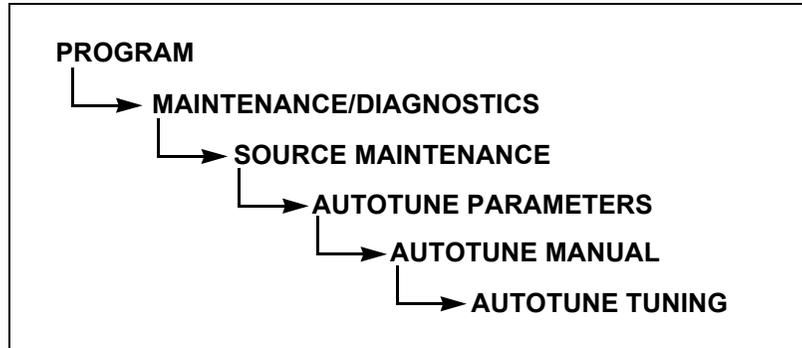
12.5.5 Cross Talk Calibration Procedural Notes

- 1 The Calibration thickness values do not include any adjustment for Sensor Tooling (set in the Material Set-Up display) This is because the cross sensitivity adjustments are done prior to the sensor tooling being factored into the sensor rate calculation. The Aggregate Rate, used to control the deposition source, DOES include the Sensor Tooling factors.
- 2 During Cross Talk Calibration CALIBRATE, if a Crystal Fail occurs the calibration is aborted and the power ramp is entered. The user can still enter the calibration thickness values of the partially completed calibration if desired, recalibrate with the failed Crystal (CALIBRATE will be set to NO automatically for the Sensor with the failed crystal), or replace the failed crystal and recalibrate.
- 3 If the instrument is set to STOP on MAX POWER in the Utility Set-Up and MAX POWER is reached, the calibration will be aborted and the Source Power zeroed. No option of entering the partially completed results is given.
- 4 When using a Dual Crystal Sensor it is important that the Crystal shutter be removed during calibration so that material will deposit onto both crystals. An alternative to removing the crystal shutter is to perform the calibration procedure allowing only one of the crystals to receive material and then manually entering this Cal Thickness Value for the secondary sensor. This manual entry of the Cal Thickness value ignores the tooling difference between the two crystal positions.

12.6 AutoTuning

The AutoTune feature of the IC/5 is used to automatically characterize the response of a system. AutoTune examines the rate change response after executing step changes in power. Control parameters are calculated for algorithms designed for either slow-responding systems or fast-responding systems, with PID parameters determined for slow systems and a process gain coefficient determined for fast sources.

Figure 12-2 Display Tree for AutoTune



There are two subsets of AutoTune. A shortened version called "Quick Tune", calculates the required values from a fixed change in source power. The "Complete Tune" process first incorporates the Quick Tune procedure and then refines the parameter values by operating at a set of rates established about the desired operating point.

Initiate the AutoTune operation by selecting the AUTOTUNE function key (F5) in the Source Maintenance display while in the READY state. This will invoke the AutoTune Parameters display; upon entry, the cursor will be found at the last referenced parameter.

Edit an AutoTune parameter by positioning the box cursor at the desired parameter value and then using the data entry keys to input a new parameter value. By using the function keys you may start the manual state of AutoTune or you may return to the Source Maintenance Display.

Figure 12-3 AutoTune Parameters Display

AUTOTUNE PARAMETERS				
Material Index	<input type="text" value="1"/>	(1-24)		F1
Desired Rate	10.0	Å/Sec		F2
Maximum Rate	100	Å/Sec		F3
Quick Tune	YES	YES/NO		F4
Compound Name	MgF2			F4
Control Loop	Non-PID			F5
Process Gain	10.00			F5
Primary Time Const.				F5
System Dead Time				F5
	12.6 Å/sec	2.520 kÅ	0.0 %	TEST
	3.8 Å/sec	0.762 kÅ	0.0 %	SOURCE MAINT-ENANCE

12.6.1 AutoTune Parameters

Refer to Sections [section 2.1.7 on page 2-11](#) and [section 12.6.3 on page 12-14](#) for a description of AutoTune.

MATERIAL INDEX 1 to 24

This parameter is used to select the Material (from the MATERIAL DIRECTORY) that is to be "AutoTuned". Values range from 1 to 24. The default value is 1.

DESIRED RATE 0.1 to 999 Å/s

For a Complete Tune, this parameter determines the Rate for which the AutoTuned control loop parameters will be calculated. For Quick Tune this parameter is ignored. Values range from 0.1 to 999 Å/s. The default value is 10.0 Å/s.

MAXIMUM RATE 0.2 to 999 Å/s

This parameter is used to set the maximum deposition Rate allowed during an AutoTune session. The events which occur upon exceeding this value are dependent upon whether a Quick Tune or a Complete Tune is designated. The range of values permitted for this parameter is dependent on the value chosen for the Desired Rate. The maximum allowed value will always be 999 Å/s. The minimum allowed value is 2 times the Desired Rate value.

QUICK TUNE YES/NO

This parameter is used to choose between a Quick Tune and a Complete Tune. Permissible values are YES and NO. A value of YES selects Quick Tune. The default value is YES.

MATERIAL NAME

This is a read-only parameter that identifies the material being deposited.

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CONTROL LOOP

This is a read-only parameter that indicates the type of control loop specified during material definition. A 0 indicates the Non-PID control loop is used. A 1 indicates a PI control loop is used, and a 2 indicates a PID control loop is being used. See [section 4.3 on page 4-5](#) and [section 2.1.7 on page 2-11](#) for more information about the control loop.

PROCESS GAIN

This is a read-only parameter that represents the rate of change of % source power for a given rate deviation.

PRIMARY TIME CONSTANT

This is a read-only parameter that represents the source's time constant. It is valid only for a PI or PID control loop.

SYSTEM DEAD TIME

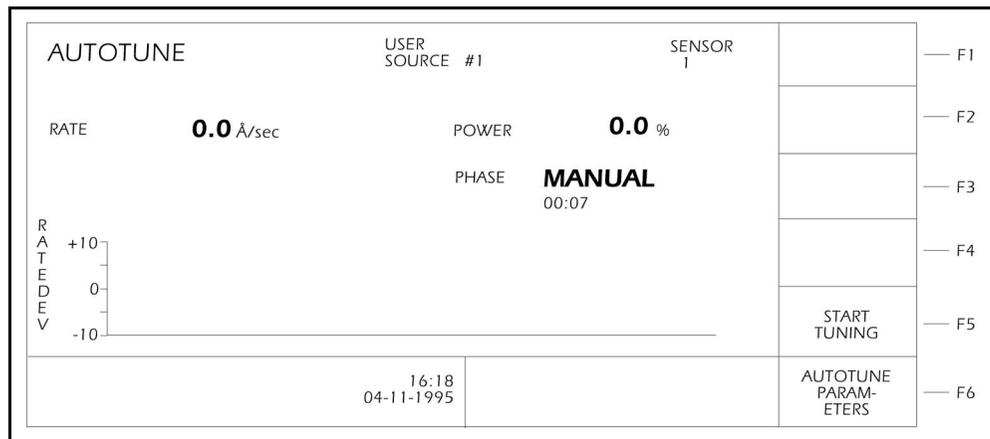
This is a read-only parameter that represents the source's lag time. It is valid only for a PI or PID control loop.

12.6.2 AutoTune Manual Display

The AutoTune Manual display is entered from the AutoTune Parameters display by selecting **START AUTOTUNE** (F6).

The AutoTune Manual display is similar to the general Operate display with the exception that Thickness and Process information will be absent. The AutoTune Manual display automatically places the instrument into the MANUAL state. Just like the normal MANUAL state, the power level can be adjusted via the Hand-Held Controller and the source shutter relay is active.

Figure 12-4 AutoTune Manual Display



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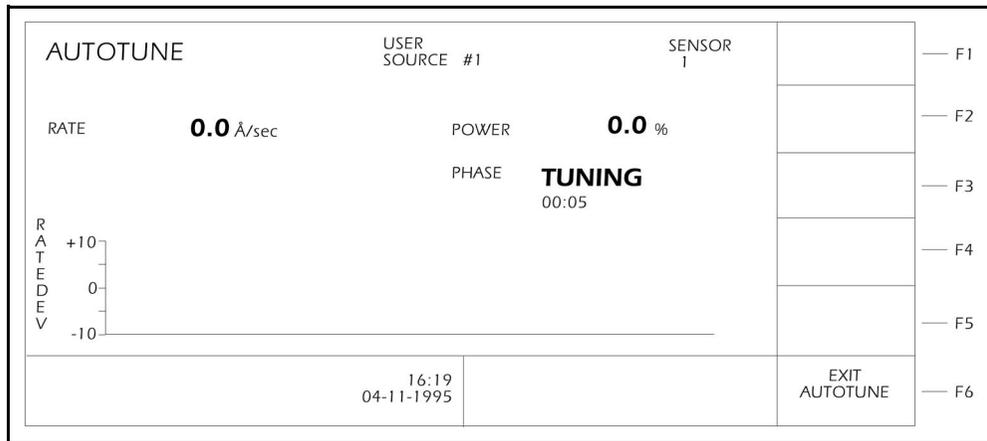
12.6.3 AutoTune Tuning Display and AutoTune Description

The AutoTune Tuning display is entered from the AutoTune Manual display by selecting **START TUNING** (F5).

AutoTune tuning is executed automatically by the instrument. Operator intervention is not required.

STOP the tuning process by pressing F6 (**EXIT AUTOTUNE**).

Figure 12-5 AutoTune Tuning Display



The instrument goes through the following algorithm when AutoTuning:

The first portion of Tuning is the Speed Test. The Speed Test calculates how quickly the system reacts to an instantaneous increase in source power level. The results of the Speed Test determine whether the system is fast or slow. Consequently, this designation of fast or slow determines what action is to follow.

For Quick Tune, the increment in power level is a pre-determined percentage of the power, while for a Complete Tune the increment in power level is calculated to obtain a specific rate increase.

If Quick Tune is chosen, the instrument will begin the AutoTune procedure by first recognizing an initial power setting. This initial power setting is the power level the operator adjusts to while in the Manual state of AutoTune. Next, the instrument will increase the power level to a value 5% greater than the initial level. If the rate of deposition exceeds the Maximum Rate value during this transition, the power level is returned to the initial power setting and the instrument will increase the power level to a value of 2.5% greater than the initial level.

Again, if the Maximum Rate value is exceeded, the power level is returned to the initial power setting and the instrument will increase the power level to a value of 1.25% greater than the initial level. If the Maximum Rate is exceeded this final time a Quick Tune Failure message will appear and the control loop parameters must be determined manually. If the rate does not exceed the Maximum Rate value

during any one of these power increments then the rate transition for this pre-determined power increment is used to calculate the control loop parameters. There is no Rate control feedback during Quick Tune.

If a Complete Tune is chosen, a Quick Tune is done first and will proceed as described above. These Quick Tune values are used as backup parameters in the event a Complete Tune fails. After completing the Quick Tune, the instrument will initially establish rate control to one-half the Desired Rate, then increment the power level to obtain a rate at twice the Desired Rate.

If the Maximum Rate is exceeded, the power level will be adjusted to reestablish rate control at one-half the desired rate and then increased to obtain a rate at the Desired Rate. If the Maximum Rate is again exceeded, the instrument will leave AutoTune and return the values calculated with Quick Tune. If the Maximum Rate is not exceeded, the control loop parameters will be calculated based on the rate transition. There is rate feedback when doing a Complete Tune.

The major difference in the implementation of AutoTune for a fast source (typically an electron beam gun) as opposed to a slow source, is the way in which rate stability is determined. For a fast source there can be many rate instabilities, such as sweep frequency fluctuations and short term thermal shorts; therefore rate noise makes determination of when the rate is stable impractical.

To circumvent this problem with a fast source the power level for both Quick Tune and Complete Tune is increased to the appropriate level and held for approximately 9 seconds. The rate transition over this time period is used to calculate the Process Gain parameter. Having calculated the Process Gain, the power level is returned to the initial power setting (or rate if in Complete Tune) and the procedure is repeated. The Process Gain value is again calculated and the two values compared. If the relative deviation between the two values is less than 40%, AutoTune for a fast source is completed.

This procedure may be repeated up to 4 times to obtain agreement between calculated Process Gain values. If agreement can not be reached after four times, Quick Tune values will be returned. A failure message will be returned if a Quick Tune can not be accomplished. The time for a complete tune of a fast source is typically no more than two minutes. A Quick Tune on a slow system typically takes 10 minutes, while a Complete Tune may take as long as 30 minutes.

12.6.4 Definition of AutoTune Messages

The following messages may appear while AutoTuning:

AutoTune Failure Inconsistent Quick Tune results are not allowing control loop parameters to be determined.

AutoTune Successful. The instrument has determined the system's control loop parameters.

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- Complete Bump 1** The first increase of source power level. It is used to determine control loop parameters for the Complete Tune portion of AutoTune.
- Complete Bump 2** The second increase of source power level.
- Complete Bump 3** The third increase of source power level.
- Complete Tune Failure** Indicates inconsistent results which do not allow the Complete Tune control loop parameters to be calculated. The Quick Tune results are then displayed.
- Fast System** Indicates a very short time delay between an increase in power level and the corresponding rate increase.
- Half Rate** The adjustment of the source's power level to establish a deposition rate which is one-half the desired rate.
- Max Power Exceeded** Indicates the power level has exceeded the AutoTune MAXIMUM POWER.

NOTE: The AutoTune max power is 5% less than the max power programmed for the material being AutoTuned.
- Quick Bump 1** The first 5% increase of source power level. It is used to determine control loop parameters for the Quick Tune portion of AutoTune.
- Quick Bump 2** The second 5% increase of source power level.
- Quick Bump 3** The third 5% increase of source power level.
- Ramp** Indicates the power level is being decreased to zero over a thirty second time period.
- Slow System** Indicates that a measurable time delay between an increase in power level and the corresponding rate increase has been measured.
- Speed Test** An instantaneous increase of source power. It is used to test the response time of the system in order to differentiate between fast and slow systems.

STOP Max Rate Exceeded Indicates that tuning has stopped because the MAXIMUM RATE parameter was exceeded three times.

STOP Rate Too Low Indicates that tuning has stopped because the initial rate was below 0.1 Å/s

12.6.5 AutoTune Preparation Instructions

The following procedure should be followed to perform an AutoTune:

1 Determine the Correct System Setup

In order to ensure good AutoTune results and good source control, careful consideration should be given to eliminating system noise, thermal shorting, and any other factors that result in rate instabilities.

2 Determine the Correct Material and Source Parameters

Because an evaporation source's behavior is material specific, careful attention should be given to choosing the correct material and source parameters.

Choose the source's voltage range that best suits the material and evaporation technique. Generally, low melting point materials use smaller ranges (0 to ±2.5 or 0 to ±5.0 Volts), while high melting point materials use the larger range (0 to ±10.0 Volts). (Refer to [section 8.3 on page 8-3.](#))

3 Determine the Correct AutoTune Parameters

Material Index Choose the index number of the desired material (from the Material Directory).

Desired Rate Choose the rate at which to control the deposition. This parameter is used only for a Complete Tune.

Maximum Rate Choose the maximum rate the system can handle safely (i.e., source doesn't spit, equipment is not damaged).

Quick Tune Choose either YES for Quick Tune or NO for a Complete Tune.

4 Press the START AUTOTUNE function key (F5) and increase the power level with the Hand-Held Controller until the rate is approximately one half the desired rate.

5 Allow the source to come to an equilibrium by leaving the power level constant for approximately three minutes.

6 When the source has reached equilibrium, press the START TUNING function key (F5), and observe the instrument as it goes through the "tuning" portion of AUTOTUNE.

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- 7 When AutoTune is completed the instrument will automatically return to the AutoTune Parameters display and the newly calculated values will be displayed next to the old values. The user then has the option of ACCEPTING CHANGES (F5) or REFUSING CHANGES (F6). Accepting the changes replaces the old parameters with the new values, while refusing the changes leaves the old values in place.
- 8 An AUTOTUNE failure means the IC/5 was unable to consistently measure the system's response characteristics.

NOTE: To ensure a successful AutoTune, there are a few items to be considered:

A well-conditioned source is imperative. Be certain the source will be able to withstand the automatic power increments without spitting or other damage occurring to the system.

A "quiet" crystal is essential. Rate noise and gun arcs will cause AutoTune Failures.

Use the Maximum Rate and Maximum Power limits to protect your equipment.

Do not set the Maximum Rate at exactly twice the Desired Rate. Allow for overshoot.

Chapter 13

Troubleshooting, Status and Error Messages

13.1 Status and Error Messages

AUTOTUNE FAILURE

This message is displayed when AutoTune is unable to calculate control loop parameters when doing a quick tune.

AUTOTUNE MAX POWER

The power setting in AutoTune has increased beyond the material's max power setting less 5%. (Autotune Max Power is set at 5% less than the maximum power programmed for the material being AutoTuned.)

AUTOTUNE SUCCESSFUL

Control loop parameters have been successfully established by AutoTune.

AUTOTUNE TIMEOUT

AutoTune is unable to maintain a stable deposition or complete the measurement of a deposition transition.

BAD XTAL AND RUNNING

This message is displayed when attempting to turn on a sensor which has a failed crystal while executing a process.

bb RAM LOCK

Indicates the battery backed RAM lock feature is active. Shown in reverse video.

BOTH SNSR ON IN MATL

Shown when attempting to change the Sensor Type parameter to a Dual sensor head while both sensors are turned on in a Material Set Up display.

CALIBRATION TIMEOUT

When in automatic cross talk calibration, each sensor used to control the aggregate rate must have a crystal frequency shift of 300 Hz. The calibration algorithm will time-out if a 300 Hz minimum frequency shift has not taken place within 15 minutes.

CANNOT DELETE CO-DEP

A layer being co-deposited cannot be deleted. Set the parameter co-deposition to NO prior to deleting the layer.

CANNOT EMPTY PROCESS

The last layer of Process 1 cannot be deleted.

CANNOT INSERT CO-DEP

A layer cannot be inserted between two co-deposited layers.

CANNOT ROTATE DUAL

The rotate crystal function can only be performed on a CrystalSix sensor head.

CANNOT TOGGLE INPUT

Output types can be toggled between Normally Open and Normally Closed. An Input does not have a type function and cannot be toggled.

CO-DEP UNCALIBRATED

Indicates the two co-deposited materials do not have Calibration Thickness values entered on the Material Set-Up displays and therefore the cross talk calibration is uncalibrated. (Refer to [section 12.5 on page 12-4](#))

COMPLETE BUMP #

AutoTune displays the change in the power supply setting.

CROSS TALK > 100%

Cross Talk percentage values for each co-deposited Layer must be less than 100%. Refer to [section 12.5 on page 12-4](#) for a more detailed description of Cross Talk Calibration.

DATA LOG FAILURE

The instrument is attempting to output the datalog string faster than the external device (e.g., computer or floppy disk) can accept the data. This means the datalog information for this Layer is lost.

DEL LAST PROC FIRST

Delete Last Process first. The last layer of a process cannot be deleted unless it is the last layer of the last defined process. The last layer of Process 1 can never be deleted.

DELAY

The instrument is in a 5-second delay between Hold and Sample of RateWatcher.

DISK IS FULL

There is not enough capacity on the floppy disk to save the requested configuration file or datalog string.

DISK MEDIA ERROR

The instrument is unable to save or retrieve information on the floppy disk.

DISK WRITE PROTECTED

The Save requested cannot be performed when the floppy disk is physically write protected.

DUPLICATE XTALS

The XL Position parameter must have unique positions for each of the 6 Crystal positions. For example, the sequence 135 is valid. The sequence 155 will return a Duplicate XTALS error message.

EDIT IN PROGRESS

The I/O Map or the User Messages displays cannot be exited while an edit name or edit message operation is occurring.

END OF PROCESS

The Process is completed when the last layer in the Process reaches the IDLE state.

FAST SYSTEM

AutoTune has detected the response of the system to be "fast".

FILE CHECKSUM ERROR

Indicates the instrument configuration file being retrieved from the floppy disk is corrupt and does not pass the checksum verification. The instrument parameters remain unchanged from prior to the retrieve operation.

FILE FORMAT ERROR

Indicates the file being retrieved from the floppy disk is not in the proper instrument configuration file format. The instrument parameters remain unchanged from prior to the retrieve operation.

FILE IS READ ONLY

A save operation cannot be performed on a file marked as read only.

FILE RANGE ERROR

This error message indicates the configuration file contains a value which exceeds the allowed range for a particular parameter. This may occur if transferring files between two different versions of instrument software and one of the software versions has a different acceptable range of values for a given parameter.

FILE READ ERROR

The retrieve operation could not be completed due to an error reading the floppy disk. The instrument parameters remain unchanged from prior to the retrieve operation.

HALF RATE

The system is being "bumped" toward half of the desired deposition rate while in AutoTune.

HOLD

The process is in the Hold portion of RateWatcher.

IEEE488 TIMEOUT

Data in the instrument parallel communications port buffer must be read by the Host computer within a given amount of time. If this does not happen the instrument will clear its communications buffer. This error message indicates the Host computer has quit communicating with the instrument.

ILLEGAL BAUD RATE

Baud rate selections are 2400, 4800, 9600, or 19200.

ILLEGAL DATE

The month or day entry is invalid. Month numbers must be in the 01 to 12 range; day numbers must be in the correct range for the month specified.

ILLEGAL INPUT - VALUE TOO LARGE

Parameter entry is out of range. Allowable values will vary according to your unit configuration or the parameter being defined. Press CLEAR to delete the value and enter again.

ILLEGAL INPUT - VALUE TOO SMALL

Parameter entry is out of range. Allowable values will vary according to your unit configuration or the parameter being defined. Press CLEAR to delete the value and enter again.

ILLEGAL LOCK CODE

The correct lock code is necessary to unlock parameters.

ILLEGAL SENSOR TYPE

Sensor type may be only 1, 2, or 6.

ILLEGAL TIME

Time is invalid. Numbers designating hours must be in the 00 to 23 range; numbers designating minutes must be in the 00 to 59 range.

INPUT IN USE

The input line in question has already been reserved for use.

INVALID EQUATION

Strings must have connectors and required numerics before exiting the Logic Statement.

I/O EQUATIONS LOCKED

The strings comprising the I/O equations cannot be accessed while the program or I/O lock code is set.

I/O LOCK

The instrument has been placed in I/O lock. This prohibits entering I/O or Source/Sensor parameters from the front panel unless the I/O Lock Code is known.

LAYER UNDEFINED

The "Layer to Start" defined in Utility Set Up must correspond to a defined layer in the active process.

MATERIAL IN USE

A material referenced in any layer cannot be deleted.

MATERIAL UNDEFINED

A material must be previously defined in the Material Directory.

MAX POWER REACHED 1 (2)

Indicates the specified maximum power has been reached on an active source in the primary (1) or secondary (2) layer.

MAXIMUM TERMS

No more than 5 terms are allowed in anyone Event or Action string.

MEM ALLOC FAIL

This message appears if a Data Log or Print Screen operation fails because of an overuse of system memory. If this message appears contact the INFICON Service Department.

MENU UNAVAILABLE

Indicates the menu tree cannot be accessed from the instrument's current display because Lock Codes have been programmed.

MUST EDIT NAME FIRST

The user requested a save name or save message operation without first having edited the name or message.

MUST ENTER OLD CODE

Utility Set-Up requires the user to enter the old Program or I/O Lock Code before updating to a new Program or I/O Lock Code.

MUST SET TAG(S)

The user may not perform a copy or delete operation without first "tagging" the layer(s) to be copied or deleted.

MUST USE 1 SENSOR

At least one sensor for each defined Material must have its Option parameter non-zero.

NO DISK IN DRIVE

Save or Retrieve requires a floppy disk to be inserted: the disk is not detected by the instrument.

NO MATERIAL DEFINED

Materials must be defined to be used in a Process Layer.

NON-DEPOSIT HOLD

Indicates the non-deposit hold Action is activated. Shown in reverse video.

NO SOURCE DAC

A DAC output must be defined in the Source Set-Up display in order to execute a process using the requested source. The source is requested on page 1 of the Material Set-Up display; the DAC output associated with this source is defined in the Source Set-Up display.

NO SWITCH: IN LAYER

A crystal switch from the Hand-Held Controller cannot be done while a layer is running.

NO SWITCH: NO OUTPUT

A crystal switch cannot be done because no output was set for crystal switching in the sensor display.

NO SWITCH: SAME XTAL

This message is displayed if an attempt is made to switch to a crystal position that is the same as the current crystal position.

NO SWITCH: SINGLE

A crystal switch cannot be requested while using a single head sensor.

NOT ENOUGH LAYERS

This message is displayed if the number of layers to copy combined with the number of layers already programmed into the instrument will exceed the capacity of the instrument. The total capacity of the instrument is 250 layers.

NOT IN READY

Indicates the instrument cannot perform the requested function unless it is in the READY state.

NOW ENTER NEW CODE

After the user verifies the old Program or I/O Lock Code, this prompt is displayed to enter a new lock code.

OTHER DUAL IN USE

This error message is displayed when the user is attempting to turn on a sensor that is configured as a Dual sensor head on the Sensor Set-Up display. When two sensors are configured as a Dual sensor type, only one of those sensors can be turned on in the Material display. The sensor that is turned on is considered the primary sensor of the Dual head.

OUTPUT IN USE

Indicates the output in question is already reserved for use in Sensor or Source Set-Up or in one of the Logic Statements.

PARAMETERS DEFAULTED

Indicates the instrument parameters have been set to their default values. Any previously programmed values will have been changed to the default values.

PROCESS UNDEFINED

The Active Process defined in Utility Set-Up must correspond to a defined Process. A defined Process is one that contains Layers.

PROGRAM LOCK

Indicates the instrument is in Program Lock. This prohibits any parameter from being entered from the front panel until the Program Lock Code is entered on the Program display.

PORT CONFLICT

An attempt is being made to output two different functions to the same output port.

QUICK BUMP #

Indicates the number of the AutoTune source power change used to measure the system response characteristics.

RAMP 1 MORE THAN 2

Start Ramp 1 value must be less than Start Ramp 2 value.

RAMP 2 LESS THAN 1

Start Ramp 2 value must be greater than Start Ramp 1 value.

RATE ABOVE MAX

Indicates the deposition rate has increased beyond the maximum allowed value in AutoTune.

REMOTE LOCK

Indicates the instrument is remote locked from an external computer. This prohibits any parameters from being entered via the front panel.

RS232 TIMEOUT

Data in the instrument serial communications port buffer must be read by the Host computer within a given amount of time. If this does not happen the instrument will clear its communications buffer. This error message indicates the Host computer has quit communicating with the instrument.

SAMPLE

Indicates the instrument is in the SAMPLE portion of RateWatcher.

SENSOR IN USE

An attempt is being made to turn on a sensor that is already in use for the other of the co-deposited materials.

SET AS RECORDER OUT

The value you are attempting to enter has been previously defined as a recorder output in either the Material Set-Up display or one of the Sensor Set-Up displays.

SET AS SOURCE OUT

The value you are attempting to enter has been previously defined as a Source DAC output in one of the Source Set-Up displays.

SLOW SYSTEM

Indicates that AutoTune determined the response of the system to be slow.

SPEED TEST

The system's speed of response is being determined by AutoTune. The source power increases by 5% during this period.

STOP - COMMUNICATIONS

STOP command received from remote communications.

STOP - COMPLETE TUNE FAIL

Indicates the complete tune portion of AutoTune did not determine reliable system response results.

STOP - CROSS TALK > 100%

Indicates the instrument is in the STOP state because one (or both) of the co-deposited Layers has a Cross Talk percentage greater than 100%. Refer to [section 12.5 on page 12-4](#) for a more detailed description of Cross Talk Calibration.

STOP - FRONT PANEL

Indicates the front panel STOP key has been pressed.

STOP - HALF RATE FAIL

Indicates AutoTune is unable to vary the source power to obtain half the desired deposition rate.

STOP - Hand-held

STOP executed from the Hand-Held Controller.

STOP - LOGIC STATEMENT n

STOP executed from Logic Statement n.

STOP - MAX POWER

Indicate the instrument is stopped because Max Power has been exceeded for over 5 seconds. The Stop on Max Power parameter is entered in Utility Set-Up.

STOP - MAX POWER ERROR

Indicates AutoTune is unable to finish a Complete Tune without exceeding the material's maximum power setting.

STOP - MAX POWER < 5%

AutoTune has stopped because the material's maximum power setting is less than 5%. AutoTune maximum power is automatically set at 5% less than the material maximum power.

STOP - NO SOURCE DAC

Indicates that a DAC output for this material's source has not been defined.

STOP - POWER LOSS

Indicates the instrument is in the STOP state due to a prior power loss.

STOP - QUICK TUNE FAIL

Indicates the Quick Tune portion of AutoTune did not get repeatable system response results.

STOP - RATE TOO LOW

AutoTuning is terminated when the deposition rate at the start of tuning is below 0.1 A/s.

STOP - SENSOR CONFLICT

Indicates the instrument is stopped because the process is trying to enter the DEPOSIT state with both layers using the same sensor.

STOP - SHUTTER DELAY

Indicates the instrument has been in shutter delay for more than 60 seconds without achieving rate control to within 5% of the desired deposition rate.

STOP - SOURCE CONFLICT

Indicates the instrument is stopped because a process is trying to START with two layers using the same source.

STOP - SOURCE SWITCH

Indicates the instrument is stopped due to a source switcher mechanical failure.

STOP - SWITCHER FAIL

Indicates the instrument is in the STOP state due to a CrystalSix sensor switcher failure.

STOP - TIME POWER

Indicates the instrument is in the STOP state because a layer completed in Time Power.

STOP - XTAL FAIL

Indicates the instrument is in the STOP state due to a crystal fail while in pre- or post-deposit, or while in deposit.

SWITCHER FAIL

Indicates that a mechanical failure of the crystal switcher has been detected.

SWITCHER ERR XTAL #

When using a CrystalSix sensor head, this error indicates the crystal position signal could not be detected at the number indicated. The absence of the position signal indicates a faulty CrystalSix sensor head and this position can no longer be accessed. The instrument will allow operation of a CrystalSix sensor having a bad position provided there are not two bad positions in a row. Two bad positions in a row will result in a Switcher Fail error message.

SWITCH IN PROGRESS

A crystal switch cannot be done unless the previous crystal switch is completed. A crystal switch is in progress until the XTAL SWITCHING message is taken down.

TEST

Indicates the instrument is in TEST mode as determined in Utility Set-Up.

2 TAGS ALREADY SET

While editing a layer this message indicates an attempt to Tag a layer after having already tagged two layers.

UNABLE TO AUTO Z #

Indicates the requested Auto Z measurement cannot be completed due to the crystal condition. This is caused by a weak or unstable first anharmonic measurement. This also may be caused by the instrument not recognizing the crystal as a new crystal, or inserting a used crystal.

UNABLE TO START

A START command cannot be processed while the display is on the I/O screens.

XTAL CANNOT EQUAL 0

A value in the XL Position parameter cannot be zero. For example, the sequence 135 is valid. The sequence 105 is not valid.

XTAL FAIL IN CAL

A crystal fail has occurred during automatic cross talk calibration.

XTAL FAIL #

Indicates the crystal at Sensor # is failed.

XTAL GREATER THAN 6

A value in the XL Position parameter cannot be greater than six. For example, the sequence 246 is valid. The sequence 247 is not valid.

XTAL SWITCHING

Indicates a crystal switch is in progress.

13.2 Troubleshooting Guide

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



CAUTION

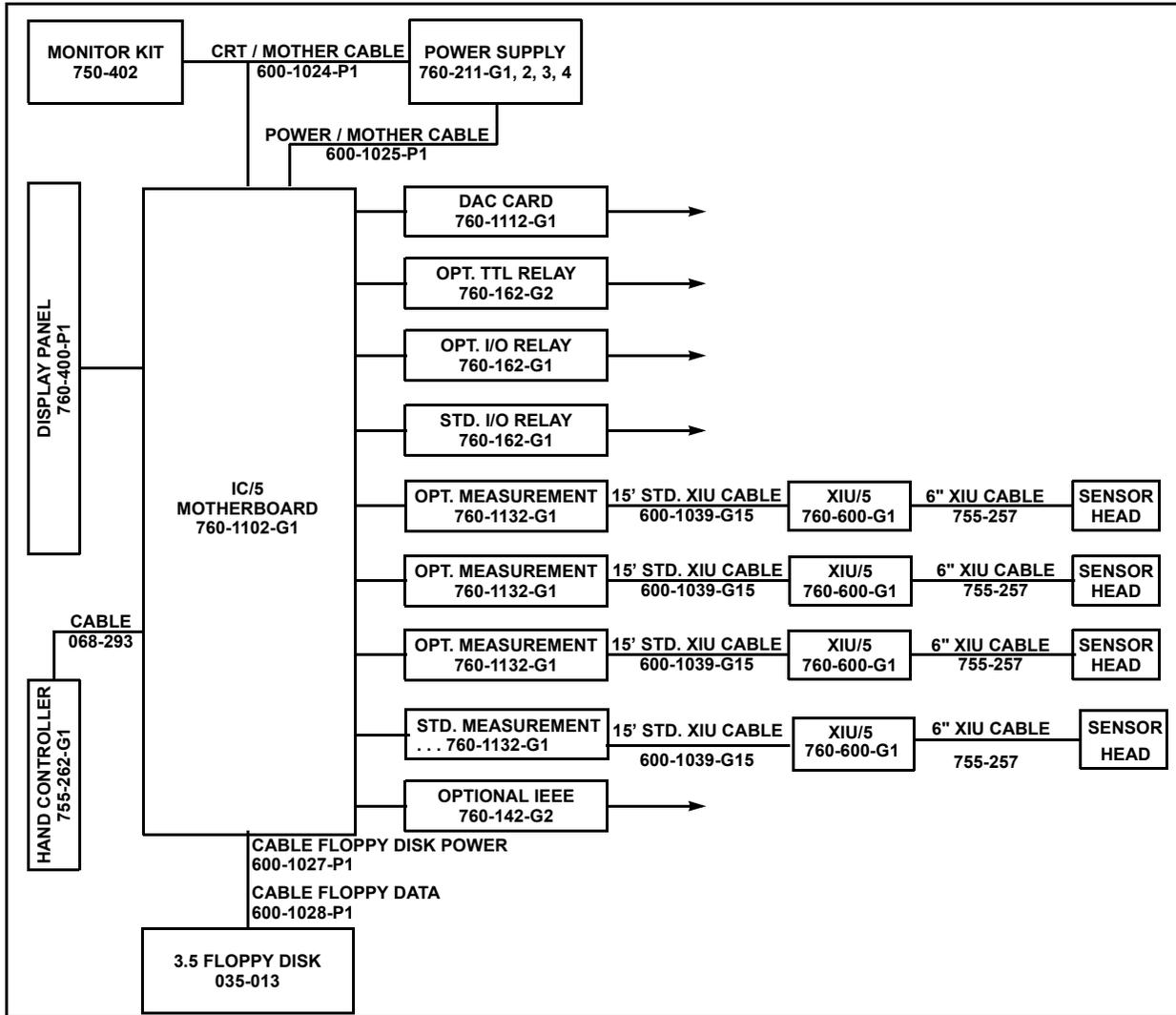
There are no user serviceable components within the instrument case.

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

Refer all maintenance to qualified personnel.

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.

13.2.1 Major Instrument Components and Assemblies



13.2.2 Troubleshooting the Instrument

Table 13-1 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. reconnect 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. reroute cables to reduce noise pickup (1 ft away from high power conducting lines makes a sizable reduction in the amount of noise entering the instrument), keep all ground wires short with large surface area to minimize ground impedance
	c. poor grounds or poor grounding practice	c. verify proper earth ground, use appropriate ground strap, eliminate ground loops by establishing the correct system grounding, verify proper instrument grounding
3. instrument does not retain parameters on power down (loss of parameters on power up)	a. faulty static RAM	a. SRAM battery has a normal life expectancy of ten years, contact INFICON service department
	b. power supply problem	b. contact INFICON service department
4. some keys on front panel function while others do not	a. faulty keypad or faulty keypad ribbon cable	a. contact INFICON service department

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Table 13-1 Troubleshooting the Instrument

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 the 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 desired
	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 instrument's measurement frequency

Table 13-1 Troubleshooting the Instrument

SYMPTOM	CAUSE	REMEDY
9 crystal fail message is always on	a. XIU/oscillator not connected	a. verify proper sensor/oscillator connections
	b. XIU/oscillator malfunctioning	b. if available, insert a known working XIU/oscillator in place of 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 DVIVI 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 DVIVI to check electrical continuity or isolation as appropriate
	e. failed crystal/no crystal	e. replace crystal/insert crystal
	f. two crystals placed into the crystal holder	f. remove one of the crystals
	g. frequency of crystal out of range	g. verify that the crystal frequency is within the required range, use INFICON crystals.

13.2.3 Troubleshooting Transducers/Sensors

NOTE: Many sensor head problems may be diagnosed with a (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 13.4 on page 13-28](#) for a discussion of its use and diagnostic capabilities.

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

Table 13-2 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 RunSaver™ 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 13-2 Troubleshooting Transducers/Sensors

SYMPTOM	CAUSE	REMEDY
2. crystal ceases to oscillate during deposition before it reaches its "normal" life	a. crystal struck by particulate or spatter" from molten source	a. thermally condition the source thoroughly before deposition, use a shutter to protect the crystal during source conditioning
	b. material on crystal holder partially masking crystal cover aperture	b. clean crystal holder
	c. existence of electrical short or open condition	c. using an ohm meter or DVM, check for electrical continuity in the sensor cable, connector, contact springs, connecting wire inside sensor, and feedthroughs
	d. check for thermally induced electrical short or open condition	d. see C above
<p>NOTE: Crystal life is highly dependent on process conditions of rate, power radiated from source, location, material, and residual gas composition.</p>		
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. bend leaves to approx. 45°
	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. cables/oscillator not connected, or connected to wrong sensor input	d. verify proper connections, and inputs relative to programmed sensor parameter

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Table 13-2 Troubleshooting Transducers/Sensors

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 tube 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

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Table 13-2 Troubleshooting Transducers/Sensors

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

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Table 13-2 Troubleshooting Transducers/Sensors

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

13.2.4 Troubleshooting Computer Communications

Table 13-3 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 (see Section 7.5)
	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 that 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

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Table 13-3 Troubleshooting Computer Communications

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 is 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 manual (placement of spaces within the command string is important)
	e. E = no data to retrieve	e. some parameters may not be in use, depending on the value of other parameters

Table 13-3 Troubleshooting Computer Communications

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 READYstate 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, use a faster CPU

13.3 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.

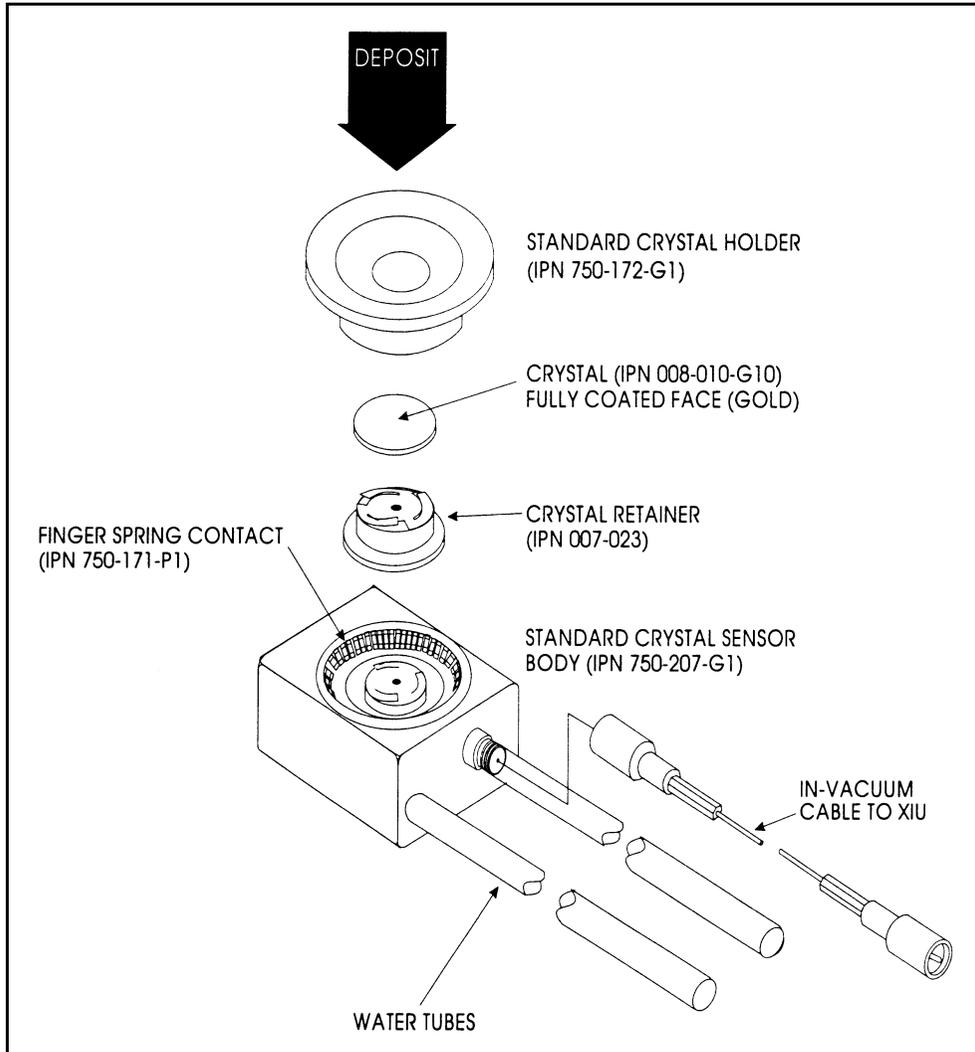
NOTE: Thick deposits of some materials, such as SiO₂, Si, and Ni will normally peel off the crystal when it is exposed to air, as a result of changes in film stress caused by gas absorption. When you observe peeling, replace the crystals.

13.3.1 Standard and Compact

Follow the procedure below to replace the crystal in the Standard and Compact sensor: (see [Figure 13-1](#))

- 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 the Crystal Snatcher; see [Figure 13-4 on page 13-27](#)).
- 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 13-1 Standard Crystal Sensor (Exploded)



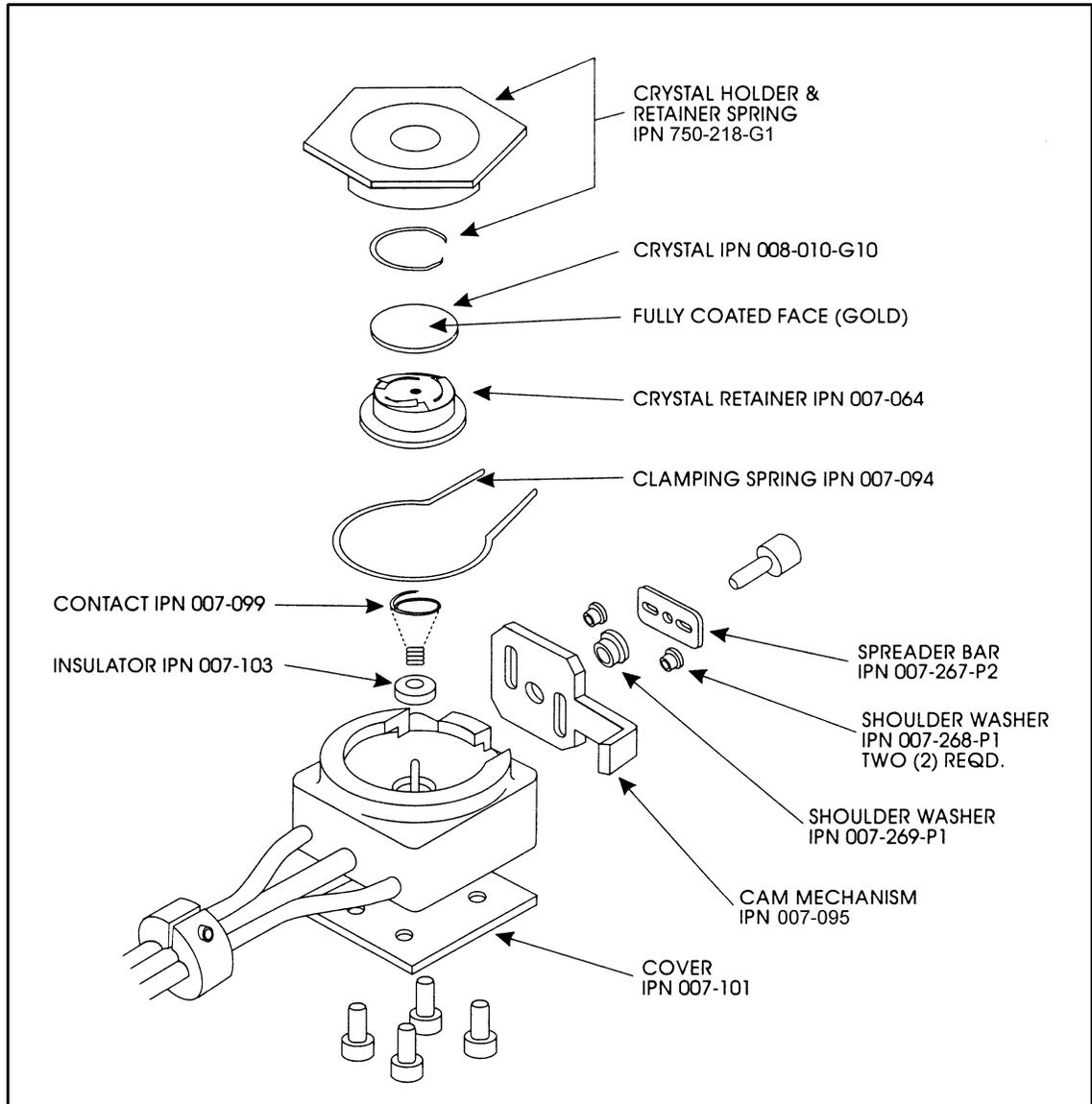
13.3.2 Shuttered and Dual Sensors

There is no difference in the crystal replacement 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.

13.3.3 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. See [Figure 13-2](#).

Figure 13-2 Bakeable Crystal Sensor



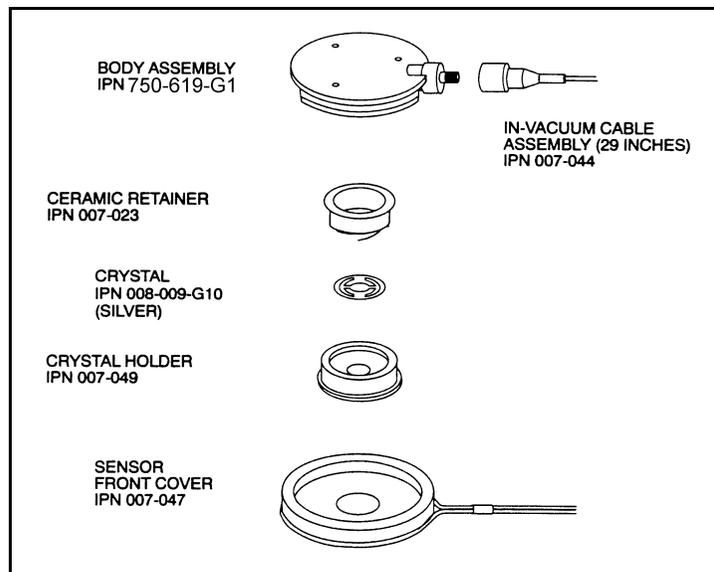
IPN 074-237AE

13.3.4 Sputtering Sensor

Observe the general precautions 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 13-3](#).
- 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 13.3.5 on page 13-27](#)).
- 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 13-3 Sputtering Crystal Sensor



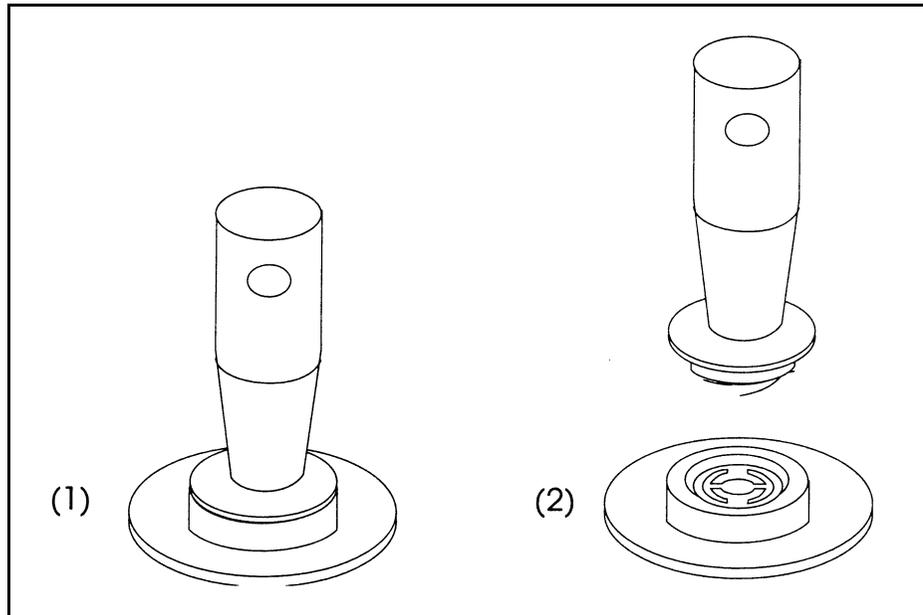
IPN 074-237AE

13.3.5 Crystal Snatcher

Use the crystal snatcher, supplied with the sensor, as follows:

- 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 Reinsert the retainer into the holder after the crystal has been replaced.
- 3 Release the crystal snatcher with a slight side-to-side motion.

Figure 13-4 Use of the Crystal Snatcher



13.3.6 CrystalSix

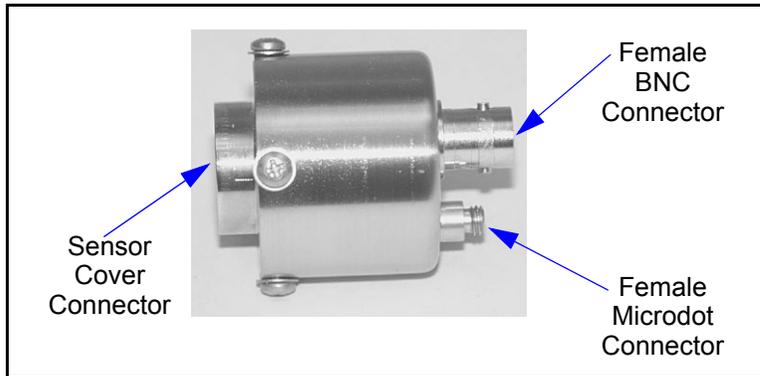
Refer to the Crystal Six Operating Manual (IPN 074-155) for specific instructions for this device.

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

NOTE: Crystal Sensor Emulator 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.

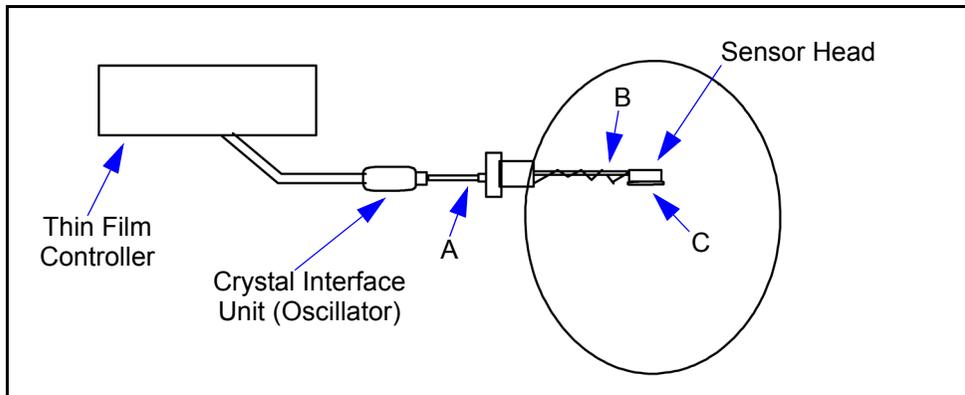
The Crystal Sensor Emulator option is used in conjunction with the Thin Film Deposition Controller to rapidly diagnose problems with the Deposition Controller's measurement system. See [Figure 13-5](#).

Figure 13-5 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 13-6](#).

Figure 13-6 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.

13.4.1 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.

13.4.1.1 Measurement System Diagnostic Procedure

- 1 Refer to [Figure 13-6 on page 13-28](#). 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 13.4.1.2](#).
 - ♦ 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. Refer to [section 1.3 on page 1-6](#).

13.4.1.2 Feed-Through Or In-Vacuum Cable Diagnostic Procedure

- 1 Refer to [Figure 13-6 on page 13-28](#). 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 13.4.1.3 on page 13-31](#).
 - ♦ 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.

13.4.1.3 Sensor Head Or Monitor Crystal Diagnostic Procedure

- 1** Remove the Crystal Cover from the Sensor Head.
- 2** Refer to [Figure 13-5 on page 13-28](#). Connect the Crystal Sensor Emulator to the Sensor Head at Point C.
 - ◆ If the XTAL Fail message disappears after approximately 5 sec. then the Sensor Head is operating properly. Re-insert the Crystal Cover into the Sensor Head and go to [section 13.4.1.3 on page 13-31](#).
 - ◆ 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. Refer to [section 1.3 on page 1-6](#).

- 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.

13.4.1.4 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.

13.4.2 % 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 30% for IC/5 deposition controllers which allow a 1.5 MHz frequency shift.

13.4.3 Sensor Cover Connection

The Crystal Sensor Emulator can be used to verify the measurement system for INFICON's Thin Film Deposition Controllers and Monitors.

NOTE: The Crystal Sensor Emulator 760-601-G1 is not compatible for use with an IC/5. Use 760-601-G2 for 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.

13.4.3.1 Compatible Sensor Heads

The Sensor Cover Connection will fit the sensor heads shown in [Table 13-4](#).

Table 13-4 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

13.4.3.2 Incompatible Sensor Heads

The Sensor Heads for which the Crystal Sensor Emulator's Sensor Cover Connector will not fit are shown in [Table 13-5](#).

Table 13-5 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	750-618-G1
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.

13.4.4 Specifications

Dimensions

1.58 in. diameter x 1.79 in.
(40.13 mm diameter x 45.47 mm)

Temperature Range

0 to 50 °C

Frequency

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

Materials

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

Appendix A

Material Table

A.1 Introduction

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

Code	Formula	Density	Z-Ratio	Material Name
0	Ag	10.500	0.529	Silver
1	AgBr	6.470	1.180	Silver Bromide
2	AgCl	5.560	1.320	Silver Chloride
3	Al	2.700	1.080	Aluminum
4	Al ₂ O ₃	3.970	0.336	Aluminum Oxide
5	Al ₄ C ₃	2.360	*1.000	Aluminum Carbide
6	AlF ₃	3.070	*1.000	Aluminum Fluoride
7	AlN	3.260	*1.000	Aluminum Nitride
8	AlSb	4.360	0.743	Aluminum Antimonide
9	As	5.730	0.966	Arsenic
10	As ₂ Se ₃	4.750	*1.000	Arsenic Selenide
11	Au	19.300	0.381	Gold
12	B	2.370	0.389	Boron
13	B ₂ O ₃	1.820	*1.000	Boron Oxide
14	B ₄ C	2.370	*1.000	Boron Carbide
15	BN	1.860	*1.000	Boron Nitride
16	Ba	3.500	2.100	Barium

Table A-1 Material Table (continued)

Code	Formula	Density	Z-Ratio	Material Name
17	BaF ₂	4.886	0.793	Barium Fluoride
18	BaN ₂ O ₆	3.244	1.261	Barium Nitrate
19	BaO	5.720	*1.000	Barium Oxide
20	BaTiO ₃	5.999	0.464	Barium Titanate (Tetr)
21	BaTiO ₃	6.035	0.412	Barium Titanate (Cubic)
22	Be	1.850	0.543	Beryllium
23	BeF ₂	1.990	*1.000	Beryllium Fluoride
24	BeO	3.010	*1.000	Beryllium Oxide
25	Bi	9.800	0.790	Bismuth
26	Bi ₂ O ₃	8.900	*1.000	Bismuth Oxide
27	Bi ₂ S ₃	7.390	*1.000	Bismuth Trisulphide
28	Bi ₂ Se ₃	6.820	*1.000	Bismuth Selenide
29	Bi ₂ Te ₃	7.700	*1.000	Bismuth Telluride
30	BiF ₃	5.320	*1.000	Bismuth Fluoride
31	C	2.250	3.260	Carbon (Graphite)
32	C	3.520	0.220	Carbon (Diamond)
33	C ₈ H ₈	1.100	*1.000	Parlyene (Union Carbide)
34	Ca	1.550	2.620	Calcium
35	CaF ₂	3.180	0.775	Calcium Fluoride
36	CaO	3.350	*1.000	Calcium Oxide
37	CaO-SiO ₂	2.900	*1.000	Calcium Silicate (3)
38	CaSO ₄	2.962	0.955	Calcium Sulfate
39	CaTiO ₃	4.100	*1.000	Calcium Titanate
40	CaWO ₄	6.060	*1.000	Calcium Tungstate
41	Cd	8.640	0.682	Cadmium
42	CdF ₂	6.640	*1.000	Cadmium Fluoride
43	CdO	8.150	*1.000	Cadmium Oxide
44	CdS	4.830	1.020	Cadmium Sulfide
45	CdSe	5.810	*1.000	Cadmium Selenide,
46	CdTe	6.200	0.980	Cadmium Telluride
47	Ce	6.780	*1.000	Cerium
48	CeF ₃	6.160	*1.000	Cerium (III) Fluoride
49	CeO ₂	7.130	*1.000	Cerium (IV) Dioxide

Table A-1 Material Table (continued)

Code	Formula	Density	Z-Ratio	Material Name
50	Co	8.900	0.343	Cobalt
51	CoO	6.440	0.412	Cobalt Oxide
52	Cr	7.200	0.305	Chromium
53	Cr ₂ O ₃	5.210	*1.000	Chromium (III) Oxide
54	Cr ₃ C ₂	6.680	*1.000	Chromium Carbide
55	CrB	6.170	*1.000	Chromium Boride
56	Cs	1.870	*1.000	Cesium
57	Cs ₂ SO ₄	4.243	1.212	Cesium Sulfate
58	CsBr	4.456	1.410	Cesium Bromide
59	CsCl	3.988	1.399	Cesium Chloride
60	CsI	4.516	1.542	Cesium Iodide
61	Cu	8.930	0.437	Copper
62	Cu ₂ O	6.000	*1.000	Copper Oxide
63	Cu ₂ S	5.600	0.690	Copper (I) Sulfide (Alpha)
64	Cu ₂ S	5.800	0.670	Copper (I) Sulfide (Beta)
65	CuS	4.600	0.820	Copper (II) Sulfide
66	Dy	8.550	0.600	Dysprosium
67	DY ₂ O ₃	7.810	*1.000	Dysprosium Oxide
68	Er	9.050	0.740	Erbium
69	Er ₂ O ₃	8.640	*1.000	Erbium Oxide
70	Eu	5.260	*1.000	Europium
71	EuF ₂	6.500	*1.000	Europium Fluoride
72	Fe	7.860	0.349	Iron
73	Fe ₂ O ₃	5.240	*1.000	Iron Oxide
74	FeO	5.700	*1.000	Iron Oxide
75	FeS	4.840	*1.000	Iron Sulphide
76	Ga	5.930	0.593	Gallium
77	Ga ₂ O ₃	5.880	*1.000	Gallium Oxide (B)
78	GaAs	5.310	1.590	Gallium Arsenide
79	GaN	6.100	*1.000	Gallium Nitride
80	GaP	4.100	*1.000	Gallium Phosphide
81	GaSb	5.600	*1.000	Gallium Antimonide
82	Gd	7.890	0.670	Gadolinium

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Table A-1 Material Table (continued)

Code	Formula	Density	Z-Ratio	Material Name
83	Gd ₂ O ₃	7.410	*1.000	Gadolinium Oxide
84	Ge	5.350	0.516	Germanium
85	Ge ₃ N ₂	5.200	*1.000	Germanium Nitride
86	GeO ₂	6.240	*1.000	Germanium Oxide
87	GeTe	6.200	*1.000	Germanium Telluride
88	Hf	13.090	0.360	Hafnium
89	HfB ₂	10.500	*1.000	Hafnium Boride,
90	HfC	12.200	*1.000	Hafnium Carbide
91	HfN	13.800	*1.000	Hafnium Nitride
92	HfO ₂	9.680	*1.000	Hafnium Oxide
93	HfSi ₂	7.200	*1.000	Hafnium Silicide
94	Hg	13.460	0.740	Mercury
95	Ho	8.800	0.580	Holmium
96	Ho ₂ O ₃	8.410	*1.000	Holmium Oxide
97	In	7.300	0.841	Indium
98	In ₂ O ₃	7.180	*1.000	Indium Sesquioxide,
99	In ₂ Se ₃	5.700	*1.000	Indium Selenide
100	In ₂ Te ₃	5.800	*1.000	Indium Telluride
101	InAs	5.700	*1.000	Indium Arsenide
102	InP	4.800	*1.000	Indium Phosphide
103	InSb	5.760	0.769	Indium Antimonide
104	Ir	22.400	0.129	Iridium
105	K	0.860	10.189	Potassium
106	KBr	2.750	1.893	Potassium Bromide
107	KCl	1.980	2.050	Potassium Chloride
108	KF	2.480	*1.000	Potassium Fluoride
109	KI	3.128	2.077	Potassium Iodide
110	La	6.170	0.920	Lanthanum
111	La ₂ O ₃	6.510	*1.000	Lanthanum Oxide
112	LaB ₆	2.610	*1.000	Lanthanum Boride
113	LaF ₃	5.940	*1.000	Lanthanum Fluoride
114	Li	0.530	5.900	Lithium
115	LiBr	3.470	1.230	Lithium Bromide

Table A-1 Material Table (continued)

Code	Formula	Density	Z-Ratio	Material Name
116	LiF	2.638	0.778	Lithium Fluoride
117	LiNbO ₃	4.700	0.463	Lithium Niobate
118	Lu	9.840	*1.000	Lutetium
119	Mg	1.740	1.610	Magnesium
120	MgAl ₂ O ₄	3.600	*1.000	Magnesium Aluminate
121	MgAl ₂ O ₆	8.000	*1.000	Spinel
122	MgF ₂	3.180	0.637	Magnesium Fluoride
123	MgO	3.580	0.411	Magnesium Oxide
124	Mn	7.200	0.377	Manganese
125	MnO	5.390	0.467	Manganese Oxide
126	MnS	3.990	0.940	Manganese (II) Sulfide
127	Mo	10.200	0.257	Molybdenum
128	Mo ₂ C	9.180	*1.000	Molybdenum Carbide
129	MoB ₂	7.120	*1.000	Molybdenum Boride
130	MoO ₃	4.700	*1.000	Molybdenum Trioxide
131	MoS ₂	4.800	*1.000	Molybdenum Disulfide
132	Na	0.970	4.800	Sodium
133	Na ₃ AlF ₆	2.900	*1.000	Cryolite
134	Na ₅ Al ₃ F ₁₄	2.900	*1.000	Chiolite
135	NaBr	3.200	*1.000	Sodium Bromide
136	NaCl	2.170	1.570	Sodium Chloride
137	NaClO ₃	2.164	1.565	Sodium Chlorate
138	NaF	2.558	0.949	Sodium Fluoride
139	NaNO ₃	2.270	1.194	Sodium Nitrate
140	Nb	8.578	0.492	Niobium (Columbium)
141	Nb ₂ O ₃	7.500	*1.000	Niobium Trioxide
142	Nb ₂ O ₅	4.470	*1.000	Niobium (V) Oxide
143	NbB ₂	6.970	*1.000	Niobium Boride
144	NbC	7.820	*1.000	Niobium Carbide
145	NbN	8.400	*1.000	Niobium Nitride
146	Nd	7.000	*1.000	Neodymium
147	Nd ₂ O ₃	7.240	*1.000	Neodymium Oxide
148	NdF ₃	6.506	*1.000	Neodymium Fluoride

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Table A-1 Material Table (continued)

Code	Formula	Density	Z-Ratio	Material Name
149	Ni	8.910	0.331	Nickel
150	NiCr	8.500	*1.000	Nichrome
151	NiCrFe	8.500	*1.000	Inconel
152	NiFe	8.700	*1.000	Permalloy
153	NiFeMo	8.900	*1.000	Supermalloy
154	NiO	7.450	*1.000	Nickel Oxide
155	P ₃ N ₅	2.510	*1.000	Phosphorus Nitride
156	Pb	11.300	1.130	Lead
157	PbCl ₂	5.850	*1.000	Lead Chloride
158	PbF ₂	8.240	0.661	Lead Fluoride
159	PbO	9.530	*1.000	Lead Oxide
160	PbS	7.500	0.566	Lead Sulfide
161	PbSe	8.100	*1.000	Lead Selenide
162	PbSnO ₃	8.100	*1.000	Lead Stannate
163	PbTe	8.160	0.651	Lead Telluride
164	Pd	12.038	0.357	Palladium
165	PdO	8.310	*1.000	Palladium Oxide
166	Po	9.400	*1.000	Polonium
167	Pr	6.780	*1.000	Praseodymium
168	Pr ₂ O ₃	6.880	*1.000	Praseodymium Oxide
169	Pt	21.400	0.245	Platinum
170	PtO ₂	10.200	*1.000	Platinum Oxide
171	Ra	5.000	*1.000	Radium
172	Rb	1.530	2.540	Rubidium
173	RbI	3.550	*1.000	Rubidium Iodide
174	Re	21.040	0.150	Rhenium
175	Rh	12.410	0.210	Rhodium
176	Ru	12.362	0.182	Ruthenium
177	S ₈	2.070	2.290	Sulphur
178	Sb	6.620	0.768	Antimony
179	Sb ₂ O ₃	5.200	*1.000	Antimony Trioxide
180	Sb ₂ S ₃	4.640	*1.000	Antimony Trisulfide
181	Sc	3.000	0.910	Scandium

Table A-1 Material Table (continued)

Code	Formula	Density	Z-Ratio	Material Name
182	Sc ₂ O ₃	3.860	*1.000	Scandium Oxide
183	Se	4.810	0.864	Selenium
184	Si	2.320	0.712	Silicon
185	Si ₃ N ₄	3.440	*1.000	Silicon Nitride
186	SiC	3.220	*1.000	Silicon Carbide
187	SiO	2.130	0.870	Silicon (II) Oxide
188	SiO ₂	2.648	1.000	Silicon Dioxide
189	Sm	7.540	0.890	Samarium
190	Sm ₂ O ₃	7.430	*1.000	Samarium Oxide
191	Sn	7.300	0.724	Tin
192	SnO ₂	6.950	*1.000	Tin Oxide
193	SnS	5.080	*1.000	Tin Sulfide
194	SnSe	6.180	*1.000	Tin Selenide
195	SnTe	6.440	*1.000	Tin Telluride
196	Sr	2.600	*1.000	Strontium
197	SrF ₂	4.277	0.727	Strontium Fluoride
198	SrO	4.990	0.517	Strontium Oxide
199	Ta	16.600	0.262	Tantalum
200	Ta ₂ O ₅	8.200	0.300	Tantalum (V) Oxide
201	TaB ₂	11.150	*1.000	Tantalum Boride
202	TaC	13.900	*1.000	Tantalum Carbide
203	TaN	16.300	*1.000	Tantalum Nitride
204	Tb	8.270	0.660	Terbium
205	Tc	11.500	*1.000	Technetium
206	Te	6.250	0.900	Tellurium
207	TeO ₂	5.990	0.862	Tellurium Oxide
208	Th	11.694	0.484	Thorium
209	ThF ₄	6.320	*1.000	Thorium.(IV) Fluoride
210	ThO ₂	9.860	0.284	Thorium Dioxide
211	ThOF ₂	9.100	*1.000	Thorium Oxyfluoride
212	Ti	4.500	0.628	Titanium
213	Ti ₂ O ₃	4.600	*1.000	Titanium Sesquioxide
214	TiB ₂	4.500	*1.000	Titanium Boride

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Table A-1 Material Table (continued)

Code	Formula	Density	Z-Ratio	Material Name
215	TiC	4.930	*1.000	Titanium Carbide
216	TiN	5.430	*1.000	Titanium Nitride
217	TiO	4.900	*1.000	Titanium Oxide
218	TiO ₂	4.260	0.400	Titanium (IV) Oxide
219	Tl	11.850	1.550	Thallium
220	TlBr	7.560	*1.000	Thallium Bromide
221	TlCl	7.000	*1.000	Thallium Chloride
222	TlI	7.090	*1.000	Thallium Iodide (B)
223	U	19.050	0.238	Uranium
224	U ₃ O ₈	8.300	*1.000	Tri Uranium Octoxide
225	U ₄ O ₉	10.969	0.348	Uranium Oxide
226	UO ₂	10.970	0.286	Uranium Dioxide
227	V	5.960	0.530	Vanadium
228	V ₂ O ₅	3.360	*1.000	Vanadium Pentoxide
229	VB ₂	5.100	*1.000	Vanadium Boride
230	VC	5.770	*1.000	Vanadium Carbide
231	VN	6.130	*1.000	Vanadium Nitride
232	VO ₂	4.340	*1.000	Vanadium Dioxide
233	W	19.300	0.163	Tungsten
234	WB ₂	10.770	*1.000	Tungsten Boride
235	WC	15.600	0.151	Tungsten Carbide
236	WO ₃	7.160	*1.000	Tungsten Trioxide
237	WS ₂	7.500	*1.000	Tungsten Disulphide
238	WSi ₂	9.400	*1.000	Tungsten Silicide
239	Y	4.340	0.835	Yttrium
240	Y ₂ O ₃	5.010	*1.000	Yttrium Oxide
241	Yb	6.980	1.130	Ytterbium
242	Yb ₂ O ₃	9.170	*1.000	Ytterbium Oxide
243	Zn	7.040	0.514	Zinc
244	Zn ₃ Sb ₂	6.300	*1.000	Zinc Antimonide
245	ZnF ₂	4.950	*1.000	Zinc Fluoride
246	ZnO	5.610	0.556	Zinc Oxide
247	ZnS	4.090	0.775	Zinc Sulfide

Table A-1 Material Table (continued)

Code	Formula	Density	Z-Ratio	Material Name
248	ZnSe	5.260	0.722	Zinc Selenide
249	ZnTe	6.340	0.770	Zinc Telluride
250	Zr	6.490	0.600	Zirconium
251	ZrB ₂	6.080	*1.000	Zirconium Boride
252	ZrC	6.730	0.264	Zirconium Carbide
253	ZrN	7.090	*1.000	Zirconium Nitride
254	ZrO ₂	5.600	*1.000	Zirconium Oxide
255		10.000	*1.000	USER

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