SENTINEL III
Deposition Controller
Technical Manual

JUNE 1989

LEYBOLD INFICON

East Syracuse, New York 13057 • Tel: (315) 437-0377 • TWX 710 541-0594 • TFX: 315-437-3803

PREFACE

This manual is intended for private use by Leybold Inficon Inc. and its customers. Contact Inficon before reproducing its contents.

USE OF THIS MANUAL

A table of contents and list of illustrations and tables located in the front of this manual provide easy access to any portion of the manual. Abbreviations and panel markings are referenced in the text exactly as they appear on the equipment.

When reading the Sentinel III Manual, please pay particular attention to the NOTES, CAUTIONS, and WARNINGS found throughout this text. For our purposes they are defined as follows:

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

CAUTION: ***Failure to heed these messages could result in damage to your instrument.***

WARNING!!

THE MOST IMPORTANT MESSAGES. FAILURE TO HEED COULD RESULT IN PERSONAL INJURY AND/OR SERIOUS DAMAGE TO YOUR INSTRUMENT.

We invite you to comment on the usefulness and accuracy of this manual by filling out the reply card and returning it to us.

WARNING!!

THE SENTINEL III USES MOS DEVICES IN ITS MEMORY CIRCUITS, WHICH MAY BE DAMAGED IF EXPOSED TO LARGE STATIC DISCHARGES. IF AT ANY TIME IT IS NECESSARY TO REMOVE A PRINTED CIRCUIT BOARD, FIRST TOUCH THE CHASSIS. HANDLE AND REMOVE THE BOARD TOUCHING ONLY THE OUTSIDE EDGE.

HANDLE OPTICAL COMPONENTS WEARING CLEAN WHITE COTTON GLOVES. FINGER-PRINTS OR DIRT ON FILTERS AND MIRRORS USED IN THE SENTINEL III MAY DRASTICALLY AFFECT THE INSTRUMENT'S PERFORMANCE. IF THESE COMPONENTS NEED CLEANING, USE CLEAN COTTON SWABS AND ALCOHOL.

WARRANTY

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

THIS WARRANTY IS MADE AND ACCEPTED IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, WHETHER OF MERCHANTABILITY OR OF FITNESS FOR A PARTICULAR PURPOSE OR OTHERWISE, AS BUYER'S EXCLUSIVE REMEDY FOR ANY DEFECTS IN THE PRODUCTS TO BE SOLD HEREUNDER. All other obligations and liabilities of Seller, whether in contract or tort (including negligence) or otherwise, are expressly EXCLUDED. In no event shall Seller be liable for any costs, expenses or damages, whether direct or indirect, special, incidental, consequential, or other, on any claim of any defective product, in excess of the price paid by Buyer for the product plus return transportation charges prepaid.

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

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

INFICON SERVICE DEPARTMENTS

SERVICE DEPARTMENT
Leybold Inficon Inc.
6500 Fly Road
East Syracuse, New York 13057-9714
(315) 434-1167
TWX: 710 541-0594
TFX: 315-437-3803

SERVICE DEPARTMENT
Leybold Inficon Inc.
1860 Hartog Drive
San Jose, California 95131
(408) 436-2828
TFX 408-436-2849

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LEYBOLD INFICON

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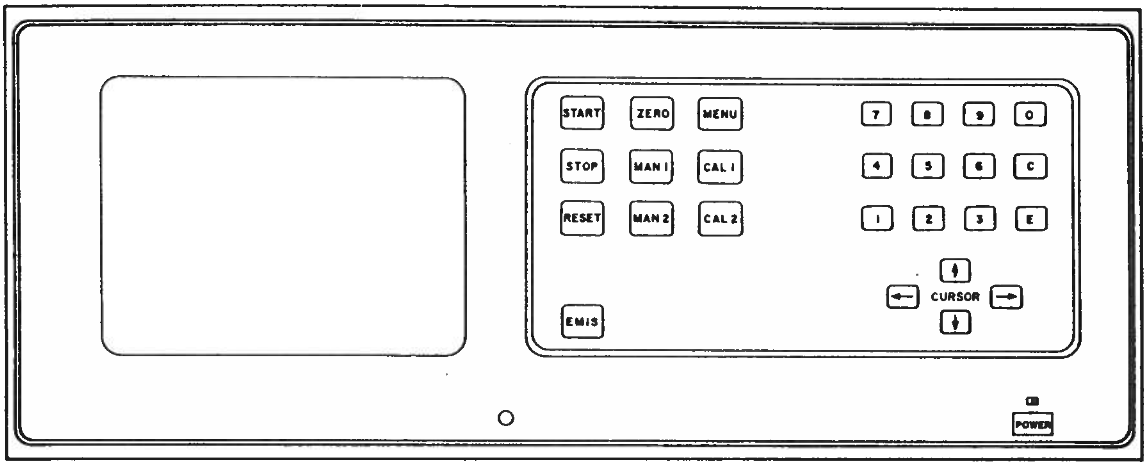


Figure 1.1 Sentinel III Operator's Console

1.0 INTRODUCTION TO THE SENTINEL III

The Sentinel III is an advanced alloy deposition process controller with Electron Impact Emission Spectroscopy (EIES) as its primary measurement transducer. The system hardware includes three subsystems.

The first subsystem is the Operator's Console Control Unit, used for all operator, system, and computer interfacing. This unit contains the Central Processor Unit (CPU), display CRT, and Keyboard.

The second subsystem is the Sensor Control Unit (SCU), providing the interface between the Operator's Console and the Sensor(s). This unit supplies power for two sensors and three Photomultiplier Tubes (PMT's). Currents from the PMT's are converted into voltages and sent to the Operator's Console for processing. This arrangement provides maximum flexibility and simplicity in the design and installation of the monitoring equipment.

The third subsystem is comprised of the Sensing components, including the Photomultiplier Tube, Feedthrough, and Sensors. These sensing components are supported by a full complement of rigid and flexible feedthroughs, discriminators, and detectors allowing custom installation for precise application.

SECTION 1
INTRODUCTION TO SENTINEL III

1.1 Specifications for the Sentinel III

GENERAL

Power Requirements	100/120/200/240/ VAC +5-10% 50/60/HZ, 150 VA
Operating Temp. (non-vacuum comp)	0° to 50°C
Warmup Time	5 min to max stability
Weight (shipping)	75 lbs.
Optical Measurement Channels	3
Control Channels	2
Crystal Measurement	1 (optional)
Measurement/Control Interval	125 mS (optical sensor) 250 mS (crystal sensor)
I/O SCAN Interval	250 mS
Display Update Interval	1 SEC
Control Output Volts (2 ch.)	0 to -10V or 0 to -5V @ 5 mÅ. 12 BIT RES
2 Channel Thickness Display	0 to 999.9 KiloAngstrom - Auto Ranged
Resolution	1 A
3 Channel Rate Display	0 to 999 Angstroms/Sec.
Resolution	0.1 Angstroms/Sec. @ Rates < 100 A/S 1.0 Angstroms/Sec. @ Rates ≥ 100 A/S
2 Chan Power Display	0 to 99%
Rate Control Resolution	0.1 Angstroms/Sec. any Rate
Analog Recorder Outputs	3 Channels Showing Rate -
Full Scale Calibration	0 to +10V
Resolution	0.1 Angstroms/Sec. @ Rates < 100 A/S 1.0 Angstroms/Sec. @ Rates ≥ 100 A/S
Remote Inputs	6 Fixed 6 Programmable
Activation	Contact Closure or 6 to 40V AC/DC
Relay Outputs	6 Fixed 6 Programmable
Ratings	1 Amp/120V Max.
Computer Interfaces	RS-232C (Standard) SECS II (Standard) IEEE-488 (optional)
Data Logging	RS-232C

OUTPUT INTERFACE

Type of Interface	Relay
Number of Outputs	12
Fixed function	6
User Programmable	6
Contact Ratings (MAX)	
Voltage	130V
Current	1 Amp
VA Rating	130
Isolation	250 Volts
Leakage Current (60 Hz)	0.5 mA @ 130V

INPUT INTERFACE

Type	Optical Isolator
Number of Inputs	12
Fixed Function	6
User Programmable	6
Activation	Contact Closure or Voltage / Current Source
Operating Ratings	
Voltage	8 to 40 VAC (RMS) or DC
Reference	Common Line for all Inputs
Isolation (Chassis)	1 KV
Impedance	820 ohms
Input Threshold	3 Volts
On Card Supply Ratings (MAX)	
Output Voltage	10V DC
Total Current Available	120 mA
Reference	Chassis Ground

AUTO CALIBRATION SYSTEM

Method	Crystal Measurement
Parameter Set	Material Density
	Material Z-Ratio
	System Tooling Factor
	Calibration Accuracy
Accuracy (Max)	1% Thickness
Elapsed Time (Min)	10 Sec
(Max)	99 Minutes
Dynamic Range	> 80 db
Initiation	Auto/Manual/External

OPTICAL DETECTION SYSTEM

# Channels	3
Method	Synchronous (500 Hz)
Bandwidth	8 Hz
Filtering	8 Pole Comb
Sensitivity (Max)	5 Angstrom/Nano Amp @ I/V Input
Gain Ranges	8
Gain Change/Range	~ 3.3
Digital Calibration Factor	0.500 to 2.500
Calibration Dynamic Range	80 db
Photomultiplier Type	Hammamatsu R-106 UH - Select
Voltage	750V
Regulation	0.1%

OPTICAL FILTER CHANGER

Method	Electro Mechanical Self Aligning
Filter Positions (Max)	4
Switching Time (Min)	3 Sec
(Max)	12 Sec
Operating Voltages	Dual Range 50/60 Hz VA (100 to 120) & (200 to 240)
Filter Dimensions	0.700 in. Diam.
Operating Distance (SCU to CHGR)	5 ft. (Std.) 30 ft. (Max)

CRYSTAL

Total Sensors	1
Usage	Calibration or Measurement
Base Frequency	6 MHz
Maximum Crystal Shift	1 MHz = 100% Life
Measurement Resolution	1 Angstrom/Measurement Interval @ Density = 1
Measurement Interval	250 mS
Thickness Accuracy	±1% over useful life

1.2 Specifications for the Sensors

1.2.1 EIES SENSOR/IN VAC CABLE

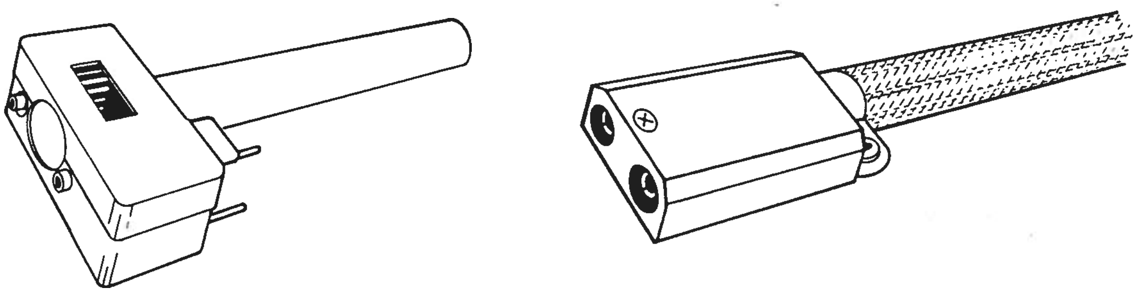


Figure 1.2 EIES Sensor/In-Vac Cable

GENERAL

Total Sensors (Max)	2 - simultaneous operation by 1 SCU
Sensitivity ([S+N])/S=2)	0.0025 Angstrom/Sec. Cu (Specified Test)
Operating Pressure (Max)	5x10^{-4} Torr
(Recommended)	< 5x10^{-6} Torr
Filament Life (Typical)	1000 Hrs
Material Type	Thoriated Iridium
Stability/Repeatability	±3.5% over 100 Hours
Linearity	2% per Decade
Emission Current (See Section 6.10 for instructions for adjusting emission current.)	4 mA Peak (nom), 500 Hz 2 mA User Option 0.1% Regulation
Electron Energy	180 Volts
Sensor Temperature (Max)	450°C
Materials	304 Stainless, Inconel x-750 Tantalum, Alumina Oxide
Size -	1.94" long 1.03" wide 0.81" high

MATERIALS

A. Insulators B. Grid C. Beamformer D. Filament brackets & pins E. Filament F. Balance of components & fasteners	a) High density aluminum oxide b) Tantalum c) Inconel x-750 d) 300 Series stainless steel e) Thoriated irridium f) 300 Series stainless steel

ELECTRICAL

A. Power requirement at 4 mA total emission at 180 V acceleration B. Electrical Connection C. Efficiency	a) 13 watts maximum b) 2 wire pluggable c) Minimum of 1.8 mA to collector for 4.0 mA total emission current.

TEMPERATURE

A. Maximum bakeout B. Operating temperature in room temperature ambient	a) 450°C continuous b) 180° to 250°C typical steady state depending on distance from filament

FEATURES

1. Deposition Cover 2. Emitter Exchange	1) Quick snap removal for heavy deposition use 2) Requires only cover removal, electrical plug removal and two screws.

EXPECTED OPERATING LIFE

1. Filament	1) 1000 hours minimum in a high vacuum environment. It is unknown if some high pressure materials may poison the cathode. Operation in Freon and other Halogenated hydrocarbon environments is not recommended.
2. Deposition Life	2) Limited only by build up of material on cover. 0.1 inch typical, depending on the material's tendency to close the material aperture.

IN-VACUUM CABLE SPECIFICATIONS

MATERIALS

A. Insulators B. Electrical contacts C. Conductors (2 ea.) D. Balance of components & fasteners	a) Aluminum oxide b) Be Copper c) 16ga Glidcop Al 15 d) 300 Series stainless steel

TEMPERATURE

A. Maximum bakeout	a) 450°C Continuous

1.2.2 2¾" FEEDTHROUGH

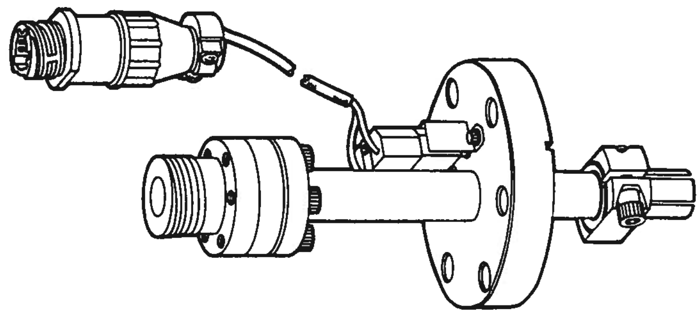


Figure 1.3

MATERIALS

A. Insulators	a) High density aluminum oxide to metal
B. Window	b) Optical grade sapphire
C. Conductors	c) 16ga Copper
D. Vacuum gaskets	d) OFHC Copper
E. Balance of components & fasteners	e) 300 Series stainless steel

TEMPERATURE

A. Maximum bakeout	a) 450°C continuous with external electrical and optical connections removed.

1.2.3 1" FEEDTHROUGH

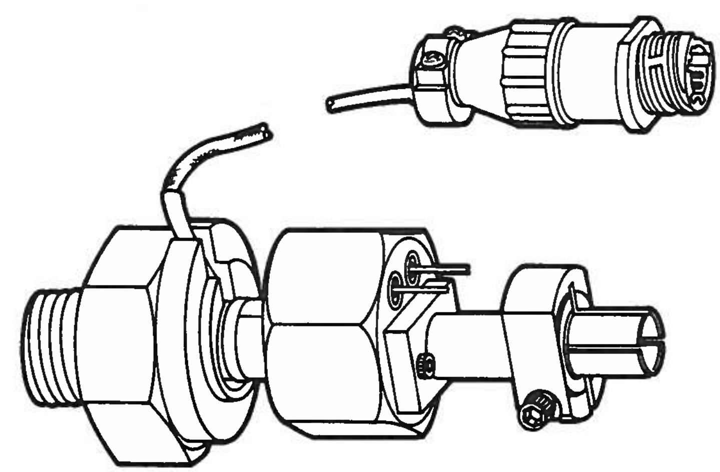


Figure 1.4 1" Feedthrough

MATERIALS

A. Insulators (electrical)	a) High density aluminum oxide to metal
B. Window	b) Optical grade quartz
C. Conductors	c) 16ga Copper
D. Vacuum seals	d) Viton O-Rings
E. Balance of components & fasteners	e) 300 Series stainless steel

TEMPERATURE

A. Maximum bakeout	a) 105°C continuous

1.2.4 FIBEROPTIC FEEDTHROUGH

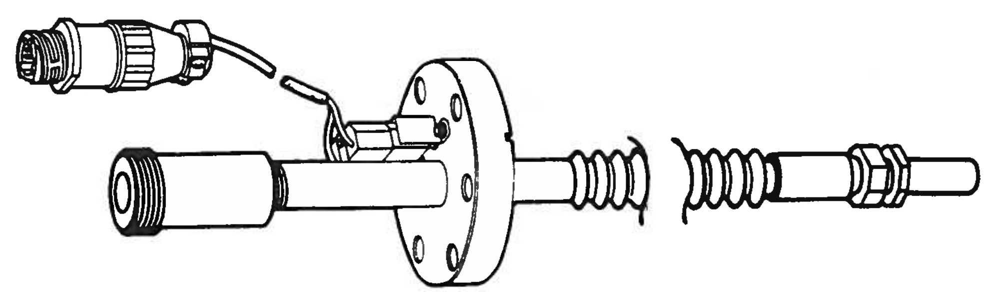


Figure 1.5 Fiberoptic Feedthrough

1.2.5 STANDARD CRYSTAL SENSOR

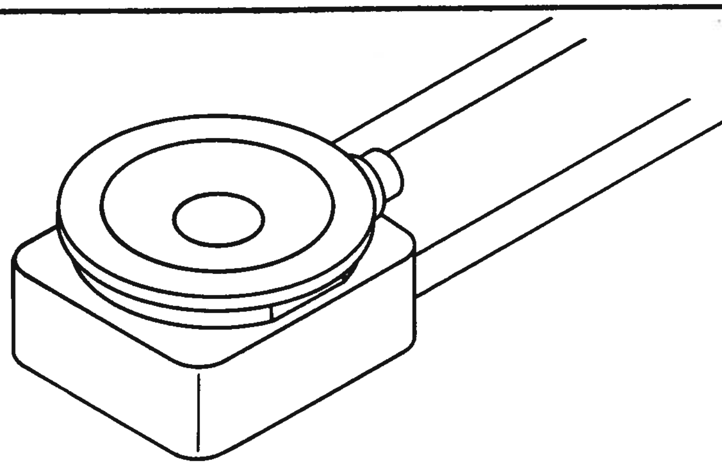


Figure 1.6 Standard Crystal Sensor

GENERAL

Maximum temperature	105°C
Size (maximum envelope)	1.063" (2.7cm)x2.35"(6cm)x0.60"(1.5cm) high
Water line and coax length	Standard 30" (76cm)
Crystal exchange	Front-loading, self-contained package for ease of exchange.
Mounting	Two #4-40 tapped holes on the back of the sensor body.

INSTALLATION

A. Feedthrough	a) 2 pass water with Microdot coax connector
B. Other	b) (1) Customer to provide vacuum-tight braze joints or connectors for the water lines. (2) Oscillator [IPN013-001] designed to interface with the XTC, IC-6000®, or Sentinel III deposition controllers.
	c) Water 150-200 cc/min, 30°C max

MATERIALS

A. Body and Holder	a) 304 type stainless steel
B. Springs	b) Au plated Be-Cu
C. Water lines	c) S-304, 0.125" (.32cm) OD
D. Connector (Microdot)	d) Stainless steel, teflon insulated
E. Insulators	e) >99% Al_2O_3
F. Wire	f) Teflon insulated copper
G. Braze	g) Vacuum process high temperature Ni-Cr alloy
H. Crystal	h) 6.0 MHz, AT-cut plano-convex with Au overcoat and Cr adhesion layer

1.2.6 COMPACT CRYSTAL SENSOR

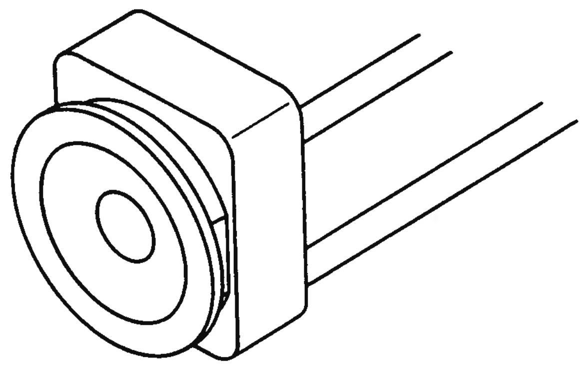


Figure 1.7 Compact Crystal Sensor

GENERAL

Maximum temperature	105°C
Size (maximum envelope)	1.063" (2.7cm)x2.35"(6cm)x0.60"(1.5cm) high
Water line and coax length	Standard 30" (76cm)
Crystal exchange	Front-loading, self-contained package for ease of exchange.
Mounting	Two #4-40 tapped holes on the back of the sensor body.

INSTALLATION

A. Feedthrough	a) 2 pass water with Microdot coax connector
B. Other	b) (1) Customer to provide vacuum-tight braze joints or connectors for the water lines. (2) Oscillator [IPN013-001] designed to interface with the XTC, IC-6000®, or Sentinel III deposition controllers. c) Water 150-200 cc/min, 30°C max

MATERIALS

A. Body and Holder	a) 304 type stainless steel
B. Springs	b) Au plated Be-Cu
C. Water lines	c) S-304, 0.125" (.32cm) OD
D. Connector (Microdot)	d) Ni plated steel, teflon insulated
E. Insulators	e) >99% Al_2O_3
F. Wire	f) Teflon insulated copper
G. Braze	g) Vacuum process high temperature Ni-Cr alloy
H. Crystal	h) 6.0 MHz, AT-cut plano-convex with Au overcoat and Cr adhesion layer

SECTION 1
INTRODUCTION TO SENTINEL III

1.2.7 BAKEABLE CRYSTAL SENSOR

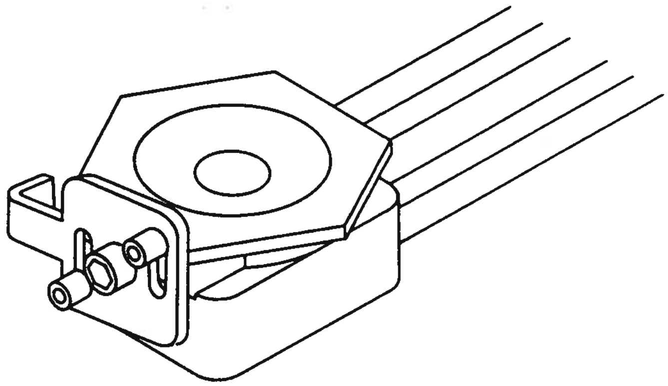


Figure 1.8 Bakeable Crystal Sensor

GENERAL

Maximum temperature	450°C continuous (for bake only; water flow recommended for actual deposition monitoring)
Size (maximum envelope)	1.35″ (3.4cm)x1.38″(3.5cm)x0.94″(2.4cm) high
Water line and coax length (from face of feedthrough to center or crystal)	a) Standard (1) 30″ (76cm) IPN 007-209 (2) 20″ (50.8cm) IPN 007-208 (3) 12″ (30.5cm) IPN 007-207
Crystal exchange	Front-loading, self-contained package for ease of exchange. CAM type locking handle allows easy removal and good thermal contact.
Mounting	a) Standard - four #4-40 tapped holes on the back of the sensor body b) Optional - right angle bracket

INSTALLATION

A. Feedthrough B. Other	a) 2¾″ ConFlat, integral with sensor head b) (1) Oscillator [IPN 013-001] designed to interface with the XTC, IC-6000®, or Sentinel III deposition controllers. (2) Water and coax lines are semi-rigid, but easily formed (min. Radius = ½″) c) Water 150-200 cc/min, 30°C max (Customer should provide means of easily disconnecting the ¼″ water lines during bakeout.

MATERIALS

A. Body and Holder	a) 304 type stainless steel
B. Springs	b) Molybdenum & Inconel X-750
C. Water and coax lines	c) S-304, 0.125″ (.32cm) OD water 0.188″ (.5cm) OD coax
D. Other mechanical parts	d) 18-8 or 304 stainless steel
E. Insulators	e) >99% Al_2O_3 in vacuum; other high density ceramics used elsewhere
F. Wire	f) (1) Ni (in vacuum) (2) Ni plated Cu (elsewhere)
G. Braze	g) Vacuum process high temperature Ni-Cr alloy
H. Crystal	h) 6.0 MHz. AT-cut plano-convex with Au overcoat and Cr adhesion layer

1.2.8 SHUTTERED BAKEABLE CRYSTAL SENSOR

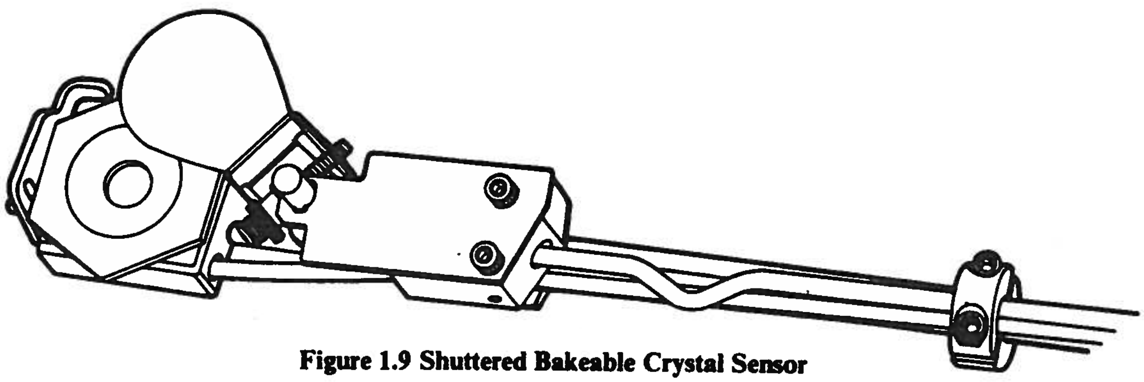


Figure 1.9 Shuttered Bakeable Crystal Sensor

GENERAL

Maximum temperature	450°C continuous (for bake only; waterflow recommended for actual deposition monitoring)
Size (maximum envelope)	1.35" (3.4cm)x1.38"(3.5cm)x0.94"(2.4cm) high
Water line and coax length (from face of feedthrough to center or crystal)	a) Standard (1) 30" (76cm) IPN 007-209 (2) 20" (50.8cm) IPN 007-208 (3) 12" (30.5cm) IPN 007-207
Crystal exchange	Front-loading, self-contained package for ease of exchange. CAM type locking handle allows easy removal and good thermal contact.
Mounting	a) Standard - four #4-40 tapped holes on the back of the sensor body b) Optional - right angle bracket

INSTALLATION

A. Feedthrough B. Other	a) 2¾" ConFlat, integral with sensor head b) (1) Oscillator [IPN 013-001] designed to interface with the XTC, IC-6000®, or Sentinel III deposition controllers. (2) Water and coax lines are semi-rigid, but easily formed. c) Water 150-200 cc/min, 30°C max (Customer should provide means of easily disconnecting the ¼" water lines during bakeout.

MATERIALS

A. Body and Holder	a) 304 type stainless steel
B. Springs	b) Molybdenum & Inconel X-750
C. Water and coax lines	c) S-304, 0.125" (.32cm) OD water 0.188" (.5cm) OD coax
D. Other mechanical parts	d) 18-8 or 304 stainless steel
E. Insulators	e) >99% Al_2O_3 in vacuum; other high density ceramics used elsewhere
F. Wire	f) (1) Ni (in vacuum) (2) Ni plated Cu (elsewhere)
G. Braze	g) Vacuum process high temperature Ni-Cr alloy
H. Crystal	h) 6.0 MHz, AT-cut plano-convex with Au overcoat and Cr adhesion layer
I. Materials	i) 60-80 psi operation; 100 psi max
J. Shutter	j) Pneumatically operated. Swings with piston activated cam, springs returned. Shutter swings out of way for easy crystal exchange.

1.2.9 CRYSTAL SENSOR SHUTTER

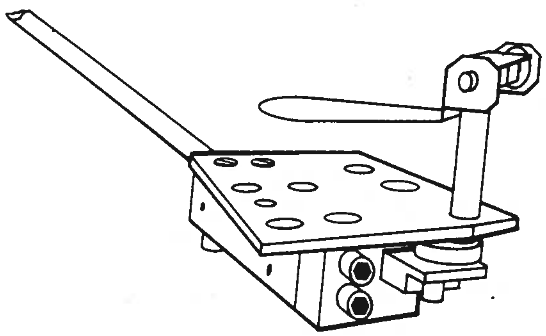


Figure 1.10 Crystal Sensor Shutter

Temperature Materials	450°C Bakeout, 300°C operation 300 series stainless steel 60-80 psi operation; 100 psi max
Shutter	Pneumatically operated. Swings with piston activated cam, spring returned. Shutter swings out of way for easy crystal exchange.
Braze	Vacuum process hi temp Ni-CR Alloy

1.2.10 EIES FILTER SPECIFICATIONS

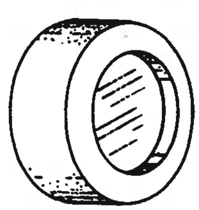


Figure 1.11 Optical Filter

GENERAL

Temperature range (storage)	-40°C to 60°C
Blocking range	180 to 1000 nm
Blocking value	less than 1×10^{-5} absolute
Size	0.700" diameter

STORAGE

It is recommended that unused filters be stored in their dessicator shipping container.

OPTICAL

Optical filters are customer fabricated for each material. The basic design is two cavity bandpass generally using all dielectric materials. General specifications for each material follow:

Material	Wavelength (Å)	Bandpass (HPHW)	IPN
Ag	3281	20	011-301
Al	3961.5	12	011-302
Ar	4596	25	011-339
Au(1)	2676	15	011-304
Au(2)/Co	2428	35	011-305
Cd	3261	18	011-324
Cr	3605.5	15	011-317
CO_2	2890	25	011-337
Cu	3247.5	20	011-306
Er	4008	20	011-328
Fe	3720	18	011-307
Ga	4170	30	011-308
He	5016	25	011-342
H_2O	3100	40	011-319
In	4511	20	011-326
Mn	2798	20	011-336
Mo	3133	20	011-309
N_2	3914	25	011-340
Ni	3415	15	011-310
O_2	2594	30	011-341
Pb/Ti	3637.5	25	011-311
Pd	2455	35	011-332
Sc	4020.5	20	011-330
Si(2)	2520	45	011-327
Sn	3175	18	011-314
Ta/Ge	2650	32	011-338
Ti(2)	3982	25	011-331
U238/Nb	3582	20	011-318
V	3184	16	011-329
W	2551	25	011-335
Y	4077	20	011-321
Zr/Hf	2983	15	011-345

TABLE OF WAVELENGTHS FOR THIN FILM FILTERS SUPPLIED BY INFICON

CHEMICAL	CHEMICAL SYMBOL	WAVE-LENGTH	1/2 BAND WIDTH (Å)	MINIMUM % TRANS	INFICON PART NO.
Aluminum	Al	3961	12	15%	011-302
Argon	Ar/Sr	4596	25	20%	011-339
Barium	Ba	3072	40	8%	011-346
Barium (2)	Ba(2)	3500	30	15%	011-348
Boron	B	2496	35	10%	011-601
Cadmium	Cd	3261	18	18%	011-324
Calcium	Ca	4226	15	15%	011-600
Carbon Dioxide	CO_2	2890	25	8%	011-337
Chromium	Cr	3605	15	25%	011-317
Cobalt	Au(2)/Co	2428	35	6%	011-305
Copper	Cu	3247	20	18%	011-306
Europium	Er	4008	20	15%	011-328
Gallium	Ga	4170	30	15%	011-308
Germanium	Ta/Ge	2650	32	8%	011-338
Gold(1)	Au(1)	2676	15	6%	011-304
Gold(2)	Au(2)/Co	2428	35	6%	011-305
Hafnium	Zr/Hr	2983	15	7%	011-345
Helium	He	5016	25	20%	011-342
Indium	In	4511	20	15%	011-326
Iron	Fe	3720	18	6%	011-307
Lanthanum	Sm/La	4422	20	15%	011-347
Lead	Pb/Ti	3937	25	25%	011-311
Manganese	Mn	2796	20	8%	011-336
Molybdenum	Mo	3133	20	7%	011-309
Nickel	Ni	3415	15	22%	011-310
Niobium	U238/Nb	3582	20	7%	011-318
Nitrogen	N_2	3914	25	20%	011-340
Oxygen	O_2	2594	30	7%	011-341
Palladium	Pd	2455	35	10%	011-332
Platinum	Pt	2659	25	7%	011-343
Rhenium	Re	2275	30	4%	011-349
Samarium	Sm/La	4422	20	15%	011-347
Scandium	Sc	4020	20	15%	011-330
Silicon(2)	Si(2)	2520	45	8%	011-327
Silver	Ag	3281	20	6%	011-301
Strontium	Ar/Sr	4596	25	20%	011-339
Tantallum	Ta/Ge	2650	32	8%	011-338
Tin	Sn	3175	18	7%	011-314
Titanium	Pb/Ti	3637	25	25%	011-311
Titanium(2)	Ti(2)	3982	25	8%	011-331
Tungsten	W	2551	25	8%	011-335
Uranium	U238/Nb	3582	20	7%	011-318
Vanadium	V	3184	16	5%	011-329
Water	H_2O	3100	40	8%	011-319
Yttrium	Y	4077	20	12%	011-321
Zinc	Zn	2025	—	>5%	011-344
Zirconium	Zr/Hf	2985	15	7%	011-345

1.3 Installation Guide

These instructions are intended as a guide to sections of the Sentinel III manual pertinent to initial installation. This will enable a quick and easy installation without a time consuming search of the manual. In this context, the Sentinel III theory of operation will not be discussed other than a brief overview.

1.3.1 BRIEF OVERVIEW OF SENTINEL III OPERATION

The Sentinel III uses the EIES sensor as its primary sensing technique. The EIES sensor provides a relative measure of the deposited material vapor density by inducing an optical emission. The intensity of this optical signal can then be calibrated to any known reference. Although the EIES sensor may be calibrated to any reference, as a convenience to our customers we have incorporated into the Sentinel III the ability to input a Quartz Crystal. The Quartz Crystal may be used as an in-situ reference and allows calibration of the EIES sensor signal to the Quartz Crystal.

NOTE:	The Quartz Crystal sensor and associated components are an option with the Sentinel III purchase.

1.3.2 INITIAL INSPECTION -- Complete the following steps first.

1. Section 1.4 of the Sentinel III manual describes the initial inspection and inventory procedure. At this time please check to ensure there is no damage to the instrument or its components. Refer to the parts list in Section 1.4 to be certain you have received all of the items purchased.

2. Having completed the inventory procedure, continue to Sections 1.5 through 1.7.

   Sect. 1.5: Lists the items needed to turn the unit on for initial power up.

   Sect. 1.6: Explains how to set up the Sentinel III Operator's console for the proper line voltage.

   Sect. 1.7: Describes how to power up the unit to verify proper operation. On initial power up it is recommended to reset the Sentinel III memory to the standard factory set conditions. Do this by following the 4 steps listed at the end of Section 1.7.

This completes the initial inspection procedure. You are now ready to proceed with the installation of the EIES Sensor.

1.3.3 EIES SENSOR INSTALLATION

This is the most crucial step to a successful Sentinel III installation. Refer to Figure 5.7 for a blow-up drawing of the EIES sensor.

DETERMINE EXACT LOCATION

At this time you must determine the exact location where the EIES sensor is to be placed. Section 3.1 describes the correct placement of the EIES sensor relative to the source. Refer to figures 3.1 and 3.2 and the diagram at the back of this guide.

NOTE:	It is imperative that during deposition material flux is able to pass through the EIES sensor. ***DO NOT MASK*** the EIES sensor opening by placing it behind obstructions.

NOTE:	If you have a Rigid Feedthrough Package (IPN 753-002-G4 or 753-002-G5) there must be a direct line of sight between the EIES sensor and feedthrough. If you have one of the Fiber-Optic Feedthrough Packages you must not bend the flexible housing in less than a 4" radius, otherwise the fiber will break.

a. *MOUNTING EIES SENSOR - RIGID FEEDTHROUGHS*

Once the location of the EIES sensor is determined: If you have a rigid feedthrough, refer to Section 3.2. If you have a fiber-optic feed-through, refer to Step "b" below.

NOTE:	We suggest you do not bolt the Feedthrough to your chamber until recommended to do so in this procedure.

Section 3.2.1 of this manual describes mounting the sensor. After having mounted the EIES sensor, determine the length between the inside face of the feedthrough and the EIES sensor. Cut the 1/2" diameter stainless steel tube to the appropriate length. This is your light pipe. The light pipe will fit inside the slotted tube extending from the Rigid Feedthrough and into the slotted tube on the EIES sensor.

Section 3.2.2 details how to assemble the In-Vacuum cable. Figure 3.7 illustrates the assembly of the cable. Use the "cutting chart" to determine the length of items 2 and 4. The total length of the In-Vacuum cable is the length between the inside face of the feedthrough and the EIES sensor connector pins. After assembling the In-Vacuum Cable, use an ohmmeter to check electrical continuity for each wire. Also check that the wires are electrically isolated from each other and each wire is isolated from the connector body.

Part "b" of Section 3.2.2 describes the use of the quartz light guide. This is an optional piece of equipment which is not sold by Inficon. Figure 3.6 is a guideline drawing for the fabrication of a light guide and is provided for customer reference.

Once you have verified that the In-Vacuum Cable is properly assembled, connect the cable to the Feedthrough and bolt the Feedthrough to the chamber. Install the light pipe into the feedthrough and into the EIES sensor and mount the EIES sensor securely, using the clamps provided.

b. MOUNTING EIES SENSOR - FIBER-OPTIC FEEDTHROUGHS

If you have a Fiber-optic Feedthrough refer to Section 3.2.3. The In-Vacuum cable is already assembled for the Fiber-optic Feedthrough Package.

1.3.4 INSTALLATION OF THE OPTIONAL SHUTTERED CRYSTAL SENSOR

As stated previously, the Quartz Crystal is an option which provides an in-situ reference to which the EIES sensor can be calibrated. Refer to Section 3.2.4 for installation instructions. Section 5.1.3 also discusses shutter maintenance.

This completes the in-vacuum portion of the installation. If your process allows, an aluminum foil wrap around the in-vacuum components can aid subsequent cleaning of the components. Care must be taken to avoid covering the opening of the EIES sensor, or shorting electrical connections.

1.3.5 INSTALLATION OF THE SENSOR CONTROL UNIT AND PHOTOMULTIPLIER TUBE

Refer to Section 3.5 for considerations for Grounding the Sentinel III. Sections 3.3.1 through 3.3.3 detail considerations for the location and installation of the Sensor Control Unit (SCU) and Photomultiplier Tube (PMT). Be certain that you have the correct optical filter in the PMT housing prior to placing the PMT onto the Feedthrough. The Sensor Power Cable (IPN 753-011-G5) is connected from J11 on the SCU to the Sensor Feedthrough Cable (IPN 016-394-G1) which in turn is connected to the two pins on the EIES Sensor feedthrough.

NOTE: On the SCU, Sensor drive 2 is the primary output for sensor power. If you are driving two EIES sensors refer to Section 2.2.2. Also connect the PMT high voltage cable, IPN 753-010-G5, to J7 on the SCU and the PMT signal cable, IPN 753-009-G5, to J4 (Channel 1) on the SCU. Finally, connect the control cable, IPN 753-205-G30, from J3 on the SCU to the SCU Interface connection on the SCU CTL board at the rear of the Sentinel III.

1.3.6 INSTALLING OPTIONS

Refer to Section 3.4 for information concerning the installation of options such as Double-Ended Sensor Adapter, Beam Splitter, Filter Changer, and IEEE-488.

1.3.7 PROGRAMMING THE SENTINEL III

After completing the installation of the EIES Sensor, Sensor Control Unit and the Operator's Console, you are now ready to begin programming the Sentinel III.

a. Connect the manual source power control cable, IPN 006-016, to the back of the Sentinel III Operator's Console. The connector is located on the Deposition Control board at the back of the unit. Also connect the source control voltage cable. This cable, IPN 753-020-G35 is connected from the "CH.1 CTL" output at the rear of the unit to the source power supply input.

b. Turn the Sentinel III on. If you have not reset the Sentinel III memory to the standard factory set conditions as described in Section 1.7, do so now.

c. At the bottom right of the video display will appear an "emission" message. Do not turn the emission to the EIES sensor on unless your vacuum chamber is lower than 5.0×10^{-4} torr. Press the RESET button on the front of the Operator's Console. If your chamber is at the proper pressure, turn the emission on by pressing the button labeled "EMIS" on the front of the console. If the electronics cannot regulate the emission of the EIES sensor, an "emission error" message will appear at the top right of the video display. If this message appears, check for electrical continuity and isolation of the EIES sensor and In-Vacuum Cable as described in Section 1.3.3. If the emission current is regulated properly, the message will not appear.

d. If you do not have a Quartz Crystal installed on your system, skip to paragraph "e." below. If you have a Quartz Crystal sensor (optional) installed in your system, connect the oscillator cable to the input on the Deposition Control Board, then to the crystal oscillator. Next, connect the cable from the crystal oscillator to the BNC connector on the crystal feedthrough. This cable should be as short as possible.

   The purpose of the following steps is a rough calibration of the EIES sensor to the Quartz Crystal. This will be accomplished by making Channel 2 a Crystal channel to monitor the actual flux (i.e., accepts Crystal information and not EIES information) while concurrently making Channel 1 an EIES channel to monitor the relative flux.

   To do this, go to Menu 4, the Executive Menu. (Press "MENU", then "4"). The only parameter to change is the XTAL DISABLED parameter. Change this by moving the cursor into the appropriate position and press "0" then "E". (E = enter). Cursor movement is accomplished via the four arrows located on the front panel. This will change the XTAL DISABLED parameter from YES to NO.

   Next, change the density and z-ratio parameters in the film menu. Do this by going to Menu 2. (Press "MENU", then "2"). The cursor position is now at the FILM # parameter. Change the FILM # parameter from 1 to 2. (Press "2", then "E"). Move the cursor to the DENSITY parameter and enter the density for the material you wish to deposit, also enter the Z-RATIO value. Finally, move the cursor to the XTAL MEAS parameter at the bottom of the right column of the Film menu. Change this parameter from NO to YES. (Press "1", then "E"). Go back to the FILM # parameter and change the film number from 2 to 1 and enter into Film 1 the appropriate density and z-ratio values. Enter only the density and z-ratio values, do not change the XTAL parameter on Film 1 as was done on Film 2. You wish to keep Film 1 an EIES channel. Now return to the MENU display.

e. Press "1" for the DATA display.

NOTE:	Be certain you have the signal cable from the PMT input into channel 1 on the SCU.

   Press the MAN 1 button to place the unit into the MANUAL phase, turn on your evaporation source power supply, and increase the power level to the source using the Manual Source Power Controller until the correct deposition rate is reached.

Determine this rate by either the power level of your power supply (knowing from previous experience the power level at which you normally run your process), the reference you normally use, or the Quartz Crystal if you have one in your system. As stated previously, the EIES sensor provides a relative measure of the flux which can be calibrated to a reference. The EIES sensor is not calibrated at this time and therefore the displayed rate is not accurate. Now, knowing approximately the rate being deposited, you can roughly calibrate the EIES sensor by adjusting the PMT RANGE parameter in FILM 1. Holding the power level constant, go to the FILM 1 menu and adjust the PMT RANGE value from 8 downward, by increments of 1, until the rate displayed by the EIES sensor approximately matches the rate at which you are depositing. Press MENU 2 to go to the FILM UPDATE menu. In FILM 1 enter the rate you wish to deposit at the parameter RATE BGN. Also enter into the FINL THCK parameter a value of 100.0 kA. Entering a large final thickness will allow the unit to remain in the DEPOSIT phase while calibration and control loop adjustments are made. The fine calibration is done by adjusting the PMT CALIB parameter. This is accomplished via the procedure outlined in section 4.3 of the manual, or if you have a Quartz Crystal in your system simply press the Manual button again to place the instrument into the DEPOSIT phase and press CAL 1. The instrument will calibrate automatically. The setting of the control loop parameters is described in Section 2.6.4.

This completes the initial installation and startup procedure. For more detailed information concerning programming the instrument and theory of operation, read Sections 2 and 4 of the Sentinel III manual.

1.4 Unpacking, Initial Inspection And Inventory

1.4.1 UNPACKING AND INSPECTION PROCEDURES

1. If you haven't removed the Sentinel III from its shipping containers, do so now.

2. Carefully examine the unit for damage that may have occurred during shipping. This is especially important if you notice signs of obvious rough handling on the outside of the cartons. REPORT ANY DAMAGE TO THE CARRIER AND TO INFICON IMMEDIATELY.

3. DO NOT discard any packing materials until you have taken inventory and completed the check procedures.

1.4.2 INVENTORY

Make sure you have received all of the necessary equipment by checking the contents of the shipping containers with the parts list below.

PARTS LISTING

Qty	Part	IPN #
CONTROLLER PACKAGE		
Sentinel III One Material System		753-002-G1 Note 1
(1)	Sentinel Control Unit	753-003-G1
(1)	Sensor Control Unit	753-200-G1
(1)	Ship Kit	753-004-G1
(1)	Manual	074-087
(1)	Filter (choose material from table on page 1-13)	011-XXX
	or	
(1)	GM200 Monochromator	011-219
Sentinel III Two Material System		753-002-G2 Note 2
(1)	Sentinel Control Unit	753-003-G1
(1)	Sensor Control Unit	753-200-G1
(1)	Ship Kit	753-004-G1
(1)	Manual	074-087
(1)	Beam Splitter	016-204-G1
(2)	Filter (choose material from table on page 1-13)	011-XXX
	and/or	
(2)	GM200 Monochromator	011-219
OPTICAL FEEDTHROUGH PACKAGES		
Rigid 1" Feedthrough Package		753-002-G4
(1)	1" Bolt Feedthrough	016-204-G2
(1)	Sensor EIES Standard	016-400-G2
(1)	Sensor Power Cable	753-011-G5
(1)	In-Vacuum Cable Kit 50"	016-405-G1
Rigid 2.75" Feedthrough Package		753-002-G5
(1)	2.75" Feedthrough	016-204-G2
(1)	Sensor EIES Standard	016-400-G2
(1)	Sensor Power Cable	753-011-G5
(1)	In-Vacuum Cable Kit 50"	016-405-G1

PARTS LISTING

Qty	Part	IPN #
	OPTICAL FEEDTHROUGH PACKAGES (cont'd)	
	Fiber-Optic 1" Feedthrough Package 15"	753-002-G6
(1)	Assy, 1" Fiber-Optic Feedthrough 15"	016-370-G15
(1)	Sensor EIES Standard	016-400-G2
(1)	Sensor Power Cable	753-011-G5
(1)	In-Vacuum Cable Assy 15"	016-237-G15
	Fiber-Optic 1" Feedthrough 30"	753-002-G7
(1)	Assy, 1" Fiber-Optic Feedthrough 30"	016-370-G30
(1)	Sensor EIES Standard	016-400-G2
(1)	Sensor Power Cable	753-011-G5
(1)	In-Vacuum Cable Kit 30"	016-237-G30
	Fiber-Optic 1" Feedthrough 45"	753-002-G8
(1)	Assy, 1" Fiber-Optic Feedthrough 45"	016-370-G45
(1)	Sensor EIES Standard	016-400-G2
(1)	Sensor Power Cable	753-011-G5
(1)	In-Vacuum Cable Kit 45"	016-237-G45
	Fiber-Optic 2.75" Feedthrough Package 15"	753-002-G11
(1)	Assy, 2.75" Fiber-Optic Feedthrough 15"	016-444-G15
(1)	Sensor EIES Standard	016-400-G2
(1)	Sensor Power Cable	753-011-G5
(1)	In-Vacuum Cable Assy 15"	016-237-G15
	Fiber-Optic 2.75" Feedthrough Package 30"	753-002-G12
(1)	Assy, 2.75" Fiber-Optic Feedthrough 30"	016-444-G30
(1)	Sensor EIES Standard	016-400-G2
(1)	Sensor Power Cable	753-011-G5
(1)	In-Vacuum Cable Assy 30"	016-237-G30
	Fiber-Optic 2.75" Feedthrough Package 45"	753-002-G13
(1)	Assy, 2.75" Fiber-Optic Feedthrough 45"	016-444-G45
(1)	Sensor EIES Standard	016-400-G2
(1)	Sensor Power Cable	753-011-G5
(1)	In-Vacuum Cable Assy 45"	016-237-G45

PARTS LISTING

Qty	Part	IPN #
	OPTIONS	
	EIES PMT W/Cables	753-002-G9
(1)	EIES PMT	016-350-G1
(1)	PMT High Voltage Cable	753-009-G5
(1)	PMT Signal Cable	753-010-G5
	Filter Changer Option	753-002-G10
(1)	Filter Changer	016-349-G1
(1)	Filter Changer Control Cable	753-012-G5
(1)	Filter Changer Controller Board Assy	753-352-G1
(1)	Filter (must choose 2, 3, or 4 filters for filter changer option)	011-XXX
	Assy, EIES Sensor Light Shield	016-427-G1
	Double Ended Sensor Adapter	016-402-G1
	IEEE-488 Communications	017-432-G4
	Assy, EIES Sensor, Sentinel III, Refract.	016-180-G1

CRYSTAL SENSORS & ASSEMBLIES (optional)

Standard Crystal Sensor (water lines and coaxial connector are mounted on side of sensor)	007-206
Compact Crystal Sensor (water lines and coaxial connector are rear mounted)	750-040-G3
12" UHV Bakeable Sensor	750-012-G5
20" UHV Bakeable Sensor	750-012-G6
30" UHV Bakeable Sensor	750-012-G7
Shutter Assembly for Stanard or Compact Sensors (requires 007-199)	750-001-G3
Pneumatic Shutter Actuator Control Valve for use with above Shutter Assemblies	007-199

1.5 Initial Check Procedures

NOTE:	Prior to performing the Initial Check Procedure you should check the inventory of your system to be sure that you have received all of the components which were ordered with the instrument. For the Initial Check Procedure you will need only the instrument and the power cord. Do not connect any other cables or devices to the unit for this check.

1.6 Correct Operating Voltage

Before you connect the power cord, check the line voltage selector card which is part of the power cord socket at the rear of the unit. To check this connection remove the power cord from the rear of the unit, slide the protective cover to the left, and pull the tab marked "FUSE" out to swing the fuse holder open (see Figure 1.12).

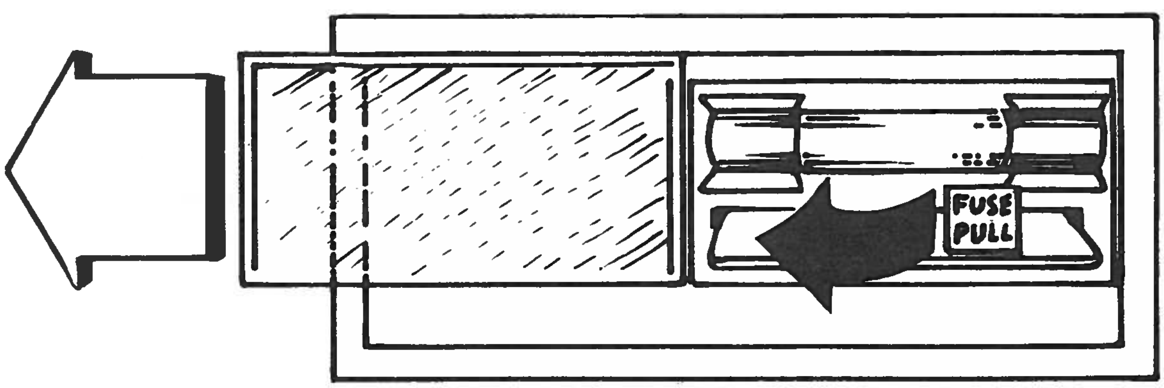


Figure 1.12 Fuse Tab

If the required voltage is not showing on the small circuit card, it must be changed prior to power up. Use needle nose pliers to remove the card. Select the required voltage (from the four voltages marked on the card) and reinsert the card with the proper voltage selection on the left side facing upward (see Figure 1.13).

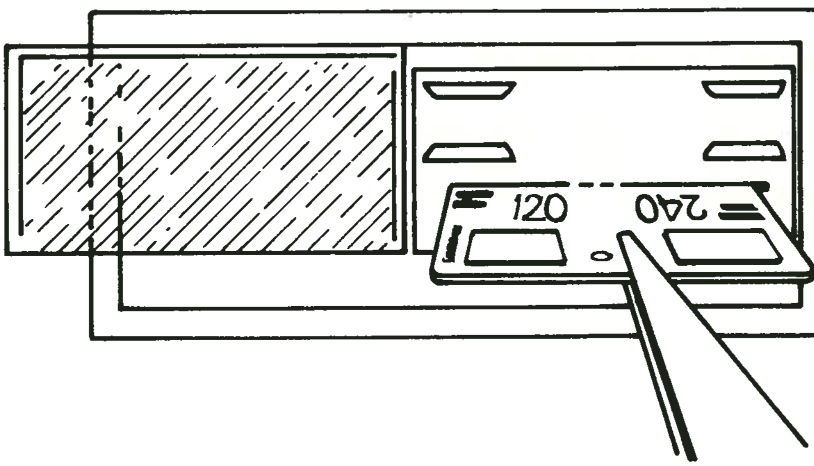


Figure 1.13 Circuit Card

Check the line fuse at this time. On 100 or 120 volt units it should be 1.5 amp; on 220 and 240 volt units it should be 0.75 amp. Swing the fuseholder back into place, slide the protective cover to the right and plug the line power cord into the back of the unit. Make sure that the power switch is OFF (extended outward) and plug the power cord into an outlet of appropriate voltage.

WARNING!!!
VOLTAGES MAY EXIST IN REAR PANEL CONNECTORS. DO NOT TOUCH THE EXPOSED CONNECTORS WHEN POWER IS CONNECTED TO THE INSTRUMENT.

NOTE: Switch 1 on the Configuration Selector Switch sets the CRT line frequency. The "OFF" position sets frequency to 60 Hz. The "ON" position sets frequency to 50 Hz. The instrument must be turned off and then back on to reset the frequency (see Figure 7.3 for location of the Configuration Selector Switch). Switches 2 and 3 are defined in the Communications section of this manual and switches 4, 5, and 6 are not used.

1.7 Initial Display

Turn the power on by pressing the POWER button. The indicator light will illuminate and, in approximately fifteen seconds, a display will appear on the CRT. Figure 1.14 shows the correct initial display.

NOTE:	The statement "STOP" will be flashing on the screen. This message is defined on page 2-58 and should be disregarded for now.

The words "PROGRAM LOSS" which appear on the screen indicate the loss of previous film programs stored in the Sentinel III memory.

Assuming the initial display check was successful, the instrument is ready for installation. Refer to Section 3 for information concerning installation of the sensing system.

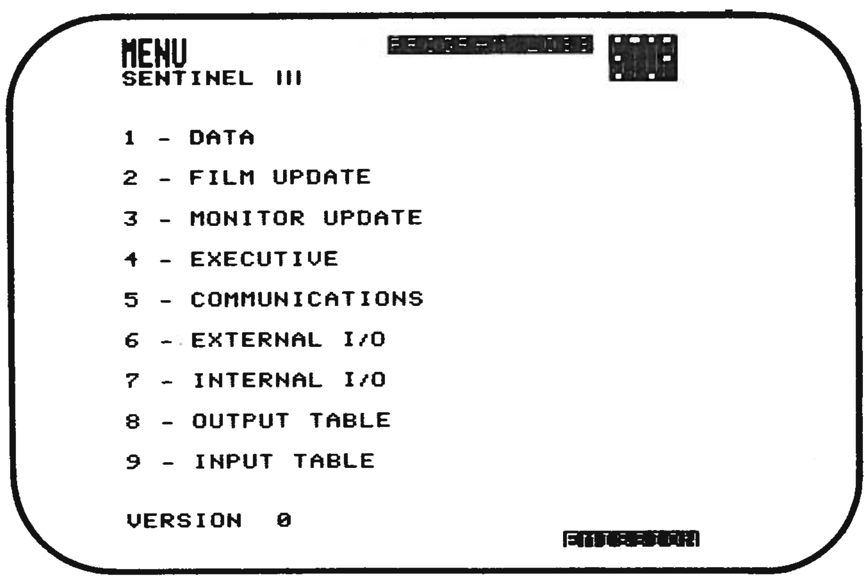


Figure 1.14 - Initial Display

If the indicator light does not light or the display does not appear, check your power outlet and the main fuse on the rear of the unit. If the indicator light comes on but the MENU display does not appear, contact Inficon Customer Service.

To reset the Sentinel III memory to standard factory set conditions, perform the following steps:

1. Turn off the instrument power.

2. Press and hold the RESET button.

3. Turn on the power while holding the RESET button.

4. After the MENU display appears, release the RESET button.

2.0 EQUIPMENT AND OPERATION DESCRIPTIONS

2.1 Rear Panel Component Descriptions

Refer to Figure 2.1 for location of the Rear Panel Components discussed on the following pages.

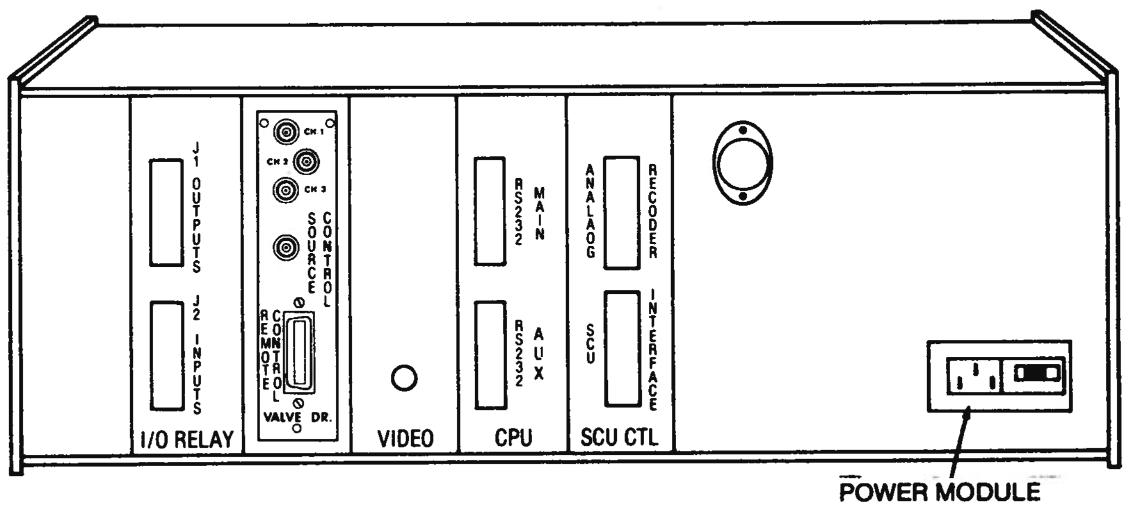


Figure 2.1 Rear Panel Components

2.1.1 POWER MODULE

The Power Module allows selection of optional voltages along with the system fuse holder and line cord connector. For directions on voltage selection and fuse replacement refer to Section 1 of this manual.

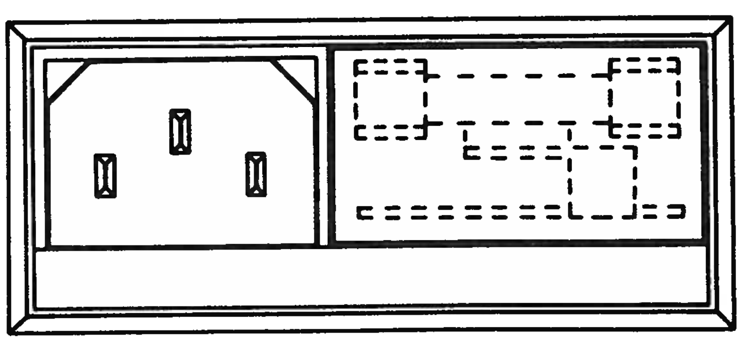


Figure 2.2 Power Module

2.1.2 SCU CTL MODULE

The SCU CTL (Sensor Control Unit Control Module) provides the interface between the Sentinel III Operator's Console and the SCU. Also provided by this module is the Analog Recorder signal which enables a strip chart copy of the Analog data.

a. ANALOG RECORDER Connection - provides an analog output of 0 to 10V for a strip chart recorder. This is useful for hard copies of the analog rate signal.
   The ANALOG RECORDER connector pin designations are as follows:

Function	Pin
CHAN 1	1
CHAN 2	2
MONITOR	3
Ground	8-14

b. SCU INTERFACE Connection - provides the interface between the Sentinel III Operator's Console and the SCU. The cable provided connects the two components.

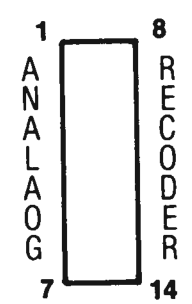


Figure 2.3 Analog Recorder Connector

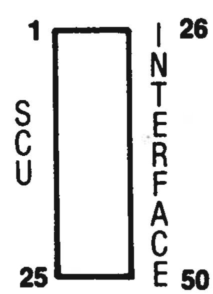


Figure 2.4 SCU Interface Connector

2.1.3 CPU MODULE

The CPU Module provides two connections for the RS-232 interface for the Sentinel III. They are:

a. RS-232 MAIN Connection - provides a means of electronic communication with the Sentinel III. Using suitable equipment, as described in Section 7, the Sentinel III can be operated from a remote location, without operator intervention, and can be integrated into computer controlled instrumentation systems. Data from the Sentinel III can also be acquired, manipulated, and stored by computer equipment.

RS-232 MAIN Connector pin designations are as follows:

Pin	Function
2	Transmit data; data sent from Sentinel III
3	Receive data; data received by Sentinel III
4	Request to send; output logic low when Sentinel III's receiver is empty.
5	Clear to send; input low to Sentinel III enables transmitter
7	Signal ground; common between user and Sentinel III
8	Data carrier detect; input low to Sentinel III enables receiver
20	Data Terminal ready; output logic low when Sentinel III is turned on

b. RS-232 AUX Connector - provides an output for the transfer of data to a serial printer for data logging purposes.

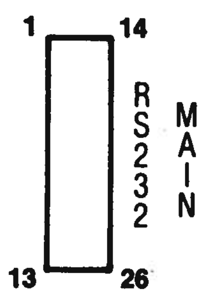


Figure 2.5 RS-232 MAIN Connector

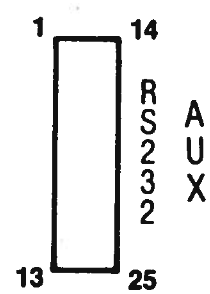


Figure 2.6 RS-232 AUX Connector

RS-232 AUX Connector pin designations are as follows:

Pin	Function
2	Transmit data; data sent from Sentinel III
5	Clear to send; input low to Sentinel III enables transmitter
7	Signal ground; common between user and Sentinel III
20	Data Terminal ready; output logic low when Sentinel III is turned on

2.1.4 VIDEO MODULE

The VIDEO connector is a BNC type (see Figure 2.7) which provides a composite video 1.5 volt signal. You can use this output to operate a video monitor at a remote location. To operate a monitor, connect a 75 ohm coax cable between the VIDEO connector on the Sentinel III rear panel and the Video input connector on your monitor.

2.1.5 DEP CTL MODULE

The DEP CTL Module provides an interface with the system to be controlled.

a. XTAL OSC Connector - Input connector (BNC) for Inficon oscillator IPN 013-001. See Figure 2.7.

b. CH.1 CTL/CH.2 CTL Connectors (see Figure 2.7) - Provide outputs of 0 to -10 volts DC to control the source power. This output voltage may be changed by removal of one or both jumpers on the Deposition Control Board. With the jumpers in place, output voltage is 0 to -10V; jumpers removed produce 0 to -5V output. Jumper J1 changes Channel 2, Jumper J2 changes Channel 1.

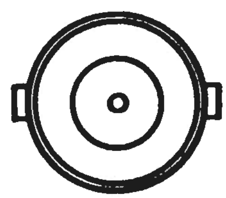


Figure 2.7 BNC Type Connector

c. MANUAL POWER - Accepts the standard Inficon hand-held source power controller. When connected, the controller provides remote control of source power when the instrument is in MANUAL mode. The controller is a three selection switch. All positions are momentary and will return to rest when released. Pushing the SWITCH left or right causes the output control voltage to increase or decrease. Pressing the switch downward causes the Sentinel III to STOP (same as pressing front panel STOP button). (See Figure 2.8)

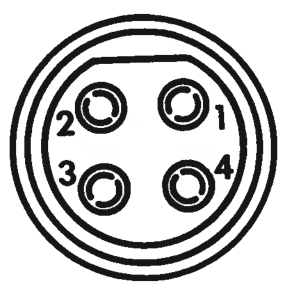


Figure 2.8 Manual Power Connector

The MANUAL POWER Connector (Figure 2.8) pin designations are as follows:

Function	Pin
Increase	3
Decrease	2
Ground	1

2.1.6 I/O RELAY MODULE CONFIGURATION

The I/O RELAY configuration module provides the ability to remotely activate the Sentinel III front panel control functions. This gives a user the ability to use a Sentinel III in conjunction with a hardware interface in a hands-off mode of operation. The user is provided with optically isolated inputs, each having a direct command function. The inputs are operated with either AC or DC voltage within the range 8 to 40 volts RMS. The following list gives the available controls:

1. START
2. STOP
3. RESET
4. CALIB CH1
5. CALIB CH2
6. INTERLOCK
7. USER 1*
8. USER 2*
9. USER 3*
10. USER 4*
11. USER 5*
12. USER 6* (see Fig. 2.11 for related pin connections)

*User programmable. See Section 2.3.8 for details.

If pulsed input commands are used, the pulse duration must be greater than .3 seconds. All inputs are leading edge detected and therefore may remain active until their function is again desired; they then must be turned off for a minimum of .3 seconds before being reactivated. All input lines share a common isolated reference input. This line is normally connected to the common side of the user's "CONTROL" power supply. If no external power source is available, a 10 volt DC power source is provided at the I/O RELAY module input connector J2. This power source should only be used to operate the input relays on the I/O RELAY module, and not as a power source for any other system needs. The common reference input line must be connected to GROUND if the internal power source is to be used. The contact closures used to activate the remote input lines are normally resident in the user's electronics system. A schematic is shown in Figure 2.12 for both types of remote input supply wiring.

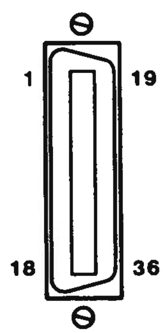
INPUT LINE SPECIFICATIONS:

OPERATING RANGE:	8 to 40 Volts AC (RMS) or DC
REFERENCE:	Common input line
ISOLATION:	1 KV Maximum
INPUT IMPEDANCE:	820 Ohms
INPUT THRESHOLD:	3 Volts

ON CARD POWER SOURCE SPECIFICATION:

OUTPUT VOLTAGE:	10 Volts DC
OUTPUT CURRENT:	120 mA Max.
REFERENCE:	Chassis Ground

NOTE: The emission interlock (fixed input number 6 or any user input coded "17") is a continuous input and not edge triggered. Emission will be held off as long as this input is present and will be turned on 2 seconds after this input is removed. Other continuous inputs include: XTAL FAIL INHIBIT, user code "23"; SOAK HOLD CHAN1, user code "24"; and SOAK HOLD CHAN 2, user code "25". All other inputs are edge triggered.



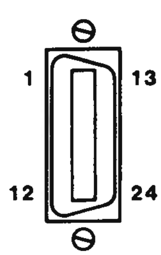
REAR VIEW - J1

Relay Outputs J1

CONTACTS	FUNCTION
9,27	STATUS
10,28	STOP
8,26	XTL SHTR
11,29	CH1 SHTR
7,25	CH2 SHTR
12,30	END PROC
6,24	USER 1
13,31	USER 2
4,22	USER 3
5,23	USER 4
15,32	USER 5
14,33	USER 6

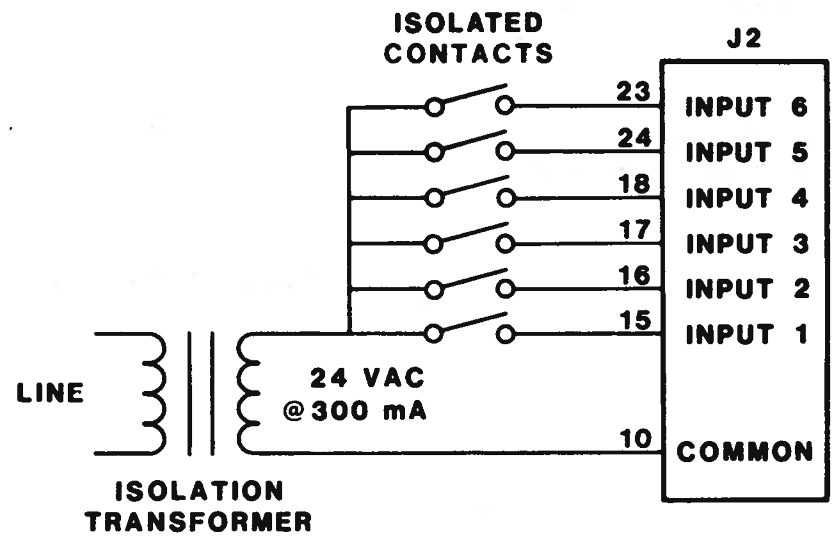
Relay Inputs J2

CONTACT	FUNCTIONS
13	START
14	STOP
17	RESET
15	CALIB CH1
16	CALIB CH2
18	INTERLOCK
19	USER 1
20	USER 2
21	USER 3
22	USER 4
23	USER 5
24	USER 6
10	INPUT COMMON LINE
3,4,5,6	POWER SOURCE GRND
1	+10 VOLT SOURCE

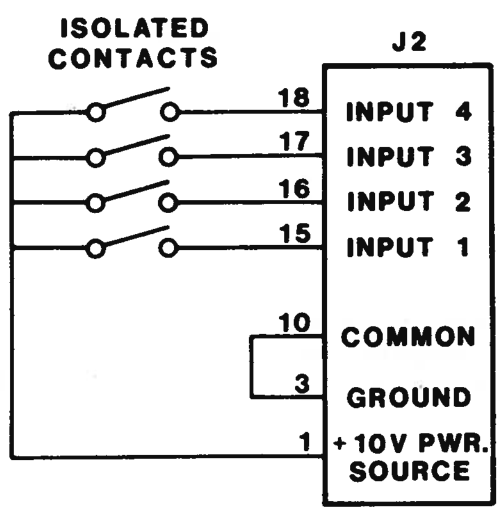


REAR VIEW - J2

Figure 2.9 I/O Relay Connector Designations



1. External Power Supply



2. Internal Power Supply

Figure 2.10 Typical Remote Input Wiring Techniques

2.1.7 IEEE MODULE (Optional)

The IEEE Module provides the IEEE-488 connector for parallel computer interfacing. This module is optional.

a. IEEE-488 Connector (Figure 2.11) - provides standard connection for IEEE communications.

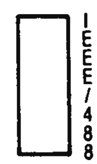


Figure 2.11 IEEE-488 Connector

b. DATA 1 0 Switches (Figure 2.12) - Provide convenient device address setting and selection of the type of communications that are to be used. Switches marked DEV ADDR are used to set the address of the Sentinel III. Address range is 0-30 and in binary code.

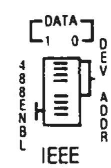


Figure 2.12 Data 1 0 Switches

2.1.8 GROUND

The GROUND stud (Figure 2.13) provides easy access for interconnecting ground straps with the system and associated components. See Sect. 3.5.

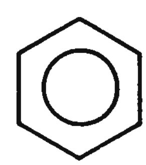


Figure 2.13 Ground Stud

2.2 Sensor Control Unit (SCU) Description (Figures 2.14 & 2.15)

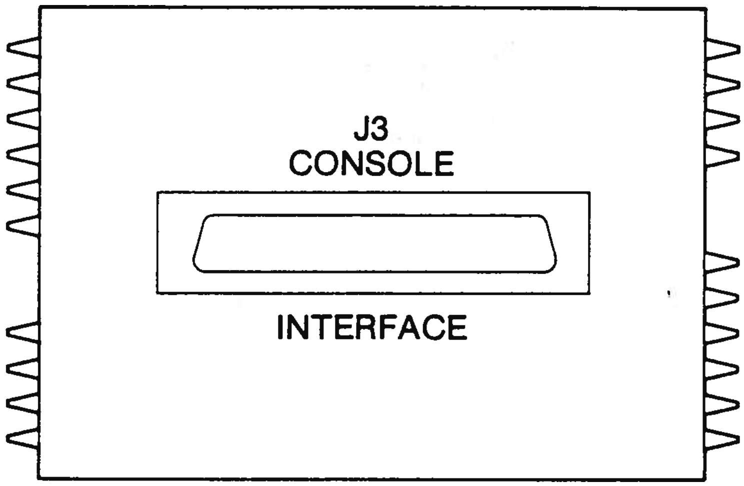


Figure 2.14 Sensor Control Unit - Front Panel / Console Interface Connector

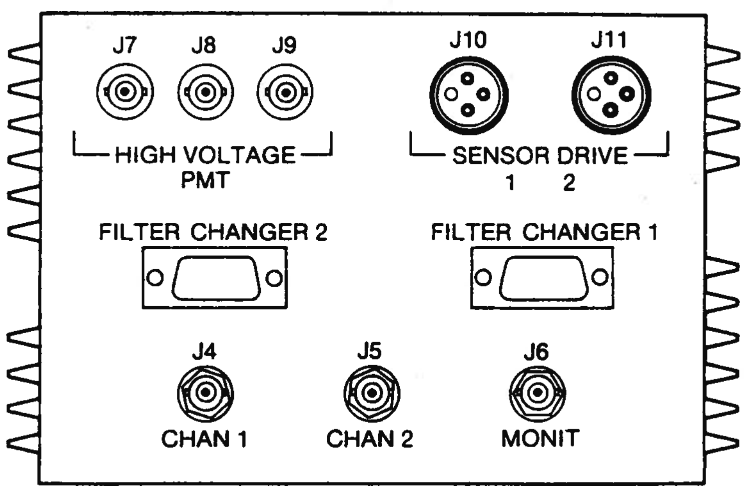


Figure 2.15 Sensor Control Unit - Rear Panel

2.2.1 HIGH VOLTAGE PMT CONNECTORS (Figure 2.16)

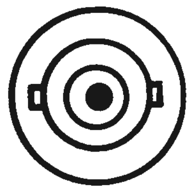


Figure 2.16 High Voltage PMT Connectors

These BNC type connectors supply -750 VDC for the Photomultipliers.

2.2.2 SENSOR DRIVE 1 and 2 CONNECTORS (Figure 2.17)

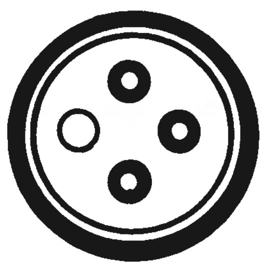


Figure 2.17 Sensor Drive 1 and 2 Connectors

These 4-pin connectors provide $\pm$180 V chopped sensor BIAS and high current filament power to the respective sensors.

Switch S2 on the AE Sensor Regulator Board* must be changed to operate two sensors simultaneously. Instruments are set to operate one sensor when they are shipped. Switch setting is as follows:

Switch S1 Position	Function
OFF	Disables SENSOR DRIVE 1; SENSOR DRIVE 2 must be used.
ON	Both SENSOR DRIVEs operate.

*See Section 6.10 for instructions on adjusting the level of emission.

2.2.3 FILTER CHANGER 1 and 2 CONNECTORS (Optional) (Figure 2.18)

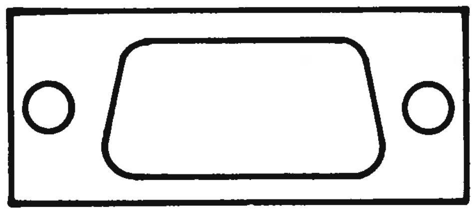


Figure 2.18 Filter Changer 1 and 2 Connectors

These 9-pin connectors provide control interface between the SCU and the respective Filter Changer modules.

2.2.4 CHAN 1 and 2 CONNECTORS (Figure 2.19)

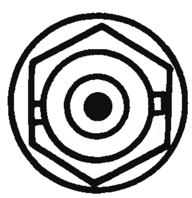


Figure 2.19 CHAN 1 and 2 Connectors

These BNC type connectors provide signal input connection for the channel 1 and 2 PMTs, respectively.

2.2.5 MONIT CONNECTOR (Figure 2.19)

This BNC type connector provides signal input connection for the Monitor PMT.

2.2.6 CONSOLE INTERFACE CONNECTOR (See Figure 2.14)

This connector provides the interface between the Sentinel III and the SCU Module.

SECTION 2
OPERATING THE SENTINEL III

2.3 Keyboard, Display, and Parameter Descriptions

The Front Panel descriptions provide information on all button functions and display formats. Read the following few pages to make yourself familiar with the Sentinel III controls and indicators.

2.3.1 KEYBOARD DESCRIPTIONS

The Keyboard descriptions given below associate button names with functions. Refer to Figure 2.20 for their locations. Some buttons have dual functions. When these buttons are discussed, the primary description is given first, followed by the secondary function and method of activation.

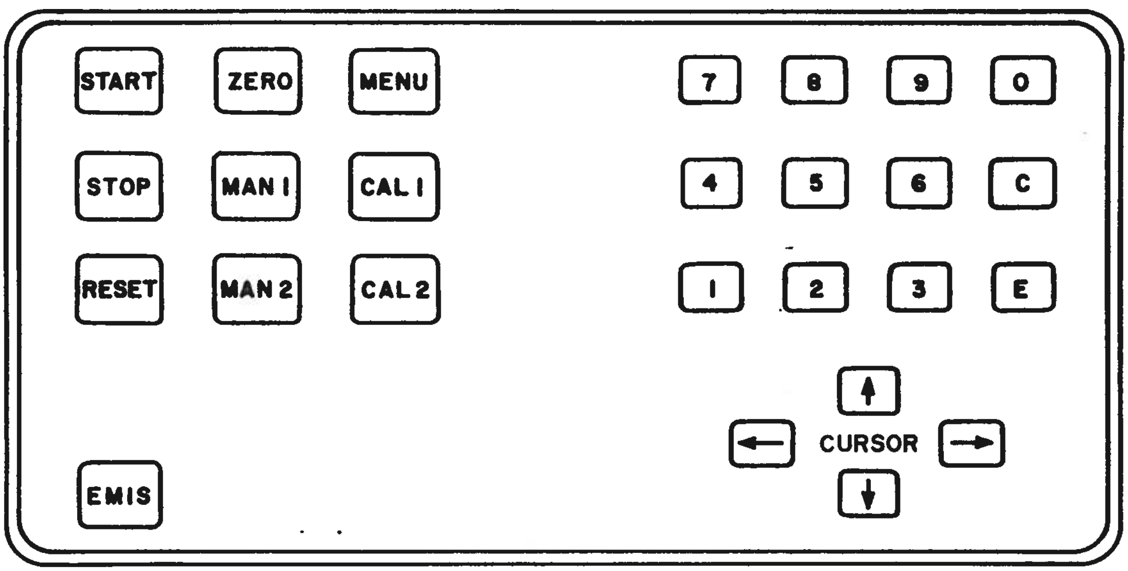


Figure 2.20 Sentinel III Keyboard

START This function operates differently depending on the status of the instrument at the time START is pressed. If there are channels in READY (after a reset) a start will start the films in those channels. If the system is in STOP, a start will continue with the film(s) that was in process when the STOP occurred. All thickness will be retained. At any other time, a START will start the next film in the process. If the last film of a process is active, a START will be ignored. (That is, a new process cannot begin before the previous one ended.)

STOP This button is used to immediately place the system in the STOP mode. When pressed, all processing stops and source powers are set to zero; STOP flashes on the CRT, and all thickness and phase time information is frozen.

RESET When pressed during a STOP, this function resets the process to the first film(s). This puts the first film(s) of the process to the READY phase. Pressing RESET during a process has no effect on the instrument.

ZERO This button is used to manually zero the accumulated thickness in both channels.

MAN 1 This button selects manual power control if channel is not in IDLE. When selected, the CRT display will display the MANUAL message, the phase is set to manual deposit, and the associated shutter is open. The instrument is returned to automatic when the button is pressed a second time. Upon returning to automatic the instrument is set in the deposit phase of the active film. MAN 1 and MAN 2 are independent. If MAN 2 was ON when MAN 1 is selected, channel 2 will immediately go to deposit.

MAN 2 Operates as MAN 1 above.

MENU This button selects the MENU display mode from which other displays are chosen. Menu selection is accomplished by pressing the numeric key corresponding to the desired display.

CAL 1 When pressed, CAL 1 initiates the automatic crystal calibration of Channel #1. If the associated source is not in the deposit mode, the selection is ignored. If XTAL DISABLED is set in the EXECUTIVE display mode, this selection will give a CAL ERR message.

CAL 2 Operates as CAL 1 above.

0 thru 9 These keys are used for entering numerical data. The place value is held by the trailing zeros, therefore no decimal point is used.

C This button is used to clear data entry errors. Cleared data is replaced with last valid data in memory. In all string entries (I/O or PROCESS) this function will clear from cursor to the end of the string. It will recall the last valid data in memory if the cursor is at the end of a string.

E This button is used to enter displayed program data into memory. If an illegal entry is attempted, error is indicated by the appearance of the ENTRY ERROR warning message. This button also steps cursor position automatically on legal entries.

↑ (&) The cursor Up button is used to move the cursor up through the display for the purpose of data entry. The Ampersand function is enabled in the Internal and External I/O displays and is used to signify the logical AND. Also in the process definitions, the ampersand indicates co-deposition.

↓ (+) The cursor Down button is used to move the cursor down through the display for the purpose of data entry. The Plus function is enabled in the Internal and External I/O displays and is used to signify the logical OR. Also in the process definition the plus signifies a final thickness override.

← The cursor Left button is used to move the cursor left through the display for the purpose of data entry. In a string display, it moves the cursor to the left through the string.

→ The cursor Right button is used to move the cursor right through the display for the purpose of data entry. In a string display, it moves the cursor to the right through the string.

POWER This button is used to apply power to the instrument; a green LED indicates power is on.

EMIS This button provides front panel control of sensor Emissions regulation and PMT power supplies. When off, the EMISSION warning message appears on the bottom line of the CRT display.

2.3.2 MENU DISPLAY (Figure 2.21)

To access this display, press the MENU key on the instrument front panel. This display appears automatically when the instrument power is set to ON. The MENU display lists all of the available displays and their corresponding selection number.

```
MENU
SENTINEL III

1 - DATA
2 - FILM UPDATE
3 - MONITOR UPDATE
4 - EXECUTIVE
5 - COMMUNICATIONS
6 - EXTERNAL I/O
7 - INTERNAL I/O
8 - OUTPUT TABLE
9 - INPUT TABLE

VERSION  0
```

Figure 2.21 Menu Display

System status and warning messages may also appear on this display.

To exit this display, make a selection from the available choices and press the associated numeric key.

2.3.3 DATA DISPLAY (Figure 2.22)

To access this display, press the MENU key on the instrument front panel and press the number (1) key.

This is the main operating display for the Sentinel III. This display mode provides all pertinent information for the process being performed, as well as system status and warning messages.

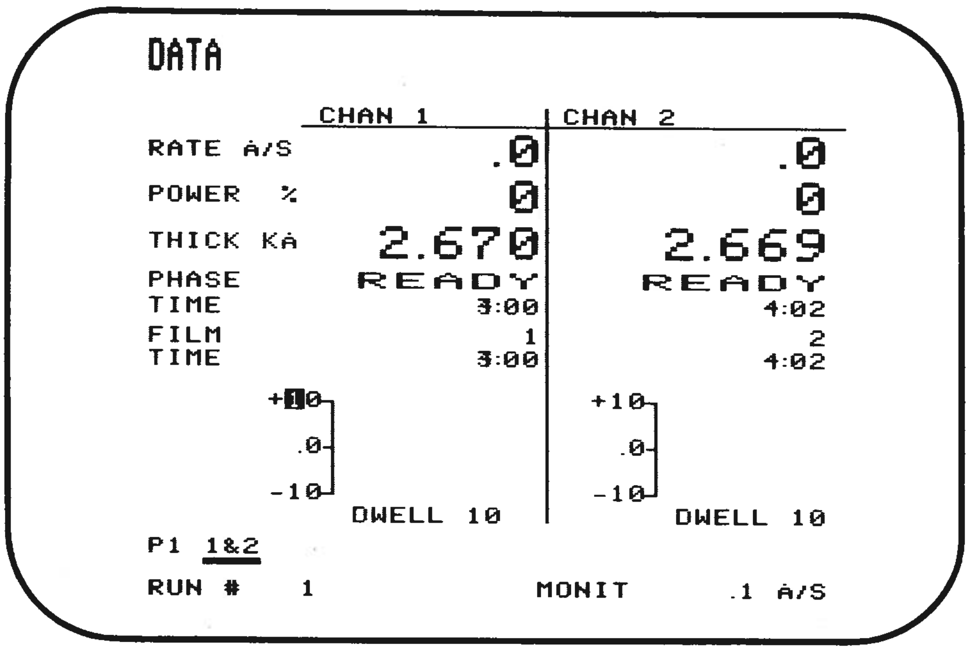


Figure 2.22 DATA Display

The DATA display provides a continuous representation of RATE, THICKNESS, POWER, PHASE, PHASE TIME, and Rate Deviation for each active channel.

RUN #, % XTAL LIFE, and the MONITOR CHANNEL RATE are indicated at the bottom of the display. The active PROCESS # and the process definition are also indicated.

The range of the Rate Deviation analog display may be programmed in this display by moving the cursor to the top deviation label and entering a new numeric value.

Enter either a 1, 2, or 4 numeric digit, and the display will now correspond to either 10, 20, or 40 Angstroms full scale. Any other numerics entered will be rejected as an entry error.

The DWELL time of the analog display can also be programmed by moving the cursor to the DWELL parameter location and by entering a numeric from 1 to 99. The DWELL numbers correspond to the number of 0.125 second measurement intervals plotted per horizontal position update. There are 68 data points plotted before a retrace occurs.

If PROCESS 3 has been selected as the ACTIVE PROCESS in the EXECUTIVE display, its definition can be updated in the DATA display. The sequence may be altered and defined in the same manner as PROCESS 1 and 2 in the EXECUTIVE display, except that no FINAL THICKNESS OVERRIDES may be programmed. It can be changed only at the end of a process or during a READY phase.

2.3.4 FILM UPDATE DISPLAY (Figure 2.23)

To access this display, press the MENU key on the instrument front panel and press the number (2) key.

This display allows you to enter film related operating parameter data and channel selection. Parameters needed for rate calibration, crystal control functions, and cross channel interference ratios are entered in this display mode. All information necessary to program a complete film deposition is accessible through this display.

```
FILM #1

CHANNEL #        1        CNTL GAIN      10
SOAK PWR1        0 %      CNTL DAMP       0
RISE TIM1      :00 M:S    MAX POWER      90 %
SOAK TIM1      :00 M:S    PMT RANGE       8
SOAK PWR2        0 %      PMT CALIB   1.000
RISE TIM2      :00 M:S    FILTER #        0
SOAK TIM2      :00 M:S    XSENS CH2      .0 %
RATE BGN        .0 Å/S    XSENS MON      .0 %
RATIO           .0 %      DENSITY      1.00
RATE NEW        .0 Å/S    Z-RATIO     1.000
SETP RAMP     .000 KÅ     TOOLING       100 %
TIME RAMP      :00 M:S    CAL ACRCY       3 %
FINL THCK     .000 KÅ     CAL INTVL       0 M
SETP THCK     .000 KÅ     CMPL TPWR     YES
SETP TIMR      :00 M:S    STOP MPWR      NO
IDLE PWR         0 %      SHUT DLY       NO
IDLE RTIM      :00 M:S    AUTO CAL       NO
                          XTAL MEAS      NO
```

Figure 2.23 Film Update Display

The following chart provides parameter entry limits and functional information:

FILM # Selects film program to be viewed.

DATA RANGE: 1 THRU 6 (Film)

CHANNEL # Selects the operating channel the film program will control. This parameter may only be updated at the end of a process or in a READY phase.

DATA RANGE: 1 OR 2 (channel)

PREDEPOSITION CYCLE CONTROLS

SOAK PWR1 A programmable power level generally used to precondition a new material melt.

DATA RANGE: 00 THRU 99
UNITS: %

RISE TIME1 A programmable time interval which sets the duration of the SOURCE POWER increase from 0% to the achievement of SOAK PWR1.

DATA RANGE: 00:00 THRU 99:59
UNITS: MIN:SEC

SOAK TIM1 A programmable time interval which sets the time the SOURCE POWER remains at SOAK PWR1.

DATA RANGE: 00:00 THRU 99:59
UNITS: MIN:SEC

SOAK PWR2 A programmable power level which is selected to produce a deposition rate close to Auto Control Rate.

DATA RANGE: 00 THRU 99
UNITS: %

RISE TIM2 A programmable time interval from the end of SOAK TIM1 to the SOAK PWR2 level.

DATA RANGE: 00:00 THRU 99:59
UNITS: MIN:SEC

SOAK TIM2 A programmable time interval which sets the time duration SOURCE POWER remains at SOAK PWR2.

DATA RANGE: 00:00 THRU 99:59
UNITS: MIN:SEC

SECTION 2
OPERATING THE SENTINEL III

RATE GROUP

RATE BGN Sets rate control reference value to be established with onset of deposition. Also determines the RATE DISPLAY resolution; ≥100Å/S = 1 Å <100 Å/S = 0.1 Å.

DATA RANGE:	000.0 THRU 999.9
UNITS:	ÅSEC.

RATIO When set above .0, controls the FILM at the programmed % of the actual RATE of the other channel rather than at RATE BGN.

DATA RANGE:	.0 THRU 999.9
UNITS:	%

RATE RAMP GROUP

RATE NEW New rate value to be established during deposition cycle. A rate equal to RATE BGN will disable the RATE RAMP function.

DATA RANGE:	000.0 THRU 999.9
UNITS:	Å/SEC

SETP RAMP Accumulated Thickness value at which to begin the RATE RAMP CYCLE.

DATA RANGE:	0.000 THRU 999.9
UNITS:	KILO Å

ME RAMP Length of time to establish RATE NEW from the present deposition rate with a linear rate ramp. A programmed value of 00:00 will disable the RATE RAMP function.

DATA RANGE:	00:00 THRU 99:59
UNITS:	MIN:SEC

DEPOSITION CYCLE SETPOINT GROUP

FINL THICK The accumulated thickness at which the deposit phase ends and source shutter closes. Total thickness is referenced from the last zero thickness command.

DATA RANGE:	0.000 THRU 999.9
UNITS:	KILO Å

SETP THCK An intermediate deposit cycle setpoint. An output can be set when this thickness is reached.

DATA RANGE:	0.000 THRU 999.9
UNITS:	KILO Å

SETP TIMR A setpoint based on elapsed film execution time. An output can be set when this time is reached.

DATA RANGE:	00:00 THRU 99:59
UNITS:	MIN:SEC

POST DEPOSITION SETPOINT GROUP

IDLE PWR A parameter which maintains SOURCE POWER at the programmed level between depositions. If IDLE PWR is set to a non-zero value, the Sentinel III will enter RISE TIM2 phase when START is pressed, unless a STOP is encountered. If set to a value of zero, RISE TIM1 phase will be entered on the next START command.

DATA RANGE:	00 THRU 99
UNITS:	%

IDLE RTIM A parameter which allows a controlled linear change in POWER from the deposition power level to the IDLE PWR level.

DATA RANGE:	00:00 THRU 99:59
UNITS:	MIN:SEC

SOURCE OUTPUT CONTROL GROUP

CNTL GAIN A function which changes the source output voltage in proportion to the error between the actual rate and the rate set point. At the programmed setting of 10, the source voltage changes at the rate of approximately 1% per second for an error of 1A x per second.

DATA RANGE:	00 THRU 99
UNITS:	NONE

CNTL DAMP Used to minimize overshoot during rate control acquisition, when the source requires a considerable length of time to reach the RATE set point. Without CNTL DAMP action, the thermal inertia of the evaporation source may cause the rate to increase above the set point. The higher the setting, the more anticipation is added to the control system.

DATA RANGE:	00 THRU 99
UNITS:	NONE

MAX POWER A programmable set point which sets the maximum allowed relative power.

DATA RANGE:	00 THRU 99
UNITS:	%

OPTICAL SENSITIVITY CONTROLS

PMT RANGE A programmable function that sets the preamplifier gain range in multiples of 3.3. (See Section 6.9 for exact gains.)

DATA RANGE:	1 THRU 8
UNITS:	NONE

PMT CALIB A programmable linear mathematical digital scaler used to fine adjust the preamplifier signal gain.

DATA RANGE: 0.500 THRU 2.500
UNITS: NONE

FILTER # The position number of the optical bandpass filter (installed in the optional filter switchers unit) necessary to operate the programmed film and channel. A value of 0 programmed will disable the FILTER CHANGE function. Filter Changer 1 output on the optional Filter Changer Board corresponds to the Film program operating Channel 1.

DATA RANGE: 0 THRU 4
UNITS: NONE

CROSS CHANNEL OPTICAL INTERFERENCE CONTROLS

XSENS CH# Number will reflect the channel number not selected by this film. This linear parameter provides a means of subtracting out a percentage of the interference data produced by the second control channel.

DATA RANGE: 00.0 THRU 99.9
UNITS: %

XSENS MON This linear parameter provides a means of subtracting out a percentage of the interference data produced by the MONITOR channel.

DATA RANGE: 00.0 THRU 99.9
UNITS: %

AUTOMATIC CALIBRATION SYSTEM CONTROLS

DENSITY This value refers to the density of the evaporated material and is used internally to convert the measured mass to a thickness value. See Section 4 and Paragraph 4.2.2 for additional information.

DATA RANGE: 0.80 THRU 99.99
UNITS: GM/CC

Z-RATIO A programmable reference value which is determined by the elastic properties of the material being evaporated. This value is used to match the acoustic properties of the film to quartz for extended accurate measured ranges. See Section 4 and Paragraph 4.2.2.

DATA RANGE: 0.200 THRU 3.999
UNITS: NONE

TOOLING

A programmable constant which corrects the thickness and rate for the geometric difference between the placement of crystal sensors and the substrate location. See Section 4 for more information.

DATA RANGE: 10 THRU 399
UNITS: %

CAL ACRCY

This refers to the % of deviation that the optical reading may be from the XTAL reading to conclude calibration.

DATA RANGE: 1 THRU 99
UNITS: %

CAL INTVL

The time interval between automatic calibration cycles after the initial auto calibration at the beginning of the deposition cycle.

DATA RANGE: 000 THRU 999
UNITS: MINUTES

USER OPTION SWITCH GROUP

YES/NO FUNCTION INDICATORS. DATA ENTRY (1 = YES, 0 = NO)

CMPL TPWR

Enables the "COMPLETE ON TIME POWER" mode of deposition completion if a sensor failure occurs.

STOP MPWR

Enables the system "STOP" function if the deposition power required to maintain rate control exceeds the MAX POWER setpoint for a continuous time of 5 seconds.

SHUT DLY

Enables a delayed system shutter opening where it is desirable to establish rate control before exposing substrates to the source. Shutter opens when rate is within 5% of setpoint.

AUTO CAL

Enables auto calibration function with onset of deposition cycle. Does not affect auto calibration from front panel or remote commands.

XTAL MEAS

Enables a film program to be completely executed using the crystal measurement system as the data measurement source.

2.3.5 MONITOR UPDATE DISPLAY (Figure 2.24)

To access this display, press the MENU key on the instrument front panel and press the number (3) key.

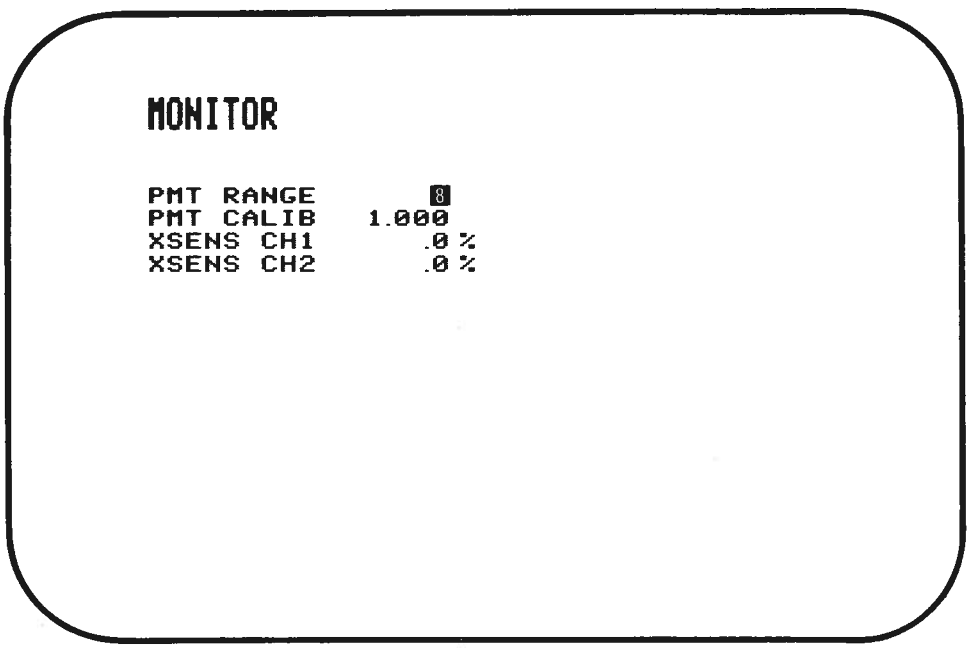


Figure 2.24 Monitor Display

The MONITOR display enables the user to program the third optical measurement channel operating parameters. This channel is used for monitoring purposes only. However, the data measured via this channel can be utilized for cross channel interference rejection in the controlling channel signal processing.

The operating parameters and function descriptions for this display mode are given in the following list:

PMT RANGE A programmable function that sets the photomultiplier preamplifier gain range. Increasing numbers raise the gain by approximately 3.3 per number. (See Section 6.9 for exact ratios.)

DATA RANGE:	1 THRU 8
UNITS:	NONE

PMT CALIB A linear mathematical digital scaler on the optical signal gain.

DATA RANGE: 0.500 THRU 2.500
UNITS: NONE

XSENS CH1 This linear parameter provides a means of subtracting out a percentage of the interference data produced by channel 1.

DATA RANGE: 0.0 THRU 99.9
UNITS: %

XSENS CH2 This linear parameter provides a means of subtracting out a percentage of the interference data produced by channel 2.

DATA RANGE: 0.0 THRU 99.9
UNITS: %

2.3.6 EXECUTIVE DISPLAY (Figure 2.25)

To access this display, press the MENU key on the instrument front panel and press the number (4) key.

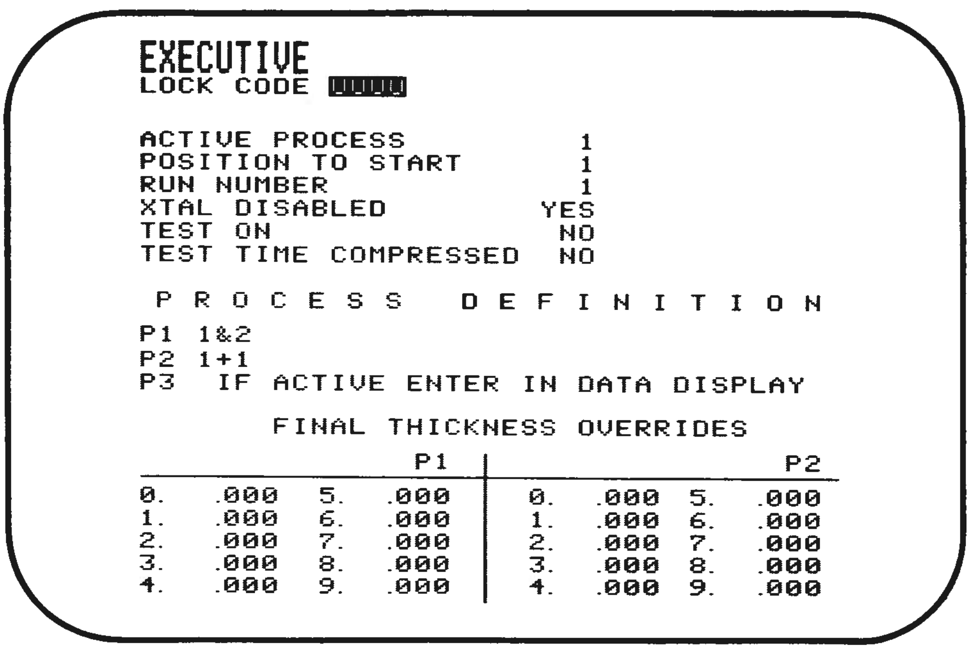


Figure 2.25 Executive Display

The EXECUTIVE display mode is used to determine the process definition of the instrument. Functions available in the EXECUTIVE display mode and parameter limits are given below:

LOCK CODE This parameter is used to "LOCK" the most important programmable parameters in the system to prevent access by persons not knowing the code. This parameter is discussed in detail in Paragraph 2.7.4.

The following parameters may be updated only at the end of process or when in the READY Phase: ACTIVE PROCESS, POSITION TO START, XTAL DISABLED, TEST ON, P1 or P2.

ACTIVE PROCESS This parameter selects the process sequence to be executed by the instrument. Process 1 & 2 are defined on the EXECUTIVE display and PROCESS 3 is defined on the DATA display.

DATA RANGE: 1 THRU 3
UNITS: NONE

POSITION TO START This parameter selects the film position within the defined process that will be the first film (or films if codeposited) executed. Numbering starts at the left side of the display. Each film of a codeposition is counted as a position.

DATA RANGE: 1 THRU 32
UNITS: NONE

RUN NUMBER SET This parameter initializes the internal process counter. This counter may be used for data logging purposes by the user. The counter is incremented by 1 whenever a process begins. The RUN NUMBER is indicated on the DATA display.

DATA RANGE: 0000 THRU 9999
UNITS: NONE

XTAL DISABLED This parameter is a switch function that is used to disable all activities and displays associated with the crystal measurement system. A numeric 1 sets yes and a numeric 0 sets no.

DATA RANGE: 0 THRU 1
UNITS: NONE

TEST ON This parameter is a switch function in that it is used to enable a "TEST MODE" signal resident within the instrument to be utilized as a means for verifying proper instrument operation. A numeric 1 sets yes and a numeric 0 sets no. A "TEST" message is indicated on the DATA display when this function is active. All Emission functions are disabled.

TEST TIME COMPRESSED If set to YES when TEST ON is set to YES, will compress time by a factor of 10.

DATA RANGE: 0 THRU 1
UNITS: NONE

P1 (PROCESS 1)

This parameter string allows the user to specify the sequence in which specific film programs will be executed. The six available film programs are specified by number and may be arranged in any order either individually or in a co-deposition mode by inserting the & symbol (up arrow key) between the desired film numbers. The film sequence will be executed in order from left to right with successive START commands. Film programs with the & symbol between them will be started simultaneously with the final thickness of the first film number specified determining the termination point.

The FINAL THICKNESS parameter set in the specified film programs may be overridden by including a + symbol (down arrow key) and a numeric value from 0 to 9 following the film number to be altered. A new FINAL THICKNESS value must be entered in the FINAL THICKNESS OVERRIDE TABLE for the desired PROCESS at the location specified by the numeric entered in the sequence definition. The data stored in the film programs remains unaltered.

NOTE: A sequence definition may be edited by moving the cursor to the desired location via the left and right arrow keys and typing over the appropriate data. Pressing the "CLEAR" key with the cursor at the end ofthe sequence will restore the previously defined sequence to the screen. Pressing the "CLEAR" key with the cursor at any location other than the end will delete all characters from the cursor location to the end, including the character at the cursor location.

A maximum of 32 characters including film numbers and symbols may be specified in a process definition.

DATA RANGE:	FILM NUMBERS	= 1 THRU 6
	OVERRIDE TABLE NUMBERS	= 0 THRU 9
	SYMBOLS	= & AND +

P2 (PROCESS 2)

Identical to P1 (PROCESS 1)

THICKNESS OVERRIDE TABLES

Each OVERRIDE corresponds to a number that may be used in P1 or P2 after the + sign. If a THICKNESS OVERRIDE has been programmed in a process, the OVERRIDE will be used as final thickness instead of the final thickness programmed in the film. These tables will not appear on the EXECUTIVE display unless a thickness override has been programmed in P1 or P2. 1 Table per process (1 & 2)

DATA RANGE:	0.000 THRU 999.9
UNITS:	Kilo Å

2.3.7 COMMUNICATIONS DISPLAY (Figure 2.26)

To access this display, press the MENU key on the instrument front panel and press the number (5) key.

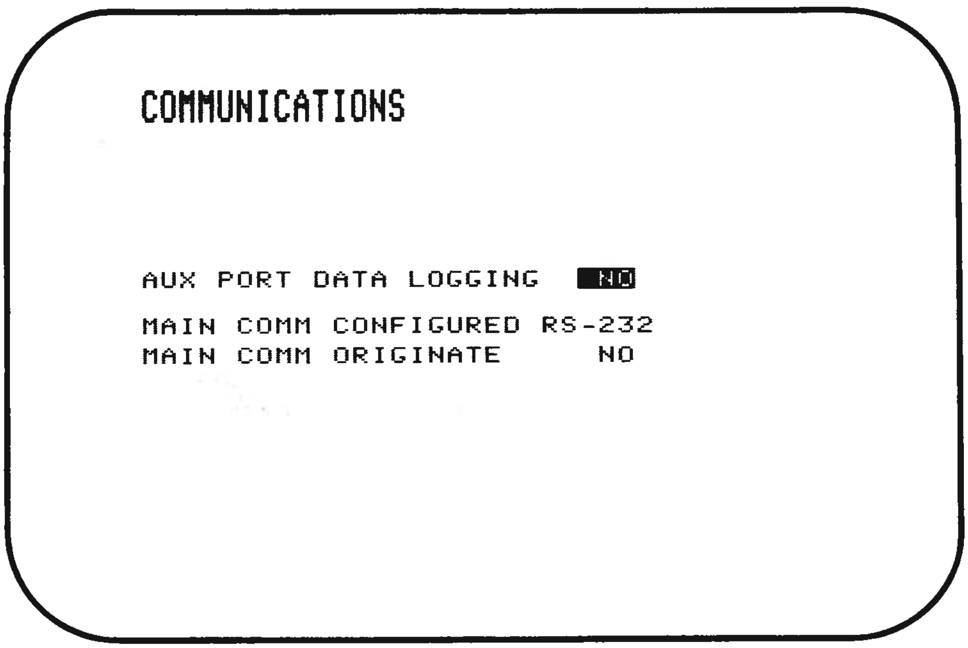


Figure 2.26 Communications Display

This display is used to indicate the type of communications configured in the Sentinel system. They are IEEE-488, RS-232, or SECS communications. This display also indicates any user messages sent to the unit when configured for the SECS protocol.

The selection of communications is done via switch settings on the CPU Board. The following table indicates switch configurations for communication selections:

1 = On/Closed　　　0 = Off/Open

S3	S2	Communication
1	1	SECS
1	0	RS-232
0	1	IEEE-488 (must have IEEE-488 interface board in unit, otherwise default to RS-232)
0	0	RS-232

In RS-232 operation, an automatic formatted datalog dump may be enabled. When enabled, the dump will occur at the completion of a process cycle and will be output via the Auxiliary service port. A remote message operation is available in SECS which makes it possible for the operator at a remote terminal to send a display message to the Sentinel III display screen. This 36 ASCII character message is for information use only and will appear above the data portion of the COMMUNICATIONS display.

DEVICE ID SECS parameters used to identify the equipment.

DATA RANGE:	0 THRU 32,767
UNITS:	NONE

RETRY COUNT SECS parameter used to set the number of times the Sentinel will try to complete a message transfer after the first failure to complete.

DATA RANGE:	0 THRU 31
UNITS:	NONE

RECEIVE TIMEOUT SECS parameter used to throw away the present command if the timeout between character reception is exceeded.

DATA RANGE:	00.1 THRU 10.0
UNITS:	SECONDS

PROTOCOL TIMEOUT SECS parameter used to set the maximum time for a host computer to accept a message sent by the Sentinel before the message will be sent again by the Sentinel.

DATA RANGE:	00.2 THRU 25.0
UNITS:	SECONDS

AUX PORT DATA LOGGING A switch parameter for the automatic dump of the process datalog system through the Auxiliary RS-232 port upon process completion.

DATA RANGE:	1=YES/0=NO
UNITS:	NONE

MAIN COMM ORIGINATE A switch parameter for auto send of "STOP" and "PROCESS DONE", and "PROCESS STARTED" codes.

The IEEE-488 Address is determined by switch settings on the IEEE Board.

2.3.8 EXTERNAL I/O DISPLAY (Figure 2.27)

To access this display, press the MENU key on the instrument front panel and press the number (6) key.

```
EXTERNAL I/O

                  INPUT FUNCTIONS

FIXED                   USER CODES
1. START                 7. ■
2. STOP                  8.
3. RESET                 9.
4. CALIB CH1            10.
5. CALIB CH2            11.
6. INTERLOCK            12.
                 OUTPUT FUNCTIONS

FIXED          TYPE     USER CODES       TYPE
1. STATUS      2 NC      7.              0
2. STOP        1 NO      8               0
3. XTL SHTR    1 NO      9.              0
4. CH1 SHTR    1 NO     10.              0
5. CH2 SHTR    1 NO     11.              0
6. END PROC    1 NO     12.              0
```

Figure 2.27 External I/O Display

This display is used to define a set of six input and six output functions for control of specific remote relay operations. A set of six dedicated input and output functions and their names is also presented on the display. The I/O parameters may only be updated at the end of a process or when in the READY phase.

Programmable Input Functions

There are six (6) available optically isolated input lines that may be assigned various functions by the user. The particular function or combination of functions will be determined by the 2 digit FUNCTION ID CODES assigned to the input line. Multiple functions may be assigned to one input line by including the & (AND) logic symbol in the definition string between ID CODES. The + (OR) logic symbol is not legal in input string definitions.

To change a definition move the cursor to the desired location with the left/right arrow keys and type over the desired data. The previously stored definition may be recalled by placing the cursor at the end of the string and pressing the "CLEAR" key. Pressing the "CLEAR" key with the cursor at any location other than the end will erase the string from the cursor location to the end. When a definition has been complete it must be entered into memory via the "ENTER" key. The definition syntax will be checked and an ENTRY ERROR will be indicated for an incorrect definition.

All input lines are in a normally non-activated state and become active with a remote contact closure of applied potential depending on the wiring scheme.

Use these for the INPUT FUNCTIONS USER CODES (7 through 12).

ID CODE	FUNCTION	INPUTS
10	Start	Same as START key on front panel.
11	Stop	Same as STOP key on front panel.
12	Reset	Same as RESET key on front panel.
13	Zero Thickness 1	Will do zero thickness on Channel 1.
14	Zero Thickness 2	Will do zero thickness on Channel 2.
15	Calibrate Channel 1	Same as CAL1 key on front panel.
16	Calibrate Channel 2	Same as CAL2 key on front panel.
17	Emission Interlock	When set, will turn emission off, and not allow emission to be turned on. When reset, will delay 2 seconds, then turn emission on.
18	Turn Emission Off	Will turn emission off.
19	Turn Emission On	Will turn emission on.
20	Final Thickness Trigger - All Channels	All channels will exit deposit.
21	Final Thickness Trigger - Channel 1	Channel 1 will exit deposit.
22	Final Thickness Trigger - Channel 2	Channel 2 will exit deposit.
23	Crystal Fail Inhibit	See Section 2.7.7
24	Soak Hold Channel 1	When set, channel will remain in Soak Time
25	Soak Hold Channel 2	2 until input reset.
26	Set Process 1 Active	Will make this the next active process (if process is running, this input will have no effect)
27	Set Process 2 Active	
28	Set Process 3 Active	

Programmable OUTPUT FUNCTIONS

There are six (6) available output relay contacts that may be programmed for a specific response function by the user. The particular response or combination of responses will be determined by the 2 digit codes made up of the group identifier digits (x) and the subset identifier digits (y) along with the logic symbols & (AND) and + (OR). Logic symbols may be mixed within a particular definition however the definition will be interpreted as if an inclusive bracket were included around all codes involving the & (AND) functions. A maximum of four (4) function codes may be included in any single definition.

Editing is performed in the same manner as in the INPUT FUNCTIONS above.

The contact action to take place when the output definition becomes "TRUE" may also be specified. This is done by entering the CONTACT TYPE code (z) following the output definition string. Five output types may be specified: 1 equals normally open (NO) and the contact will close when true. 2 equals normally closed (NC) and will open when true. 3 equals pulsed closed (PC) and will be normally open and pulse closed for one second when true. 4 equals pulsed open (PO) and will be normally closed and will pulse open for one second when true.

5 equals Computer Controlled (CM) normally open and operation will be controlled via computer interface.

The contact type code 0 (ZERO) will disable the relay definition and will leave the contact in a normally open (NO) condition.

Use these codes for the OUTPUT FUNCTIONS USER CODES (7 through 12)

(X) Group 0 thru 6 -			(Y)	(Film/Phase Group) - (Outputs)
0	Any Film	–	0	Ramp 1 - Film in Rise Time 1 phase.
1	Film 1	–	1	Soak 1 - Film in Soak Time 1 phase.
2	Film 2	–	2	Ramp 2 - Film in Rise Time 2 phase.
3	Film 3	–	3	Soak 2 - Film in Soak Time 2 phase.
4	Film 4	–	4	Shutter Delay - Film in Shutter Delay phase.
5	Film 5	–	5	Rate Ramp - Film in Rate Ramp phase.
6	Film 6	–	6	Idle Ramp - Film in Idle Ramp phase.
			7	Calibrate - Film in Calibration.
			8	Setpoint Thickness - Film's thickness exceeds setpoint thickness.
			9	Timer Complete - The Total time a film has been active exceeds setpoint timer.

(X) Group		(Y) (Film/Phase Group) - (Outputs)	
7 - Endpoint:	0	Any film	Film has finished. Output will remain active until another film starts in the same channel.
	1	Film	
	2	Film 2	
	3	Film 3	
	4	Film 4	
	5	Film 5	
	6	Film 6	
	7	Process 1	Process has finished. Output will remain active until another process starts.
	8	Process 2	
	9	Process 3	
8 - Shutter	0	Any Channel Deposit	Channel is in deposit, rate ramp, or manual phase - shutter open.
	1	Channel 1 Deposit	
	2	Channel 2 Deposit	
	3	Any Channel Crystal	Channel is running with crystal, and is in deposit, rate ramp, or manual phase.
	4	Channel 1 Crystal	
	5	Channel 2 Crystal	
	6	End Any Process	Any process has finished (see above).
	7	Process 1 Active	Process in progress.
	8	Process 2 Active	
	9	Process 3 Active	
9 - Status:	0	Stop	System in "STOP". A "START" command will begin a new process.
	1	Ready	
	2	Filter Error	Tried to change a filter when filter changer not installed or malfunctioning.
	3	Crystal Fail	Crystal has failed while crystal enabled.
	4	Time Power	System is running in Time Power.
	5	Calibration Error	Calibration attempted, but not successfully completed.
	6	Max Power	A channel is running at maximum power.
	7	Status	Power failure, no emission if needed, no crystal if needed, interlock input set.
	8	Shutter Error	Desired rate not reached within 60 seconds.

Use these codes for OUTPUT relay contact TYPE.

(Z)			
0	-	Relay Not Used	
1	-	Normally Open	(NO)
2	-	Normally Closed	(NC)
3	-	Pulses Open (1 sec)	(PO)
4	-	Pulses Closed (1 sec)	(PC)
5	-	Computer controlled	(CM)

Refer to Figure 2.9 for associated Input/Output pin information.

2.3.9 INTERNAL I/O DISPLAY (Figure 2.28)

To access this display, press the MENU key on the instrument front panel and press the number (7) key.

```
INTERNAL I/O

     EVENTS                          RESULTS
    (OUTPUT)        TYPE             (INPUT)

1. █                 0
2.                   0
3.                   0
4.                   0
5.                   0
6.                   0
7.                   0
8.                   0
```

Figure 2.28 Internal I/O Display

This display provides the user with a means of linking the programmable INPUT and OUTPUT functions together without using the hardware interface connections. In this display up to eight (8) specific output logical definitions may be individually assigned to eight (8) specific input logical definitions.

The programming method and codes for this display are exactly the same as the EXTERNAL I/O DISPLAY method and the same rules apply with one exception. In this display the PULSED CONTACT and COMMUNICATION CONTROL TYPES are not allowed.

These parameters may only be updated at the end of process or when in the READY phase. If the contact type is NO(1), when the OUTPUT DEFINITION becomes true, the INPUT DEFINITION becomes activated. If the contact type is NC(2), when the OUTPUT DEFINITION becomes false, the INPUT DEFINITION will be activated. This system provides the user with great system versatility with no hardware usage.

2.3.10 OUTPUT TABLE DISPLAY (Figure 2.29)

To access this display, press the MENU key on the instrument front panel and press the number (8) key.

OUTPUT TABLE

0-6 FILM/ PHASE GROUP (0=ANY FILM)	0 RAMP 1 1 SOAK 1 2 RAMP 2 3 SOAK 2 4 SHUT DLY 5 RATE RMP 6 IDLE RMP 7 CALIBRAT 8 THCKNESS 9 TIMER	8 SHUT- TER GROUP	0 ANY DEP 1 CHAN 1 DEP 2 CHAN 2 DEP 3 ANY XTL 4 CHAN 1 XTL 5 CHAN 2 XTL 6 END PROC 7 PROC 1 ACT 8 PROC 2 ACT 9 PROC 3 ACT
7 END- POINT GROUP	0 ANY FILM 1 FILM 1 2 FILM 2 3 FILM 3 4 FILM 4 5 FILM 5 6 FILM 6 7 PROC 1 8 PROC 2 9 PROC 3	9 STAT- US GROUP	0 STOP 1 READY 2 FILTER ERR 3 XTL FAIL 4 TIME POWER 5 CAL ERROR 6 MAX POWER 7 STATUS 8 SHUT ERROR

Figure 2.29 Output Table Display

This display provides a list of available OUTPUT FUNCTION USER CODES for use with the INTERNAL I/O and EXTERNAL I/O Displays. Use this display for reference only.

2.3.11 INPUT TABLE DISPLAY (Figure 2.30)

To access this display, press the MENU key on the instrument front panel and press the number (9) key.

```
INPUT TABLE

10 START
11 STOP
12 RESET
13 ZERO THICKNESS 1
14 ZERO THICKNESS 2
15 CALIBRATE CHAN 1
16 CALIBRATE CHAN 2
17 EMISSION INTERLOCK
18 EMISSION OFF
19 EMISSION ON

20 FINAL THICKNESS ALL CHAN
21 FINAL THICKNESS CHAN 1
22 FINAL THICKNESS CHAN 2
23 XTAL FAIL INHIBIT
24 SOAK HOLD CHAN 1
25 SOAK HOLD CHAN 2
26 PROCESS 1 ACTIVE
27 PROCESS 2 ACTIVE
28 PROCESS 3 ACTIVE
```

Figure 2.30 Input Table Display

This display provides a list of available INPUT TABLE USER CODES for use with the INTERNAL I/O and EXTERNAL I/O Displays. Use this display for reference only.

2.4 Process Description

2.4.1 RUNNING A PROCESS

To run a process, set up a process string in the EXECUTIVE display. The ACTIVE PROCESS will indicate which process will be run.

Assuming that the Sentinel III is in STOP the following steps will run a process:

1. Press RESET. This will put the first film(s) to the READY phase.

2. Press START. This will start any film that had been in READY.

3. Pressing START again will start the next film in the processing string. Note that if a START is done while another film is running in the same channel as the film to be started, a CHANNEL CONFLICT message will appear, and the process will STOP.

4. If, for any reason, a STOP occurs while a process is in progress, the process can be continued where it left off. This is done by pressing START (instead of RESET) while in STOP. If this is done, the films that were running will start again, from RISE 1. However, the thickness accumulation will not be zeroed on the start of deposit.

2.4.2 CO-DEPOSITION

Two films can be executed simultaneously on the two channels by placing them in a process string connected by an &. When a START is done, both channels will start. Both channels will continue controlling until the first film (the one to the left of the &) reaches its final thickness. At that point, both films will terminate. If the final thickness of the second film is reached before the first one, the second film will terminate, but the first one will continue until it reaches its final thickness.

2.5 Phase Descriptions

2.5.1 OVERVIEW OF PHASES

To operate the Sentinel III as a film thickness/rate controller it is necessary to program film sequence parameters. A film sequence begins with a START command and ends when the film in process reaches the idle phase. Any process control that occurs between these events is determined by the values programmed in the possible parameters. A film sequence consists of many possible phases, with a phase being defined as one process event. These phases are described below: See Figure 2.31.

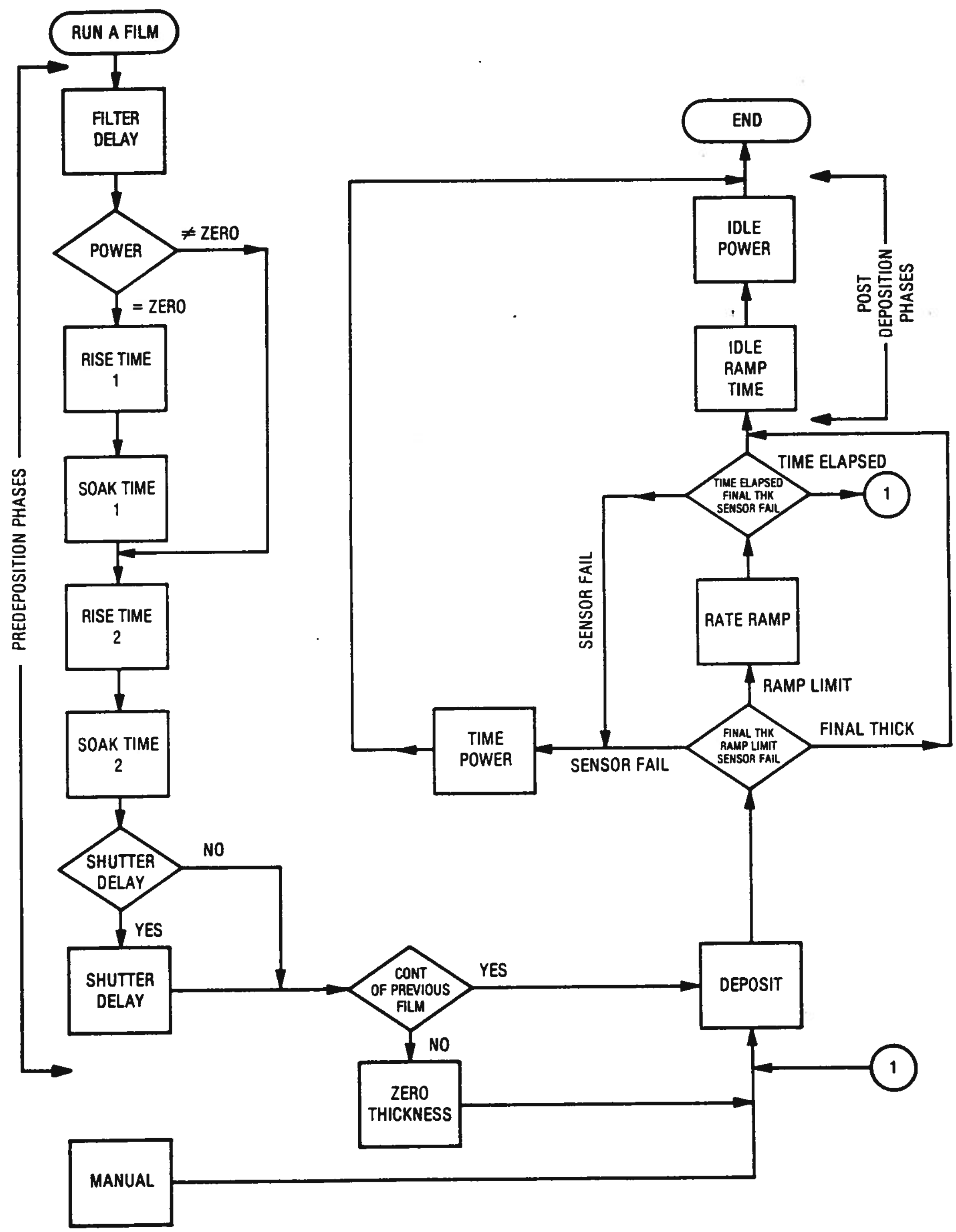


Figure 2.31 Phase Diagram

> **NOTE:** The STOP phase - All source shutters closed; sensor shutter closed; instrument will accept a START or RESET; All source powers at zero; the operating display is frozen.

In the sequential mode of operation, either channel may be sequencing through the above phases as described. In the alloy mode of operation, both channels are in use simultaneously. It is unnecessary to start both channels simultaneously, although this may be done. (See Section 2.3.6 for P1 definition.) A start command will be executed even if one channel is operating provided the next sequential film calls for the non-active source.

2.5.2 SHUTTER DELAY

Shutter Delay is used to establish rate control before exposing the substrates to the evaporant. The sensor must be exposed to the source during the Shutter Delay phase for this to be accomplished. Shutter delay is accessed by setting the shutter delay parameter in the film display to YES. The control loop attempts to establish rate control at the end of the pre-deposition film phases. The source shutter opening is delayed for a period of time to insure stable rate control. When rate control has been established, the shutter opens, the accumulated thickness is zeroed, and the substrates are immediately exposed to an evaporant that is under tight rate control. With proper adjustment of the control loop parameters, the delay time can be kept to a minimum. If the Sentinel III is unable to establish rate control in 60 seconds the shutter error relay on the I/O RELAY Module will close.

2.5.3 RATE RAMPING

a. Programming Rate Ramp

The Sentinel III film program includes a means to change the rate during the deposition phase. It may be used to generate a precise linear variation in the evaporation rate. These rate ramp programs operate during the deposit phase of the film sequence, and are initiated when the programmed SETPOINT RAMP is reached. The rate ramp phase will continue for the programmed duration of the ramp, or until the Final Thickness set point of the film program is reached.

An additional Rate Ramp may be done by zeroing the thickness and resetting the NEW RATE. The deposition will continue to be controlled at the previous NEW RATE until the SETPOINT RAMP is reached. The rate ramp will then be done as before, ramping from the previous NEW RATE to the current NEW RATE.

If the rate ramp phase terminates before reaching Final Thickness, the Sentinel III will return to the Deposit phase. The slope of a rate ramp is determined by the following equation: change in rate per second = (NEW RATE - previous control rate) divided by ramp time. If a ramp parameter is changed during a ramp, the new slope will be calculated, taking into consideration the time the ramp has already been in process. Rate ramps are disabled by setting RATE RAMP TIME to 00:00 or by setting NEW RATE equal to RATE BGN.

b. Rate Ramp to Zero Rate

It is sometimes desirable to ramp to zero rate for phasing purposes, and also to complete the film processing as if the Final Thickness had been achieved. Therefore, when a NEW RATE value of 00.0 is achived, the film program will proceed as if the Final Thickness limit had been reached.

2.5.4 COMPLETE ON TIME-POWER

The Sentinel III has the ability to complete a deposition normally if a sensor fails during the deposit phase. Depending on the parameter setting, the Sentinel III will either complete on TIME-POWER (1), OR STOP (0) on sensor fail. When the Sentinel III is set up to complete on TIME-POWER and a sensor fail is encountered the average power is used to accumulate thickness at the Rate setpoint. When the deposition reaches final thickness, the Sentinel III will automatically go to STOP. The thickness accuracy will depend on the duration of the TIME-POWER phase. A shorter duration will increase the Final Thickness accuracy; longer durations will decrease accuracy.

2.5.5 STARTS FROM IDLE POWER

When a film program terminates at a non-zero Idle Power, a subsequent start of film in the same channel will initiate the film sequence at the Rise Time 2 phase. The Rise Time 1 and Soak Time 1 phases will be ignored. The cycle time between layers is decreased, since the source has been maintained at some interim power level and does not require the long preconditioning time provided by the Rise Time 1/Soak Time 1 phases. The Rise Time 2 phase will begin at the Idle Power level at the time of the START command, and will ramp to the programmed Soak Power 2 level. A film program that is started from either the READY phase or the Idle Power (0) phase will always execute the Rise Time 1 phase.

2.6 Selecting Parameter Values

2.6.1 INITIAL VALUES OF PARAMETER

On power up the Sentinel III will retain the most recently entered values for the following parameters. However, in a new (unprogrammed) instrument, or in case of a PROGRAM LOSS, the following parameters will be assigned default values. All other parameters will be programmed to 0.

PARAMETER	DEFAULT VALUE
TOOLING	100.0%
DENSITY	1.000 gm/cc
Z RATIO	1.000
MAX POWER	90%
GAIN	10
DAMP	0
PMT RANGE	8
PMT CALIB	1.000
CAL ACRCY	3%
CMPL TPWR	YES
CHANNEL #	1 (except on film 2, where it is 2)
ACTIVE PROCESS	1
POSITION TO START	1
XTAL DISABLED	YES
P1, P2, P3	1
RETRY COUNT	3
RECEIVE TIMEOUT	.5
PROTOCOL TIMEOUT	10.0
DEVIATION DWELL	10
DEVIATION SCALE	10

2.6.2 SETTING SOAK POWER 1 PARAMETERS

Soak Power 1 is typically set at a level that produces a source tempera-ture just below significant evaporation. This is easily translated into a power percentage (Soak Power 1) with the help of the hand held controller in the MANUAL phase. Slowly bring the power level to the apparent desired deposition rate and then note the power percentage value on the video display. Use this value for the Soak Power 1 setting. This power level may also be used in fast coaters for a non-zero Idle Power. Set the associated Rise Time and Soak Time to insure that the melting does not cause violent turbulence but does not waste excessive time.

2.6.3 SETTING SOAK POWER 2 PARAMETERS

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

2.6.4 SETTING GAIN AND DAMP

The function of the control loop is to stabilize the evaporation rate at the programmed Rate. By selecting the most favorable gain and damp values, you can control sources with nearly any physical characteristics.

Even though theoretical methods exist for determining initial control settings, an experimental approach remains the most practical and least time-consuming for most installations. This approach requires recognition of basic symptoms of incorrect adjustment, from the shape of the analog rate output on a chart recorder or the rate deviation display. The most usual diagnostic technique is to observe both the negative and positive step changes in the Rate. In some processes it may be necessary to compromise final adjustments for the sake of best overall control action.

You should avoid setting the control loop to values of gain and damp where minor changes in process conditions can introduce cyclic system responses. Satisfactory control settings are those which produce acceptable results in overall rate control without sacrificing control stability. These settings will be arrived at experimentally as described below. Remember to allow conditions to stabilize between adjustments in order to properly assess the adjusted performance, especially in the case of slow sources. Once the best settings have been determined, they should be recorded to facilitate future resetting.

The RATE Deviation displays provide an analog indication of Deposition Rate Control. You may choose a deviation Range of + and - 10, 20, or 40 A/sec. These numbers appear at the upper and lower ends of the graph. The center number indicates the actual Deposition Rate. An analog signal, to the right of each graph, indicates the deviation level, with respect to the Deviation Range. Table 2.1 gives some starting values to be used when beginning to adjust the control loop.

Table 2.1 Typical Control Loop Parameters

SOURCE	GAIN	DAMP
E Beam	60-99	0
Slow Resistance or Induction	5-10	40-80
E Beam w/Crucible	20-40	5-30

a. Setting Gain

As you initially adjust the gain, you should keep the damp parameter at the preprogrammed value of 0. As the gain is increased, the control voltage rate of change increases for a given error. To find the initial gain setting, the gain setting on the Sentinel III must be progressively increased. Observe the effect of gain change on a chart recorder or deviation display. Use the same rate change for both rate increases and decreases. Allow sufficient time after each adjustment for the system to stabilize. When the system is cycling (oscillating) steadily, note the frequency and magnitude of the cycle and decrease the gain until the cycling stops or is minimized. If extremely low values of gain (less than 10) are necessary to achieve this, increase the damp by units of five and repeat the above procedure until cycling is eliminated.

b. Setting Damp

Damp should be increased when the rate control displays overshoot (or undershoot) of the Rate or if the rate controls oscillate when an incremental change of rate is made. Experiment to achieve the correct approach setting, in conjunction with the gain setting. Use the minimum value of damp that eliminates (or nearly eliminates) overshoot, since large values tend to increase control loop noise. Figure 2.32 shows the effects of the damp setting adjustment on the control loop. Curve A illustrates the effect of increasing the Damp relative to Curve O and is "Critically Damped". Curve B illustrates the effect of increasing the Damp relative to Curve A and is "Over Damped".

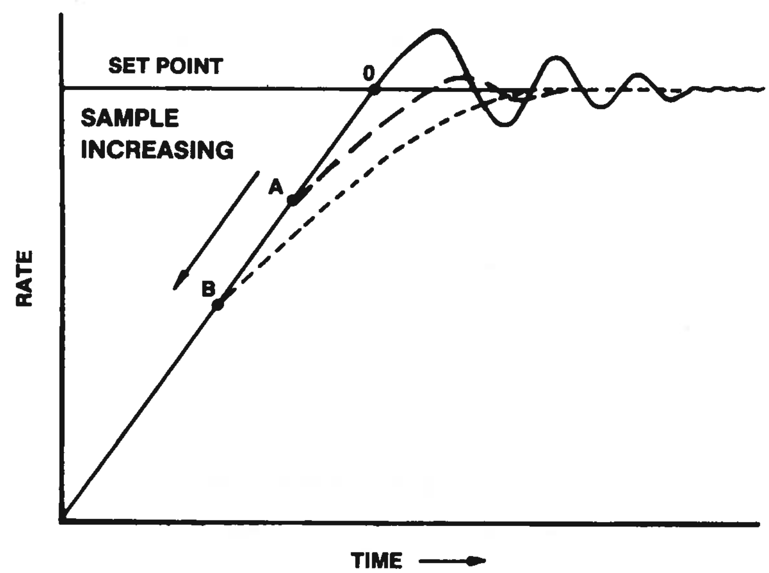


Figure 2.32 Effect of DAMP Setting on Control Loop

c. Summary of Control Loop Adjustments

NOTE:	Allow sufficient time after each adjustment for the system to stabilize. Use a chart recorder or the rate deviation display.

1. Adjust gain to the maximum table setting for acceptable rate deviation.

2. If cycling or overshoot with step change of rate occurs, increase the damp setting. As gain and damp controls interact, steps 1 and 2 should be repeated to determine the best values.

3. Reverse any adjustments that deteriorate control performance. If cycling cannot be totally eliminated, adjust damp and gain for best overall control action.

4. If the output power necessary to operate the source is always less than 5 volts, removing Jumpers J1 and/or J2 (on the Deposition Control Board) will reduce the maximum output voltage and improve control action by allowing smaller steps.

Figure 2.33 shows the analog display response to both positive and negative rate steps.

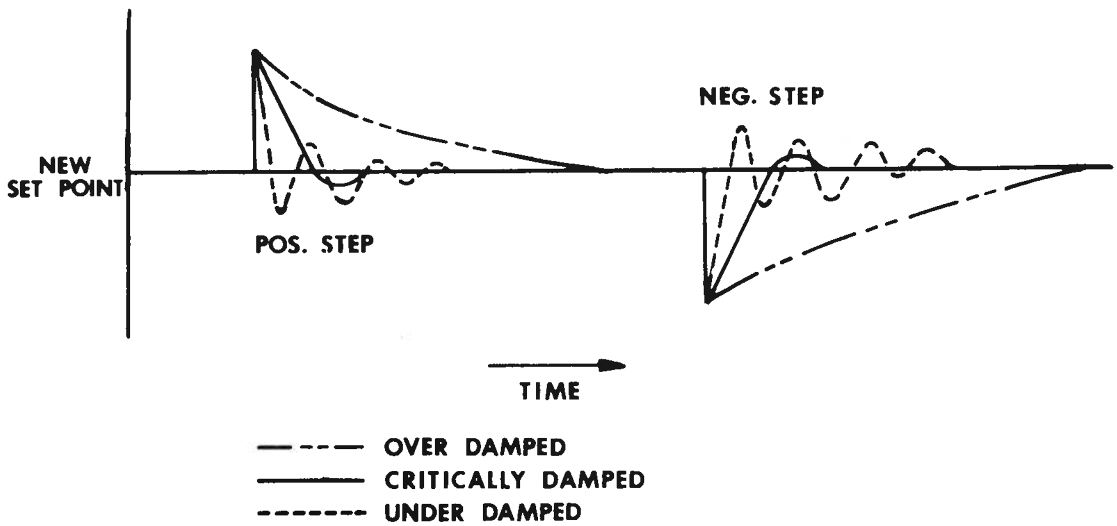


Figure 2.33 Analog Display Response to Rate Steps

2.7 Special Functions

2.7.1 MANUAL POWER OPERATION

Manual Power operation provides an easy method of increasing or decreasing the source power for the selected channel or setting the instrument to STOP. If the instrument is in STOP, or the channel to be selected is in IDLE, Manual Power selection will not be accepted. To select Manual Power, press the MAN 1 or MAN 2 button. The channel under control will display MANUAL as the phase. Control of the source power for the selected channel is provided at the hand held Manual Controller. All positions are momentary and will return to the rest when released. Pushing the switch to the left or right will cause the output control voltage to increase or decrease. Pressing the switch downward causes the Sentinel III to STOP (same as pressing the front panel STOP button).

2.7.2 RUNNING IN TEST

When the TEST ON parameter is set to YES, the Sentinel III will run in TEST MODE. The Sentinel III will function normally, except instead of receiving the signal read from a sensor, a resident test signal will be read. A TEST message is displayed, and all emission functions are disabled.

If a channel is being controlled by the crystal while in TEST, a simulated constant rate will be generated. All crystal fails will be ignored.

2.7.3 AUTO CALIBRATION

The Sentinel III is designed to interact with a built-in quartz crystal microbalance for fast and accurate calibration or verification of accurate operation. With the optional Crystal sensor, shutter, and oscillator installed, the operator may fully calibrate the unit with a single keystroke. This operation does require preprogramming of the necessary information. To use this feature you must implement the following:

a. Install the feedthrough, sensor, shutter, shutter valve, oscillator and cables following the guidelines in section 3.2.4.

b. Program density, Z-Ratio, and tooling into the FILM display to be used. See Table 4.1 and Sections 4.2.4 and 4.2.5.

c. Connect wiring between the EXTERNAL OUTPUT and the corresponding Crystal Shutter valve.

d. Operation may be initiated by one of the following:

   1) Manual operation from the Sentinel III front panel, for either channel 1 or channel 2, by pressing the CAL 1 or CAL 2 keys.

   2) Remote operation is available through a properly programmed EXTERNAL INPUT (see Section 2.1.8).

   3) Computer controlled operation via one of the computer interface modules.

   4) At the start of a film if AUTO CAL parameter set to YES.

e. Periodic recalibration may be accomplished throughout a long or continuous process at intervals up to 999 minutes. The appropriate FILM display CAL INTVL parameter must be selected for this type of operation.

The calibration sequence, following activation, is as follows:

a. The shutter valve is activated, exposing the crystal to the deposition flow.

b. Following a five (5) second period of thermal stabilization, the crystal accumulates deposit.

c. The PMT and fine gain controls are automatically adjusted to calibrate the unit. (No changes are made if the crystal and optical readings agree within the CAL ACRCY limits.)

d. When the PMT and fine gain are adjusted, the shutter automatically closes.

Because of this brief exposure, a crystal may be used over an extended period of time, thus reducing the chance of failure.

Auto calibration works properly in systems with a significant crosstalk signal if the proper procedures are followed on system setup. Once the proper cross-sensitivity parameter is established the subsequent auto calibration may be performed at any pressure and the calibration will hold at any of the normal pressures encountered. The cross-sensitivity and calibration parameters must be determined manually on system startup as follows:

a. At the lowest achievable system pressure possible, initiate an auto or manual calibration to adjust the material channel PMT RANGE and PMT CALIB parameters. The CROSS-SENSITIVITY MONITOR parameter must be set to zero at this time.

b. With the deposition stopped, adjust the monitor channel gain to provide a significant rate reading for the monitor channel.

c. Adjust the CROSS-SENSITIVITY MONITOR parameter to a value that nulls the displayed rate on the material channel of interest.

d. Perform a second calibration on the material channel.

e. If the calibration constants differ by more than 10% it is recommended that steps c & d be repeated until successive calibration constants agree within 10%.

Once the cross-sensitivity parameter is established it will not need to be adjusted until the monitor filter requires replacement. Auto calibration will now be valid at all pressures.

The procedure is of course much simpler in cases where gasses are not a problem and the only interferences are due to other materials. A more detailed explanation of the cross sensitivity correction is given in Section 4.1.7.

2.7.4 LOCK CODE

The Sentinel III instrument gives the user the ability to prevent access to programmable process parameters without prior knowledge of a locking code. This code may consist of any four digit number combination.

The lock code is entered in the EXECUTIVE display. Programming the lock code to 0000 will put the instrument in an unlocked condition, with all parameters accessible. If this is true, no lock message will appear on displays other than the EXECUTIVE display. When the instrument is unlocked the EXECUTIVE display will show a UUUU message. When a parameter other than 0 is entered, all parameters will be locked, except those on the DATA display. When any other display is entered, the LOCK CODE XXXX message will appear under the display header. The cursor will not move to any parameters except the lock code (and the film number in the FILM display). To unlock the display, enter the proper lock code. This will only unlock the current display until the display is exited.

Note that to change a lock code that is already present, two steps must be taken. First, go to the EXECUTIVE display and enter the existing lock code to unlock the display. Then, move cursor back to the lock code and enter the new lock code, or 0000 to unlock all displays.

If the "LOCK CODE" is lost or forgotten it may be erased from system memory by turning POWER off and then back on with the "RESET" key held down.

CAUTION: *Only the "LOCK CODE" will be cleared if there is one present, but if the "LOCK CODE" is not present and a power-up RESET is done all program parameters will be erased and reset to initial values.*

NOTE: The computer interface lock code overrides the front panel lock code.

2.7.5 USING AND CALIBRATING THE ANALOG OUTPUT

The analog output may be calibrated prior to actual deposition by using the internal TEST mode which provides adequate simulation to fine adjust the recorder for zero and span. Rate must total 0 for zero analog output; all three rate readings must be 200 or 2000 for a full span deflection. The analog output signal is available at the ANALOG RECORDER connector using Pins 1, 2, and 3 for the signal and Pins 8-14 for analog ground. The available output voltage range at this pin is 0 volts to 10 volts. For proper operation the chart recorder must be configured to accept a 0 to +10 volt signal for a full deflection sweep and the recorder inputs must be connected to the pins noted above. Refer to Back Panel Descriptions for additional information on the contact ratings for this output.

2.7.6 FILTER CHANGER

The optical bandpass filter can be changed using the optional filter switcher unit. (See Section 6.12 for details on the filter change controller board.) When a film is STARTed, the filter number will be checked. If the filter indicated is different from where the filter switcher is set, it will be changed before entering the RISE 1 phase of processing. This is the FILTER DELAY phase. Note that changing the filter number while a film is in progress will have no effect, until that film is started again.

2.7.7 CRYSTAL FAIL INHIBIT

In many coating plants the crystal fail output is given major importance and causes the entire system to shut down. This can cause problems when the crystal is changed as part of the normal reloading procedure. This potential conflict is resolved by utilizing the crystal fail inhibit input. When this input is activated any crystal fail will be ignored. The operator may now change the crystal and verify that it is operating without inducing a major process interruption. This input may be switched using the I/O relays or the computer interface.

NOTE: Crystal Fail Inhibit is a continuous input and will remain active until the input is reset.

2.8 Messages

The Sentinel III is designed to warn of conditions that would result in no data, or invalid data, being taken.

If the system is stopped, an oversized STOP warning will flash in the upper right corner along with a message describing the cause for the stop condition. One of the following messages may appear with the STOP warning:

POWER LOSS The line power to the instrument has been interrupted. The instrument has shut down and restarted.

PROGRAM LOSS Previous program parameters stored in the instrument have been erased and default conditions from an internal table have been inserted into the operating memory. Battery backup for the CMOS is designed to protect the program memory. If the battery fails and a power loss is encountered the program parameters will not be protected.

CABLE ERR An attempt has been made to operate the instrument without having the SCU Interface Cable installed.

POSITION ERR An attempt has been made to START a process when the POSITION TO START is set to a position without a programmed film number. POSITION TO START is a parameter on the EXECUTIVE Display.

CHAN CONFLICT An attempt has been made to operate two (2) films at the same time which are programmed to operate on the same channel.

XTAL FAIL This message indicates a crystal has failed. This message will appear if an attempt is made to start a film when the crystal will eventually be used in the process.

> **NOTE:** If the XTAL DISABLED parameter on the EXECUTIVE Display is set to YES, the XTAL FAIL message will not be displayed.

XTAL CONFLICT An attempt has been made to operate the crystal on both channels at the same time.

CHANGER ERR This message indicates a problem with the Filter Changer(s). Following activation and a one (1) minute delay, the Filter Changer has not advanced to the programmed position.

NO CHANGER An attempt has been made to operate the Filter Changer(s) without proper cable or module connections.

EXTERNAL A STOP has occurred due to an external control. This may be initiated by: pressing STOP on the instrument front panel, pressing STOP on the hand held power control during Manual operation, a STOP received through the I/O RELAY Board, or by a computer interface STOP command.

SENSOR FAIL A sensor has failed prior to Deposit, or during Deposit when CMPL TPWR was not programmed.

RATIO ERR Ratio Control has been attempted when only one (1) channel is operating, or Ratio Control has been selected to control both channels.

The following group of messages can appear while the system is running.

MAX POWER 1 2 The programmed value of MAX POWER for the specified channel has been reached. If the instrument stays at MAX POWER for 5 seconds and the STOP on MAX POWER is enabled, the instrument will stop.

CAL ERR 1 2 An attempt has been made to calibrate a film on the specified channel when the crystal was unavailable for calibration. This may be due to one of the following:

a. XTAL FAIL
b. XTAL DISABLED
c. XTAL in use on the other channel
d. The time limit for calibration has been exceeded.

XTAL FAIL Crystal has failed.

CALIBR 1(or)2 The channel indicated is currently being calibrated.

CABLE ERR The SCU Interface cable is not connected. In place of CABLE ERR, one of the following messages may appear:

EMIS ERR 1 2 Indicates a problem with the emission system.

MAX LEAK 1 2 The emission leakage level of the sensor is very high and a SENSOR FAIL and STOP is about to occur.

50% LEAK 1 2 Indicates emission leakage value is approximately + of maximum allowed.

SHT ERR 1 2 The shutter delay phase has exceeded one (1) minute.

> **NOTE:** The "1 2" in the messages above indicates channel 1 and channel 2. The display may indicate 1 or 2 or both, depending on the circumstances.

Other messages include:

ENTRY ERROR A flashing message located in the lower left corner of the display indicates an incorrect parameter entry has been attempted.

TEST Located in the lower middle of the display indicates TEST operation has been selected on the EXECUTIVE Display.

EMISSION Located in the lower right of the display indicates sensor EMISSION is off.

> **NOTE:** If the active process contains films using only the crystal, that is if all films to be used have crystal measurement parameters set, the emission message will not be displayed (although the EMISSION will be set to OFF).

3.0 INSTALLING SENSING SYSTEMS

Refer to Figure 3.1 for an overview of the sensing system.

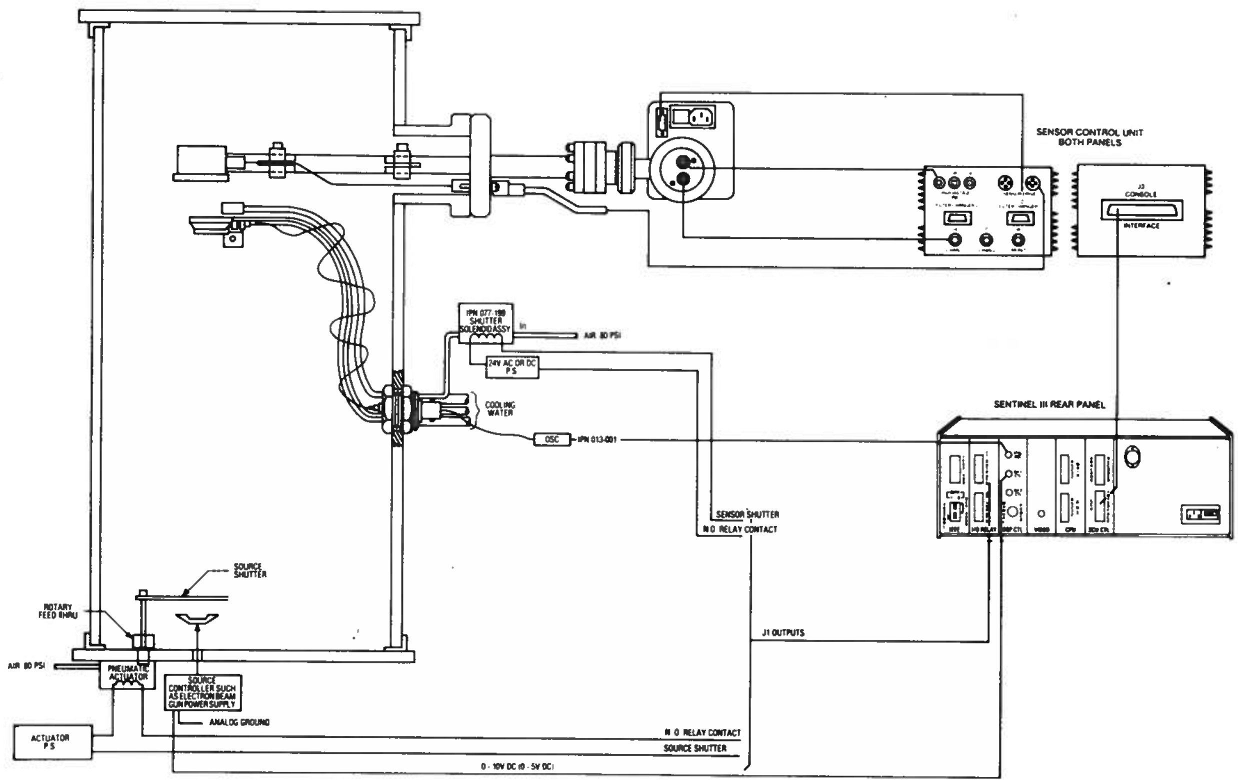


Figure 3.1 Overview of Sensing System

SECTION 3
INSTALLING SENSING SYSTEMS

3.1 Locating Sensors and Feedthroughs

Correct sensor location within the chamber is important to the Sentinel III's overall performance. (See Figure 3.2.)

In general, the preferred installation is as follows:

1. Locate the sensor directly above the evaporant source.

2. Use a straight section of optical coupling (as short as possible) between the sensor and feedthrough.

3. Provide a rigid support between the sensor and the vacuum chamber wall.

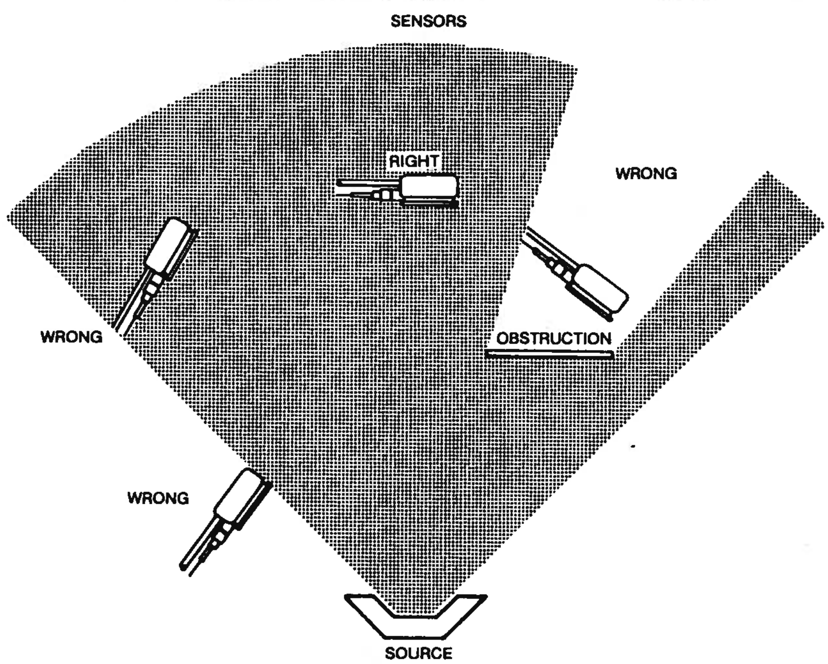


Figure 3.2 Preferred Sensor Location

CAUTION: *Do not use the optical coupling (light pipe) for support.*

4. Install additional shielding around the filament leads and light pipe to reduce accumulation of evaporated material. Aluminum foil is easy to use and provides effective shielding as long as it does not conflict with the process requirements.

5. Include special provisions for cooling if your process requires, to allow sensor temperature to remain below 450^{o}C.

6. Be sure the sensor is in an area with less than 2 gauss of stray magnetic field during deposition. Higher fields may deflect the electron beam and cause the sensor to have little or no sensitivity to evaporant.

Obviously, many installations will not allow all the above guidelines to be met. However, the net gain in system performance justifies their strong consideration.

3.1.1 OPTIMUM REPEATABILITY

Optimum repeatability is generally obtained when the sensor is located directly above the source. Always minimize the source to sensor angle for best results.

Preferred sensor location (Figure 3.2) is along the vertical center line from evaporant source as shown. If the center line location is not possible, the sensor can be mounted as shown with the optical coupling through an angled feedthrough. However, the greater the angle from the perpendicular center line, the greater the variation in sensitivity relative to changes in source conditions, (pool height and power density).

3.1.2 OPTIMUM LIGHT SIGNAL

Rigid optical couplings are best used when the coating system is designed with minimizing the sensor to detector distance. The optical signals falls off roughly on the square of the light pipe length. Care in the initial system configuration can avoid the cost and complexity of fiber optics. In general, if the light pipe distance exceeds 9", fiberoptics will provide higher throughput, independent of length.

3.1.3 DOUBLE ENDED SENSOR

In certain situations requiring the maximum optical signal a second light pipe may be attached to the Sensor. Since the light produced in the sensor is approximately isotropic, the second light pipe effectively doubles the light available for two material systems. The implementation requires accessory 016-402-G1 and a second feedthrough. Feedthroughs are mounted directly across from each other and the recommendations of 3.1.1 and 3.1.2 should be followed.

3.1.4 CRYSTAL CALIBRATION CONSIDERATIONS

The automatic crystal calibration feature requires a shuttered Quartz Crystal. Although the overriding concern should be for the EIES Sensor, the Crystal should be located as close to the EIES Sensor as possible so as to minimize the spatial variations of the evaporation sources. See the recommendations of Section 3.2.4. It is possible to mount the crystal sensor so as to capture the evaporant passing through the EIES sensor.

3.1.5 LIGHT SHIELD FOR REFRACTORY METALS (Optional)

In certain extreme cases the black body radiation emitted by the evaporation source can overwhelm the detection of the synchronously detected Sensor generated photons. In these extreme cases, an optional light shield (IPN 016-427-G1) is recommended. It is designed to reduce the angle of possible stray light entrance into the Sensor and is typically useful for materials like Nb, Ta, W and Mo. It is not recommended for the majority of vacuum deposited materials.

When installing a light shield, be sure you will have clearance for easy removal for Sensor maintenance. See the light shield outline drawing (Section 6) prior to system design.

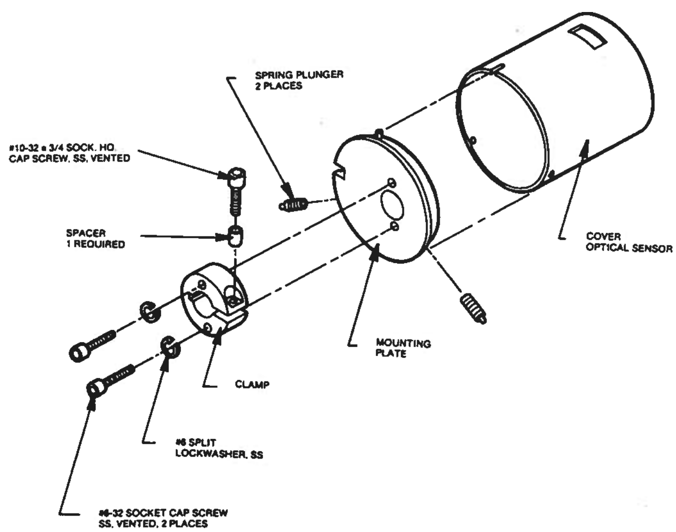


Figure 3.3 EIES Light Shield

3.2 Installing Sensors and Feedthroughs (Figure 3.4)

3.2.1 MOUNTING EIES SENSOR

Once the location of the sensor is determined, rigidly attach it relative to the evaporation source. If the positioning is not secured, calibration cannot be maintained. A sensor mounting bracket is included for this purpose.

For light pipes over 10", flexible feedthroughs and any situation where maximum rigidity is required, the use of the mounting bracket or some other attachment method is mandatory. The bracket is designed with considerable flexibility of positioning and mounting method in mind. Once the feedthrough and light pipe are placed and sensor location established, the bracket may be attached by welding or screwing it to a suitable fixture member.

3.2.2 INSTALLING RIGID FEEDTHROUGHS

a. Design For Easy Removal

The EIES Sensor is easily removed from the inside of most production coaters by loosening the clamp and pulling the Sensor away from the feedthrough. In these cases the In-Vacuum Cable will unplug from the Sensor or may be disconnected prior to Sensor removal.

Another class of systems that are often used are quite small or inaccessible from the inside. In these cases, a flange that is large enough to allow the entire Sensor to pass through is required. A 4½" ConFlat flange or any other flange with a 2½" minimum internal clearance adapted to the 2¾" ConFlat allows the use of standard components to achieve easy installation and removal from the outside of the system. See Figure 3.5.

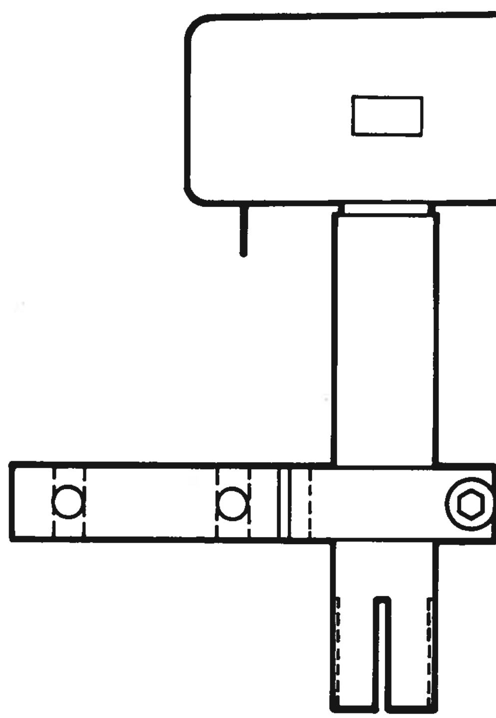


Figure 3.4 EIES Sensor

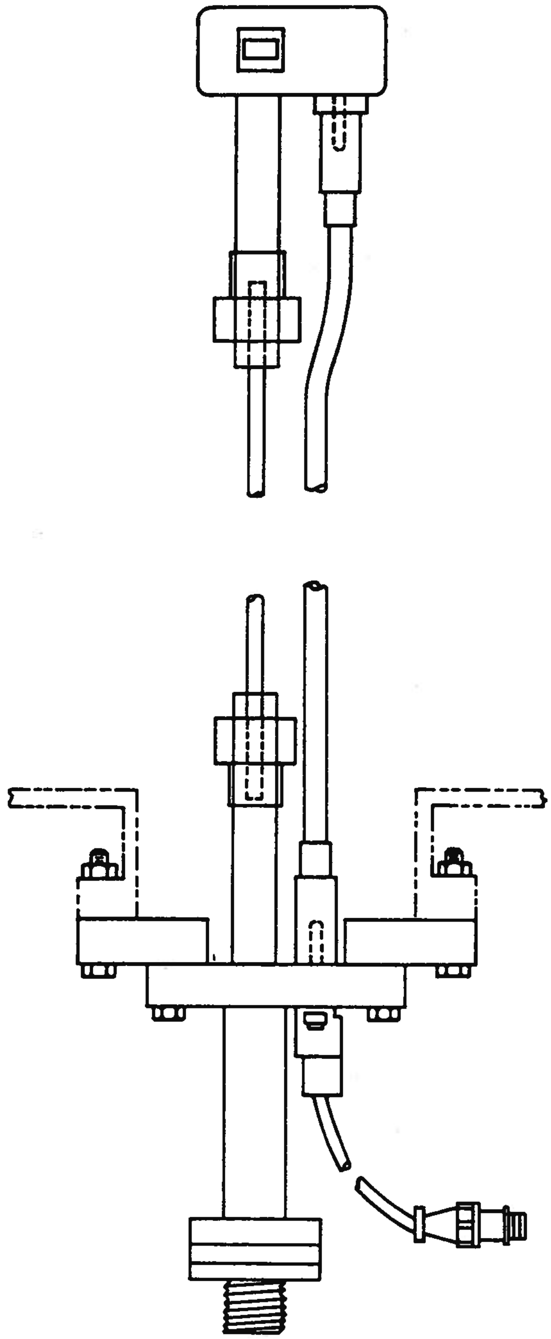


Figure 3.5 EIES Sensor with ConFlat Flange

b. Rigid Light Guide

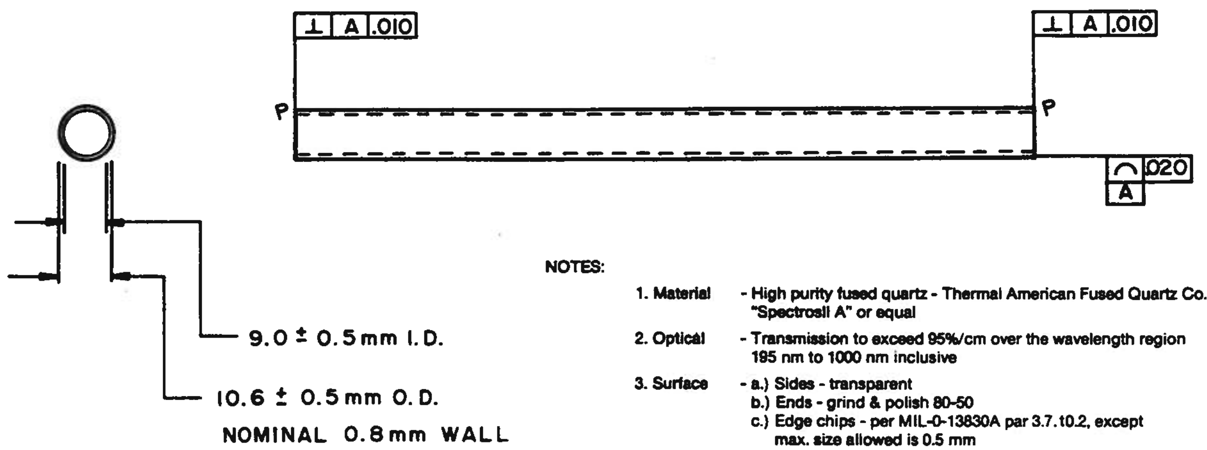
The achievement of long-term composition control in the order of a few percent is aided by maximizing the portion of the total optical signal generated in the sensor that reaches the detector (see Figure 3.1). There are many ways of doing this. The simplest way is to minimize the sensor to detector distance by integrating the measurement system into the design of the coating system. The photons generated in the sensor are emitted in all directions almost without preference. For this reason alone, the further the detector is located from the sensor, the fewer photons will ultimately reach the detector. This reduction in the photon count related to the deposition flow ultimately reduces the signal to noise ratio and the short-term control loop performance.

A means of shortening the effective distance is to incorporate a rigid light guide (see Figures 3.6 a & b). The properties of the light guide are such that they effectively reduce the length of the light path nearly by the length of the light guide. Since the number of photons reaching the detector is approximately proportional to the inverse of the distance squared ($1/D^2$) the improvement on a system can easily be a factor of ten.

Figures 3.6a and b are guideline drawings for the fabrication of a suitable light guide. The length should be tailored for the specific installation and be equal to the distance between the vacuum window and the sensor minus 0.5 inch. The 0.5 inch insures that the coating of the end of the rod is kept to a very low level. The use of hollow tubing instead of solid is suggested because even the best grade of quartz will strongly attenuate the optical signal when the path through it is exceptionally long. With the hollow tube the losses due to absorption are restricted to the path length the photons take through the quartz, which is small compared to the path in vacuum. Nevertheless, the more rugged nature of the solid rod makes its use desirable for shorter light paths (<15") where the attenuation loss is acceptable. It is considerably easier to damage the thin wall tubing during system maintenance than the solid rod.

Figure 3.6a is a guideline for fabricating hollow quartz light guides.

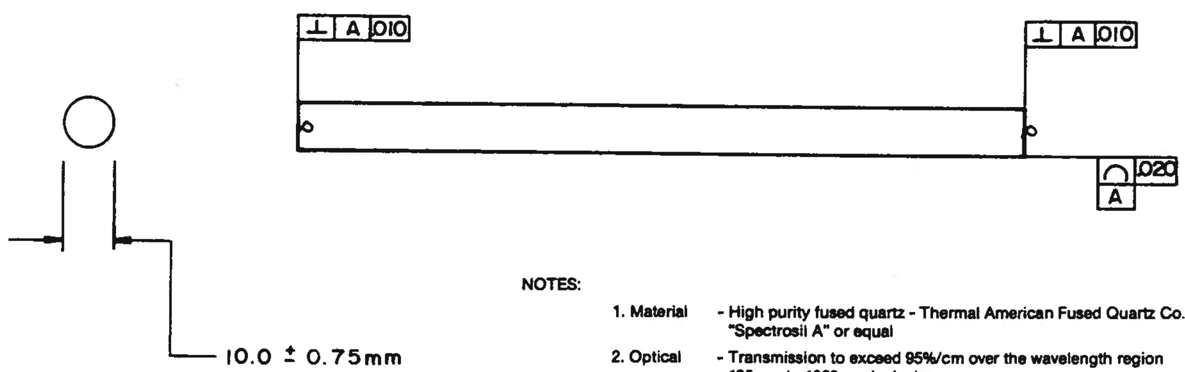
Figure 3.6b is a guideline for fabricating solid quartz light guides.
Inficon does not supply or manufacture these parts.



NOTES:

1. Material - High purity fused quartz - Thermal American Fused Quartz Co. "Spectrosil A" or equal
2. Optical - Transmission to exceed 95%/cm over the wavelength region 195 nm to 1000 nm inclusive
3. Surface - a.) Sides - transparent
   b.) Ends - grind & polish 80-50
   c.) Edge chips - per MIL-0-13830A par 3.7.10.2, except max. size allowed is 0.5 mm
4. Cleanliness - Clean parts to remove both organic and inorganic materials visible to the unaided eye. Rinse in high purity alcohol required.

Figure 3.6a Hollow Quartz Light Guide



NOTES:

1. Material - High purity fused quartz - Thermal American Fused Quartz Co. "Spectrosil A" or equal
2. Optical - Transmission to exceed 95%/cm over the wavelength region 195 nm to 1000 nm inclusive
3. Surface - a.) Sides - transparent
   b.) Ends - grind & polish 80-50
   c.) Edge chips - per MIL-0-13830A par 3.7.10.2, free aperture 8.0 mm
4. Cleanliness - Clean parts to remove both organic and inorganic materials visible to the unaided eye. Rinse in high purity alcohol required.

Figure 3.6b Solid Quartz Light Guide

c. In-Vacuum Cable

In-vacuum cable provides the electrical power to operate the EIES sensor and stretches between the feedthrough and the sensor.

Since every installation varies, Inficon provides a partially completed kit of materials to tailor the length of the in-vacuum cable to your particular needs.

The inventory list below will help you verify a complete kit and is to be used for part identification during assembly.

Qty.	Item	IPN	Description
1	-	016-405-G2	High Temp In-Vac Cable
2	2	011-383	Stainless Steel Tubular Braid
2	5	016-246-P2	Tube Clamp
1	6	016-241-G2	Connector Cover Assembly
1	7	082-023	Phillips Flat Head Screw
4	8	016-247-P1	Fish Spline Bead
2	9	016-245-P1	Push On Connector
1	10	016-242-P1	Connector Body
2	11	082-024	Hex Socket Head Cap Screw
2	12	082-026	Hex Nut
4	13	082-022	Plain Washer
A/R	15	016-308-P1	Insulating Bead
2	16	016-248-P2	Set Screw
3	17	011-386	Stainless Steel Spring
1	-	072-279	Flute Spline Wrench

CAUTION: *The parts in the kit are clean. To avoid contamination you must wear lab gloves or finger cots during assembly. Tools and surfaces used for assembly must be clean.*

CAUTION: ***DO NOT*** *use cracked or broken fish spline beads. Check that both wires are electrically isolated from the connector body.*

Refer to Figure 3.7 for each assembly step below. The overall length of the cable will be referred to as "X".

1. Remove the cable assembly from the bag and remove the twist ties from the cable. Straighten the cable and prepare to cut it to the appropriate length (up to 50"). This length is determined by using the cutting chart on the assembly drawing.

2. Determine the length for the stainless steel tubular braid (011-383), Item 2, using the cutting chart on the assembly drawing. Be sure the braid is not stretched when it is measured. Cut the braid and set it aside.

3. To begin the assembly, clip the nylon cable tie located near the completed end of the cable. Do not allow the beads to slide off the wire.

4. Open the bag of insulating beads (016-308-P1), Item 4. These beads are designed to be installed in one continuous direction. Begin to place the beads on the wire in the same manner as the first few were installed.

5. Once the beads are installed, place the stainless steel tubular braid on the cable assembly as shown on the drawing. Place both tube clamps 016-246-P2, item 5, around the braid. Position the clamp nearest the completed connector as shown on the drawing and install one each of the hex socket head cap screw (082-024), item 11, plain washer (082-022), Item 13, and hex nut (082-026), item 12. Do not install the hardware on the second clamp at this time.

6. Place the connector cover assembly on the cable at the unfinished end. It may be necessary to add or delete beads to provide correct exposed wire length.

7. Refer to the drawing for push-on connector installation. Each wire must be insulated with (1) fish spline bead (016-247) item 8. Note the bevel position.

8. Refer to ENLARGED VIEW B. The wires must be insulated with additional insulating beads (016-308-P1), item 15, and bent as shown.

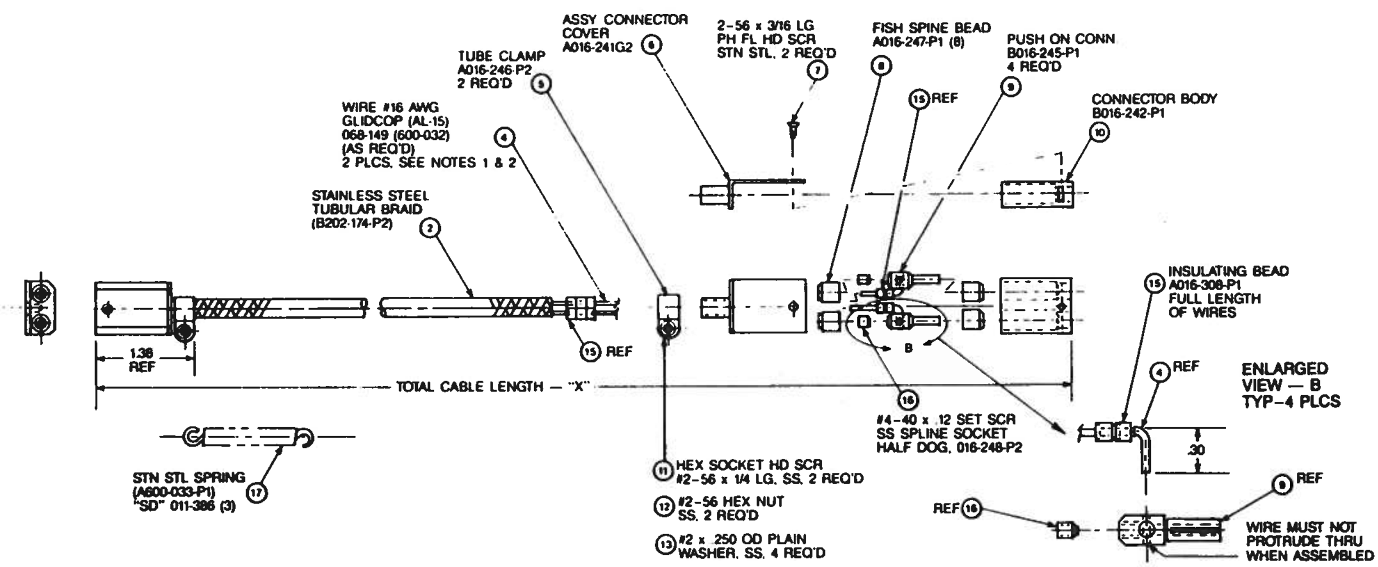
9. The push-on connectors (016-245-P1), item 9, and set screws (016-248-P2), item 16, are installed as shown in the main portion of the assembly drawing. Use the flute spline wrench (072-279), included with the kit, to tighten the set screws.

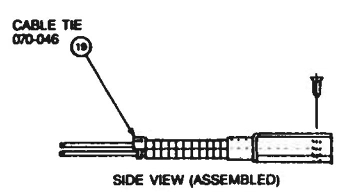
10. Install the remaining fish spline beads (016-247-P1), item 8, as shown on the drawing. Note the bevel position.

11. Slide the connector body (016-242-P1), item 10, onto the connectors until it is firmly seated. Fasten the connector body using the Phillips flat head screw (082-023), item 7.

12. Install the hardware on the remaining tube clamp and secure the tubular braid.

The (3) stainless steel springs (011-386) are used to attach the cable to rigid supports when installed.





CUTTING CHART	
ITEM	LENGTH
2	"X" MINUS 2.00
4	"X" MINUS .75

Figure 3.7 - In-Vac Cable Assembly

3.2.3 INSTALLING FIBER-OPTIC FEEDTHROUGHS

753-002 G6, G7, G8 fiber-optic feedthrough package

> ***CAUTION:*** *Loosening or tightening any nut covered specifically in these instructions voids warranty.*

1. The ends of this feedthrough must be handled with care at all times. Special attention must be paid to the vacuum end of the bellow assembly. The polished end of the optical fiber is exposed at the tip of the bellows. Any damage to this fiber or its polished face will render the feedthrough useless.

2. DO NOT BEND ANY PART OF THE BELLOWS OR SPIRAL TUBING IN LESS THAN A FIVE (5) INCH RADIUS OR DAMAGE TO THE OPTICAL FIBER MAY RESULT.

3. Mount the EIES sensor assembly securely in vacuum system. DO NOT DISASSEMBLE THE SENSOR FROM THE COUPLING TUBE. The coupling tube contains a focusing lens.

4. Place the copper sealing gasket over the bellows and push it up to the face of the 2 3/4" flange. Plug the in-vacuum cable to bellow with spring retainers provided.

5. Install feedthrough on vacuum system being careful to protect free end of bellows.

6. Route cable and bellows through system to EIES sensor. Try to position the bellows as close to its permanent mounting position as possible. It may be difficult to reposition later. MINIMUM BEND RADIUS FIVE (5) INCHES.

7. Carefully insert end of bellows into sensor coupling tube. A line has been scribed on the fiber coupling near where it connects to the bellows. Align this line with the end of the coupling tube. Tighten retaining clamp securely. This is the proper focus point between the sensor and the fiber.

8. Plug sensor cable onto the filament connections on sensor. Secure bellows and cable in their final position in the system. The in-vacuum part of the installation is now complete.

9. The PMT (IPN 011-121) ASSEMBLY MUST BE RIGIDLY MOUNTED WITHIN REACH OF THE PMT COUPLING AT THE END OF THE FIBER. The spiral jacketed fiber-optic tube CANNOT support the weight of the PMT assembly. MINIMUM BEND RADIUS, FIVE (5) INCHES.

10. Connect cooling water supply to 1/8" nylon lines on the feedthrough. The inlet line is marked with blue bands several places along its length. The outlet line is unmarked. Correct inlet and outlet polarity must be observed to obtain proper cooling. Minimum flow should be six (6) gal/hr. (0.1 gal/min).

3.2.4 INSTALLING THE OPTIONAL SHUTTERED CRYSTAL SENSOR

a. General Guidelines

To provide shutter capability on the Standard and Compact sensors, shutter modules must be installed prior to installing the sensor into the vacuum system. The Bakeable sensor includes the shutter and requires no assembly prior to installation.

Before any shuttered sensor is installed into a vacuum system the shutter should be tested. Care should be taken when planning and installing shuttered sensors to ensure no obstructions exist between the source and all shutters.

b. Pre-installation Shutter Checkout

Temporarily connect an air supply (60-80 psi, 100 psi max.) to the actuator air line and test the shutter operation (10-25 cycles). Shutter movement should be smooth, rapid, and complete. When activated, the shutter should completely cover the crystal opening; when deactivated, the shutter should retract completely from the crystal opening. You may have to reposition the shutter assembly to achieve optimum on/off positioning. If operation is impaired, lubricate the moving parts with molybdenum disulfide or graphite. Should operation continue to be impaired, adjustment of the Shutter Module must be completed. If verification was successful, make appropriate air line, water line, and coax cable connections.

c. Pre-Installation Sensor Check Out

Before you install the sensor in the vacuum system, you should make sure it is in proper working condition by following the procedure outlined below:

1. Connect the sensor end of the oscillator cable to the sensor using either the feedthrough ordered or a coax adapter (Microdot™ BNC).

2. Plug the coaxial connector end of the oscillator cable to the receptacle marked OSC on the DEP CTL module at the back of the Sentinel III.

3. Connect power to the Sentinel III and set power switch to ON. Set density at 01.00gm/cc, and zero the thickness. The display should indicate 0 or +/- 0.001. Crystal life should read from 0 to 3%.

4. Breathe on the crystal and observe whether a thickness indication of 1.000 to 2.000kÅ appears on the display. When the moisture evaporates, the thickness indication should return to approximately zero.

If the above conditions are observed, you can assume the sensor is in proper working order and may be installed.

d. Installing the Compact and Standard Sensors

The Compact and Standard sensors may be installed in any appropriate location within the vacuum system. Two tapped holes are provided on the back of the sensor body for attaching to the system. The cable length from the sensor to the feedthrough is 30 inches (76.2cm). It is not recommended that this distance exceed 40 inches (101.6cm). With all line connections installed, install the sensor and feedthrough assembly into the process system and secure all retaining hardware. Shield the coax cable from heat radiating from the evaporant source or the substrate heater. You can do this very simply, if your process allows, by wrapping aluminum foil around the cable and water lines. Connect the external water lines from the feedthrough to your water supply system and flow controller. We recommend using a detachable coupler (Swagelok[R] or equivalent) for external water line connections. Apply water pressure and verify the water connections. For information on installing shutters refer to the Installation Instructions sent with the optional shutters.

e. Installing the Shuttered Bakeable Sensor

The Bakeable sensor may be installed as described above, or with clamps on the lines running to the sensor. The cable length and air lines are not adjustable, and it is not necessary to shield the cables. However, we do suggest that you install a shield to prevent accumulation of material on the cam mechanism. If the water and coax lines require bending, maintain a minimum bending radius of 1/2" (1.3cm). Always use a bending tool or form to avoid kinking. Refer to Section 1 for other installation requirements, including maximum operating temperatures.

CAUTION: *Bend the lines between the clamps. DO NOT bend near the sensor head. This is the location of the vacuum fish spline bead for the electrical line. Stress in this area can crack the ceramic feedthrough and cause loss of vacuum integrity.*

f. Installation of Shutter Control Valve Assembly

The shutter control valve assembly (IPN 007-199) and the feedthrough should be installed at the same time. The same valve assembly is used for both the 1" and the (recommended) 2-3/4" feedthroughs. However, if the assembly is to be used with the 2-3/4" feedthrough, you will need to modify the valve bracket as follows:

1. Align the slot in the valve assembly over the edge of a table or other square edge.

2. Using pliers, grasp the part of the bracket extending over the edge and push down. The assembly will break along the slot. Use a file to smooth any rough edges which may be formed along the break.

Installation with 1" Bolts

You will need two 1" bolts. Use the first as is; on the second, one water line must be plugged, the other must have a fitting adapter (IPN 007-133) soldered to it. (This part is only available from Inficon.)

Now follow the steps below:

1. Insert 1" bolt
2. Add bracket
3. Add washer
4. Add nut
5. Tighten
6. Add the air fitting to the water line which has the fitting adapter installed.
7. Connect 1/8" teflon air line
8. Install air line to 80 psi source

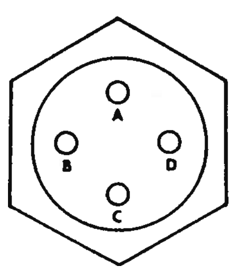
Installation with 2-3/4" Feedthrough

1. Install feedthrough
2. Add valve bracket (modified) to desired location
3. Tighten feedthrough bolts
4. Install air fitting to fitting adapter
5. Connect 1/8" teflon air line
6. Install air line to 80 psi source

NOTE:	Maximum assembly temperature is 105^{O}C for bakeout and operation.

Pin Connections

To complete the installation of the assembly, make connections for either 25 Vac or dc, using the diagram below



Use pins D & B for dc;
pins A & C for ac.

3.3 Locating and Installing SCU and Optical Processors

3.3.1 LOCATION OF SCU

The most important location requirement for the SCU is cable length. The high voltage cable, signal cable, and sensor power cables are 5' long. The SCU may be mounted anywhere and in any orientation that is convenient within the cable length constraint.

For other SCU requirements see Section 2.2.

3.3.2 CONNECTING THE SCU

The SCU provides connection between the Sentinel III and the sensing devices.

The J3 CONSOLE INTERFACE provides connection to the Sentinel III via the control cable. Press cable connectors completely into instrument connectors and engage the retaining clips.

NOTE: The Control Cable is available from Inficon in the following lengths:

753-205-G30	30'
753-205-GXX	From 10' to 60' in increments of 10'

The HIGH VOLTAGE PMT connectors provide the necessary output to operate the photomultiplier tube(s). Connect the PMT high voltage cable between the SCU PMT connector(s) and the photomultiplier HV connector(s). These are MHV type connectors.

The SENSOR DRIVE connectors provide bias voltage and filament power to the EIES sensors. Connect the sensor power cable between the SCU SENSOR DRIVE connector(s) and the EIES sensor(s) cable. These are keyed, (4) pin connectors.

The FILTER CHANGER connectors, on the optional filter changer controller board, are (9) pin connectors providing control signals to the filter changer option module(s). Connect the filter changer control cable between the SCU FILTER CHANGER connectors and the filter changer module.

The CHAN 1 and CHAN 2 connectors provide the control signal input for the photomultiplier tube(s). Connect the PMT signal cable between the SCU CHAN 1 connector, CHAN 2 connector, or both, and the respective PMT SIG connector(s). These are BNC type connectors.

The MONIT connector provides the signal input for the monitor PMT, uses the same cable as CHAN 1/CHAN 2 connectors above. Connect as above using the Monitor PMT SIG connector.

3.3.3 INSTALLING RIGID FEEDTHROUGH PMT'S

To install the PMT's select the appropriate optical filter and place it in the filter holder. Be sure to observe the light direction arrow for proper filter installation.

For installation in single material systems the PMT must be attached directly to the 1' - 14 coupling in a convenient orientation. Hand tighten the connection.

For installation in a two-material system attach the beam splitter (016-204-G1) to the feedthrough and hand tighten the connection.

Install the loaded PMT's onto the two output ports of the beam splitter.

It is advantageous to install the PMT using the shortest wavelength on the port that is straight through. The port that is at a right angle to the straight through is reflected through a prism and is slightly less efficient at the lowest wavelengths.

The beam splitter is set for nearly equal throughput at the factory. If, for some reason, the signal is not suitable for the installation it may be adjusted by turning the prism inward or outward by removing the PMT on the reflected side.

WARNING!!!

BE SURE HIGH VOLTAGE IS OFF WHENEVER PMT IS EXPOSED TO ROOM LIGHT TO AVOID DAMAGE TO THE PMT.

Under certain low level conditions a small gain in optical signals may be noted at certain orientations of the PMT's.

3.4 Installing Options

3.4.1 DOUBLE ENDED SENSOR ADAPTER OPTION

This option is designed for use in processes requiring simultaneous maximum signal on more than one material. Installation of the option is accomplished by removing the sensor cover and two socket head screws which hold the side cover in place. Install the adapter, install and tighten the screws, and replace the cover.

Installation then proceeds normally within the constraints of attaching two rigid couplings.

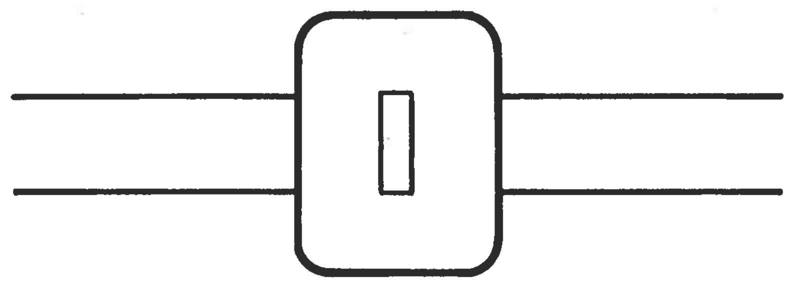


Figure 3.8 Double-Ended Sensor Option

3.4.2 INSTALLING THE FILTER CHANGER OPTION

The Filter Changer Option (753-002-G10) allows the use of more than one filter on a single output port without the use of a beam splitter. The main advantage of this option is the ability to maximize the signal strength received by the PMT (Photomultiplier Tube) for sequential material depositions. The option is not shipped with the PMT and base assembly. The user must follow the installation procedures provided below before attempting operation.

a. Installing Filters

The filter changer option accepts installation of up to four (4) filters. Inficon offers custom made filters for use with the photomultiplier tube and filter changer. A list of the available filters and the associated part numbers is given in Section 1.

If the PMT housing has been installed on the filter changer it must be removed prior to installing filters. Refer to steps 1 and 2 on page 3-22 for removal procedures.

1. Locate and remove the three (3) flat head Phillips screws mounting the PMT housing to the filter changer mechanism assembly (refer to Figure 3.9).

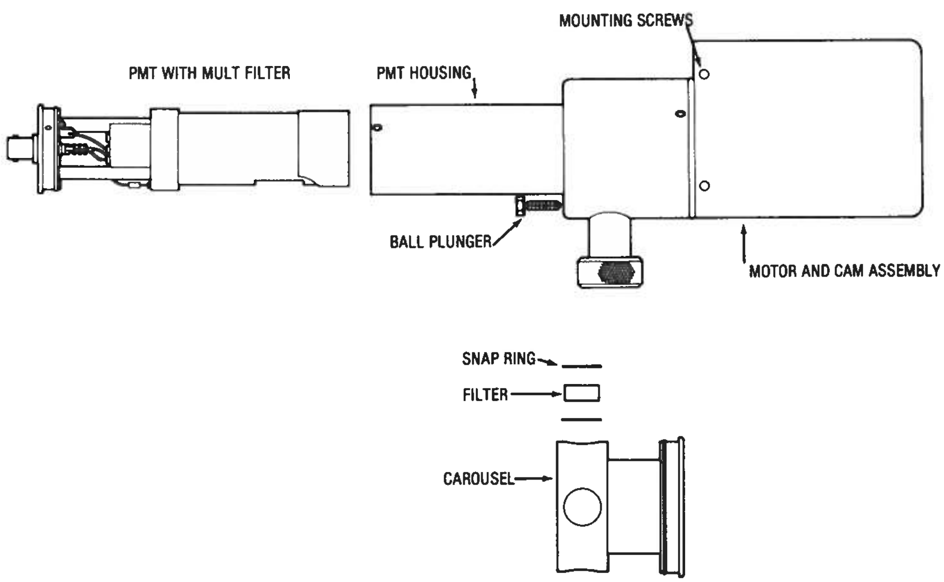


Figure 3.9 Filter Changer Assembly (Side View)

2. Gently, slide the PMT and base assembly away from the main assembly. The housing is sealed from light with an O-ring, and may fit tightly. Apply firm pressure until the housing is free of the light seal.

3. Locate the numbers stamped in the top of the carousel.

   Use these numbers to assign locations to filters.

4. Using internal snap ring pliers, remove the outer snap rings from the filter openings to be used for filter installation.

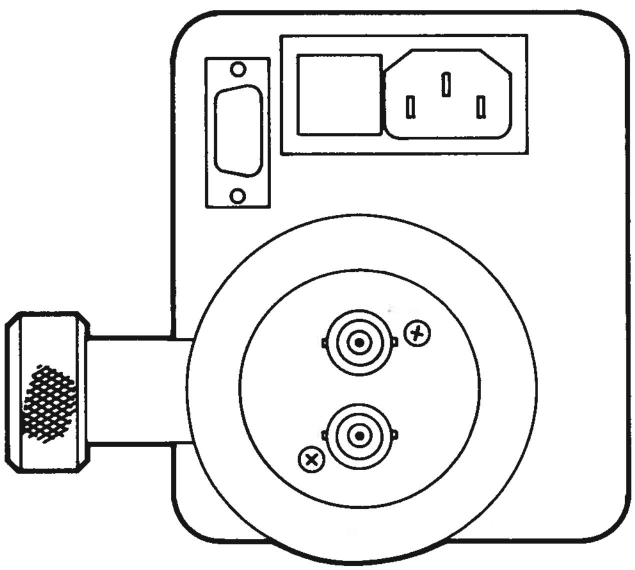
5. Install the filters in the appropriate openings with the directional arrow (on the side of each filter) pointing to the carousel (with the light). If the filter is not marked with an arrow, place the filter in the carousel with the reflective side facing outward.

NOTE:	Be certain to record the filter number (on the carousel) and the filter type at each location.

CAUTION:	*The filter changer carousel is shipped from the factory with blanks in two of the filter openings, secured by snap rings. If a filter is not used in an opening, a blank must be inserted to avoid light damage to the photomultiplier tube.*

6. Install the snap rings.

7. Install the PMT housing on the main assembly. Once the PMT housing is fully seated against the mounting plate, rotate it until the light tube is perpendicular to the long side of the main assembly (refer to Figure 3.10). Next, rotate the PMT housing slightly to align the screw holes.



This assembly has the PMT and base installed.

Figure 3.10 Filter Changer Assembly (End View)

8. Install the three (3) flat head Phillips screws removed in step "1" above.

b. Installing PMT and Base

The filter changer option, as shipped with a complete system, requires installation of the standard PMT and base supplied with the Sentinel III.

1. Remove the PMT and base from the standard PMT assembly by removing the two (2) Phillips head screws on the side of the housing.

> **CAUTION:** *Care should be taken during the following steps to avoid damaging the PMT. This tube is expensive and replacement time will delay the installation.*

2. Pull the base out carefully--it is a tight fit because an O-ring is used for light sealing.

3. Carefully pull the electrostatic shield from the base. Pull the red shield insulator from the electrostatic shield and replace it with the shield insulator from the ship kit. Carefully replace the electrostatic shield on the base.

4. Now place the complete base assembly (base, PMT, and shield) into the corresponding opening of the filter changer. Turn until the two screw holes are aligned. The screw holes are not symmetrical. Incorrect installation cannot occur if both screw holes are aligned.

5. Install the two (2) Phillips head screws.

6. The changer may now be attached to the feedthrough and hand tightened.

c. Final Connections

1. Verify instrument power is set to OFF.

2. Remove the Option slot cover on the SCU.

3. Install the filter changer controller board (753-352-G1) (Refer to Figure 3.11 for correct installation.) Secure the board with the two (2) screws removed in the previous step.

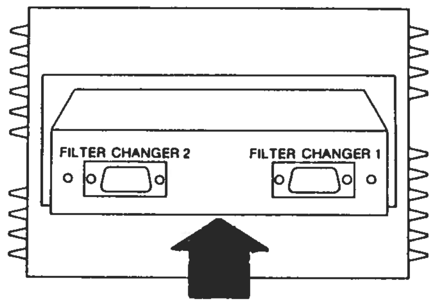


Figure 3.11 Installing Filter Changer Board

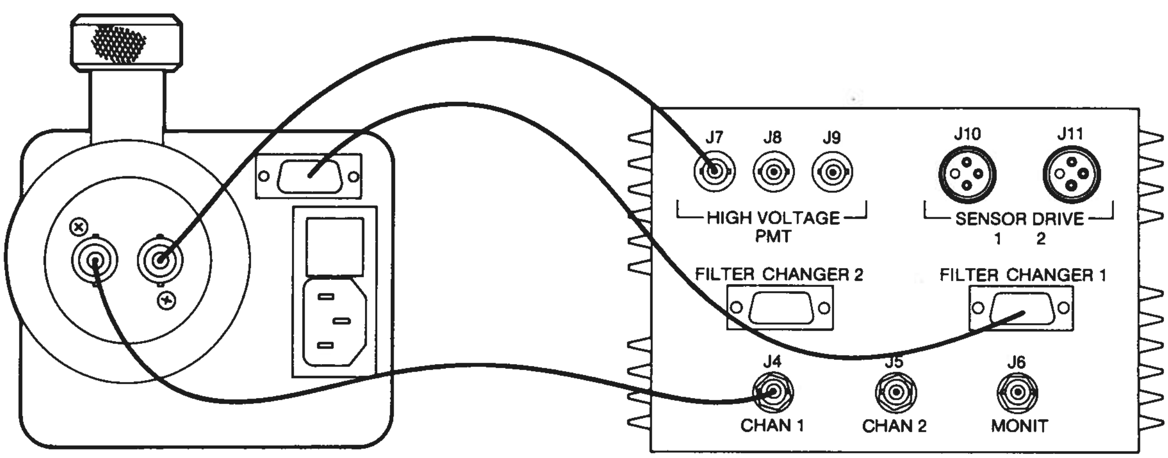


Figure 3.12 Filter Changer Option Cable Connection

3.4.3 IEEE-488 COMMUNICATIONS OPTION

WARNING!!!
HIGH VOLTAGES ARE PRESENT INSIDE THIS UNIT WHEN POWER IS APPLIED. DO NOT OPEN THE COVER UNLESS THE POWER CORD IS REMOVED FROM THE REAR OF THE UNIT.

NEVER OPERATE WITH THE COVER OFF!

1. Remove the two screws in the upper corners of the rear panel so that the top of the control unit can be removed by sliding it to the rear. Take the top completely off. (See Figure 3.13).

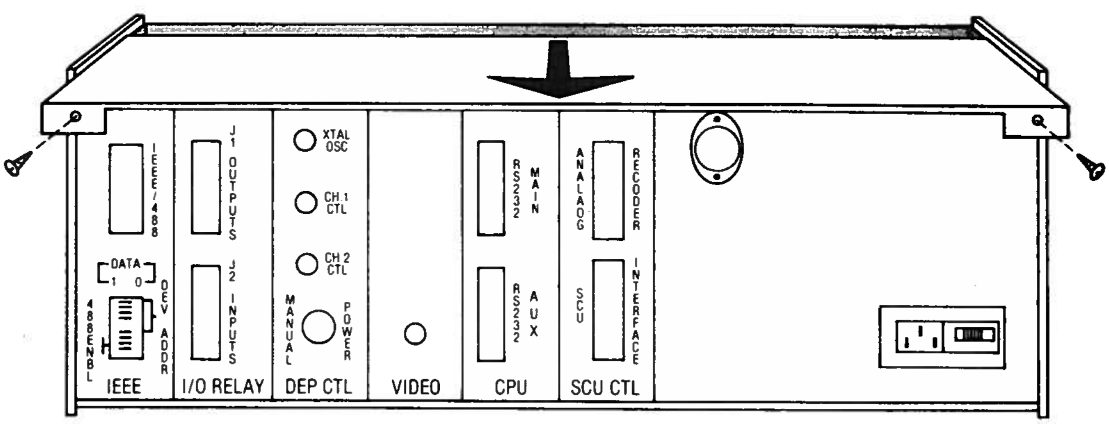


Figure 3.13 - Operator's Console Cover

2. The IEEE option module should be installed in the empty slot at the left (as viewed from the rear). Remove the cover plate from the empty slots. Then carefully insert the card as shown in Figure 3.14, noting that there are alignment slots to insure the correct mating of the board and sockets. Make sure the board is fully inserted in the sockets. Install the 3 screws in the rear panel and replace the cover.

WARNING!!!

REINSTALL THE COVER BEFORE APPLYING POWER TO THE UNIT.

CAUTION: *Refer to the IEEE Interface Section before installing the PCB into the instrument.*

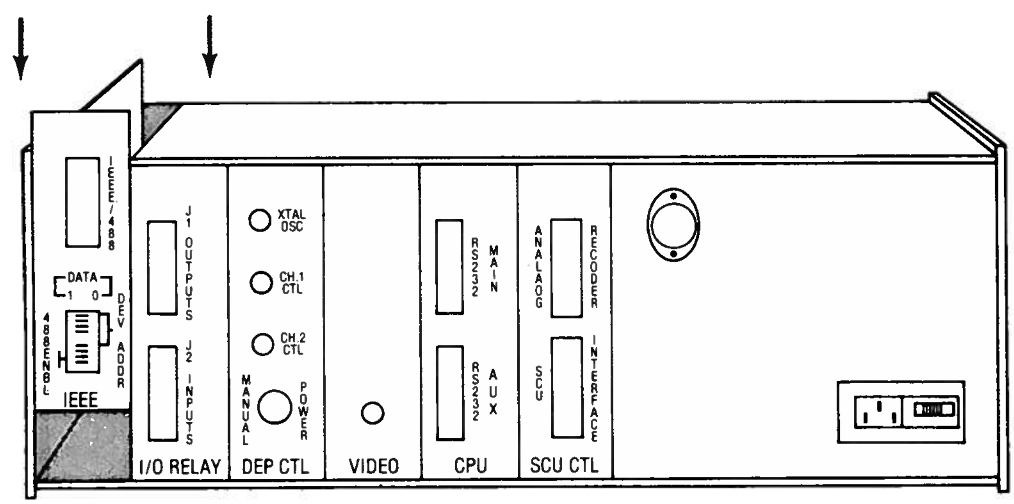


Figure 3.14 - IEEE-488 Board Placement

3.4.4 GM200 MONOCHROMATOR OPTION

The GM-200 Grating Monochromator is a 200mm, f4.0 two-grating instrument capable of both high throughput and fine resolution. The grating is blazed at 240 nm and maintains high efficiency over the 200-500 nm range of interest. It has the following features:

a. A knob determines resolution and selects one of five bandwidths, with detent stop positively indicating the chosen bandwidth. The supplied bandwidths of 1,2,3,4 or 5 nm are adequate for almost all process applications. In general, the trade-off for better resolution (narrower bandwidths) is a loss of throughput. Reducing the bandwidth by a factor of two reduces the throughput by a factor of four.

b. A linear wavelength drive makes the setting directly readable off the front panel dial indicator (range (180-750 nm). The least significant digit is divided into 5 parts yielding a 2Å resolution.

c. The general optical layout is a modified, reflective double off-axis Ebert type. This design enables an inline layout of the entering (polychromatic) and exiting (monochromatic) beams.

d. Adapters are supplied with each monochromator for optically coupling the unit to the feedthrough and optical processor. Included in the adapter is a collimating lens which focuses the light signal on the entrance of the monochromator.

Installation

Although the couplings supplied with the monochromators will support the assembly, the size and weight of these units plus the optical processor make it preferable to provide additional support. Inficon does not supply this support because the multitude of system installation possibilities does not allow the design of a common one.

The GM-200 is shipped without the adapters connected. Remove the two screw-on dust caps from the GM-200 and thread in the two adapters. These adapters may be arranged in either orientation and can be chosen for operator convenience.

Operation

Once the monochromator and the optical processor have been installed, you can set the wavelength readout to the chosen point, using the 5 nm slit width and making sure the wavelength lock is loose. Once deposition has begun, the wavelength may be selected more accurately by varying it slightly around the initial set point. The maximum rate reading (at constant power) indicates that the wavelength has been turned, the slit appropriate for operating conditions may be chosen. Slight wavelength tuning may improve signal throughput at this point. Record the final wavelength; this will speed the return to this emission line in the future. Tighten the wavelength lock.

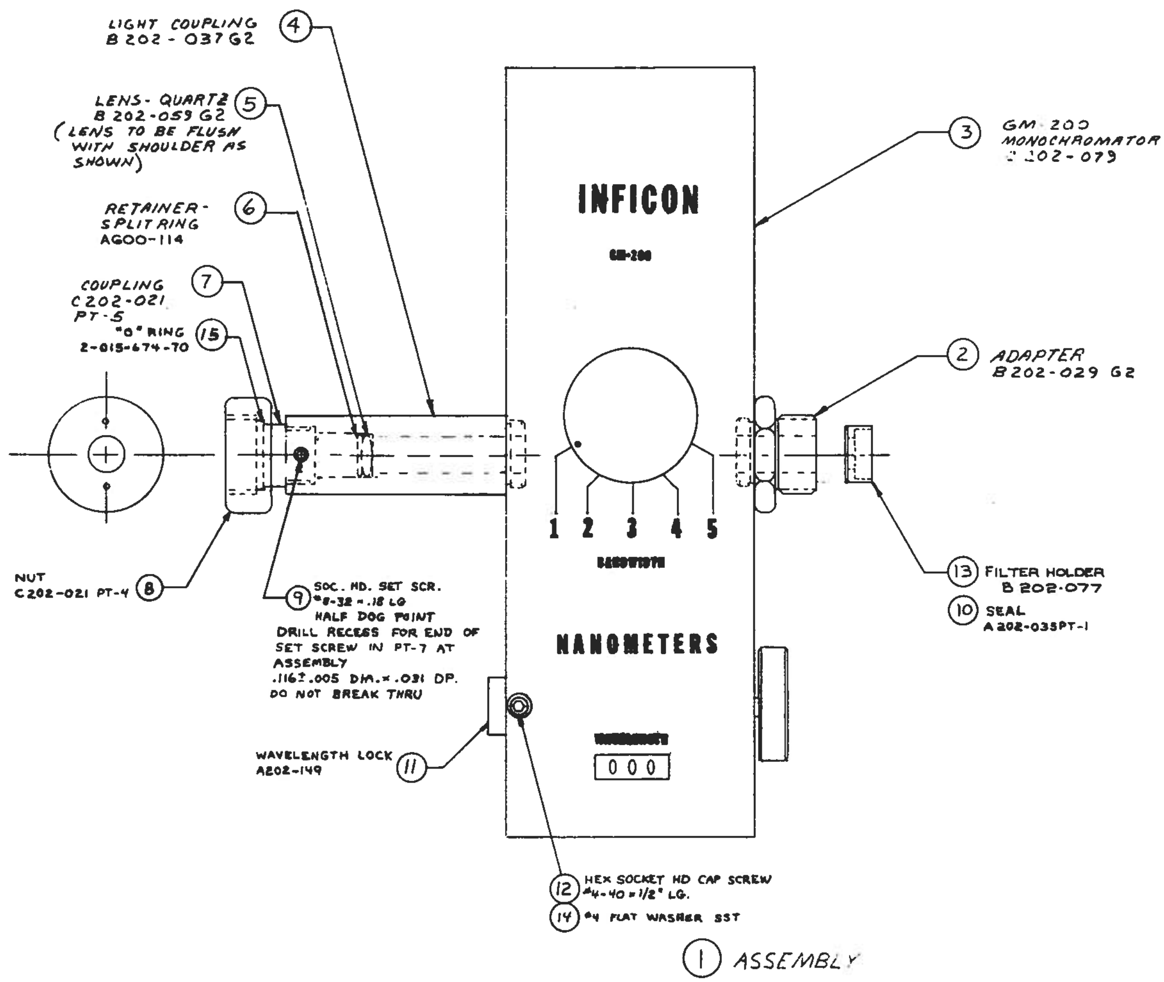


Figure 3.15 - GM-200 Monochromator Assembly Drawing

3.4.5 WATER COOLED EIES SENSOR OPTION

For the great majority of materials the EIES sensor does not require water cooling. However, for materials with a high vapor pressure such as Zinc and Cadmium it is found that the EIES sensor requires water cooling. Initial data taken while evaporating Zinc showed characteristics similar to an interference due to a background gas. It is believed that some of the Zinc atoms are being trapped inside the body of the EIES sensor. Due to the temperature of the sensor the atoms do not condense on the walls of the sensor and consequently the zinc atoms can again pass through the interaction volume. In the interaction volume they may be "re-excited", emitting another photon, leading to a non-linear output. This process also occurs for atoms striking, and not condensing, to other hot surfaces inside the vacuum chamber and these atoms may also re-enter the interaction volume. Upon water cooling the EIES sensor, the residual signal is nearly eliminated and a stable and linear calibration can be obtained. Cadmium, also with a high vapor pressure, is found to exhibit similar characteristics, and, again, upon water cooling the sensor a stable and linear calibration is obtained. The water cooling is routed through the cooling block on top of the sensor and the faraday cup is supported on threaded studs for increased thermal dissipation.

Figure 3.16 shows the design of the water cooled sensor. The water cooled EIES sensor may be purchased from Inficon as an option. (IPN 753-002-G15.

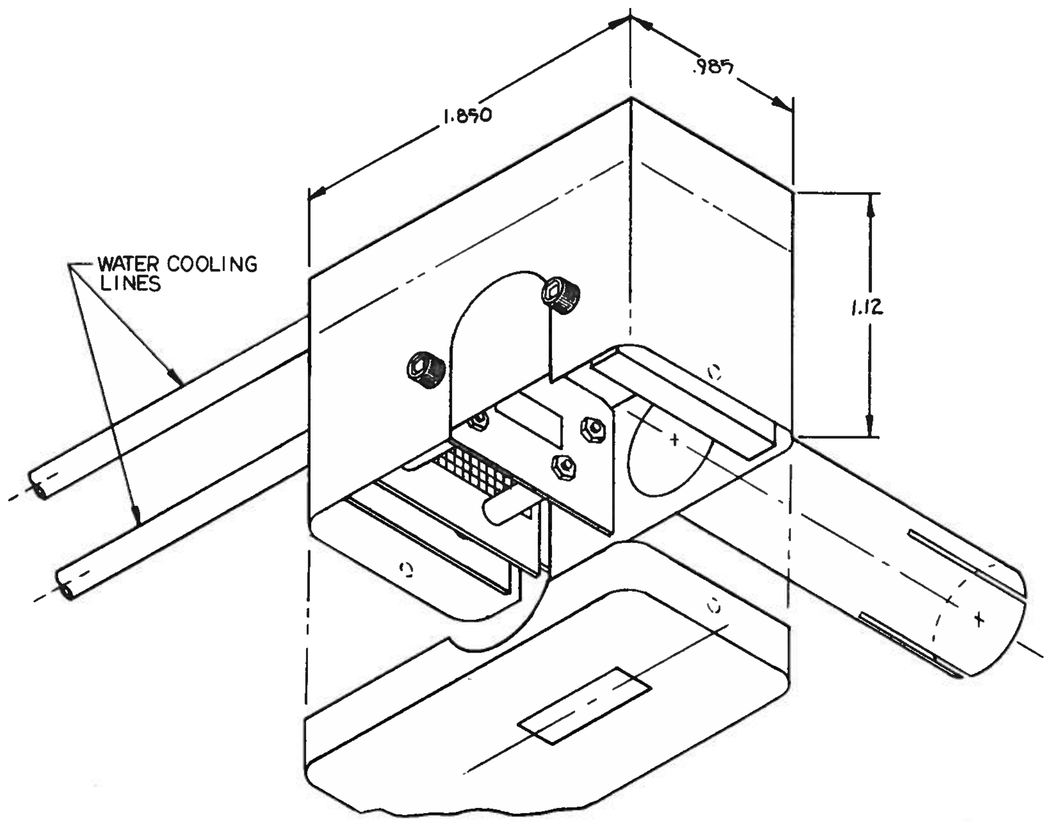


Figure 3.16 - Water Cooled EIES Sensor

3.4.6 EIES SENSOR SCATTERED MATERIALS SHIELDS OPTION

For applications in which the substrates are RF etched prior to deposition it may be necessary to use the Scattered Materials Shields with the EIES sensor. During the etching process, oxides from the substrate may be scattered into the EIES sensor and consequently the inside of the sensor becomes coated with a thin oxide film. Subsequently, during deposition, primary electrons generated by the EIES sensor may strike the oxide film producing secondary electrons. These secondary electrons may then excite atoms passing through the sensor and thus generate additional photons. Since the EIES sensor is calibrated without the presence of these extra photons an inaccurate rate reading results, consequently the calibration is in error. Additionally, the standard sensor cover is not adequately RF grounded to the body of the sensor.

To reduce the occurrence of this phenomena, the scatter shields are added to the entrance and exit apertures of the sensor, thereby restricting the amount of material entering the sensor during the etching process. Also, a self-tapping 2-56 grounding screw is added to ensure proper electrical grounding. This improvement must be implemented if the etch is RF driven.

Field retrofit of the Scattered Materials Shields is possible simply by drilling the appropriate hole into the side of the EIES sensor body. The outline drawing, Figure 3.17, illustrates the Scattered Materials Shields kit for the EIES Sensor and the location of the hole to be drilled into the sensor body. The kit may be purchased from Inficon as an option.

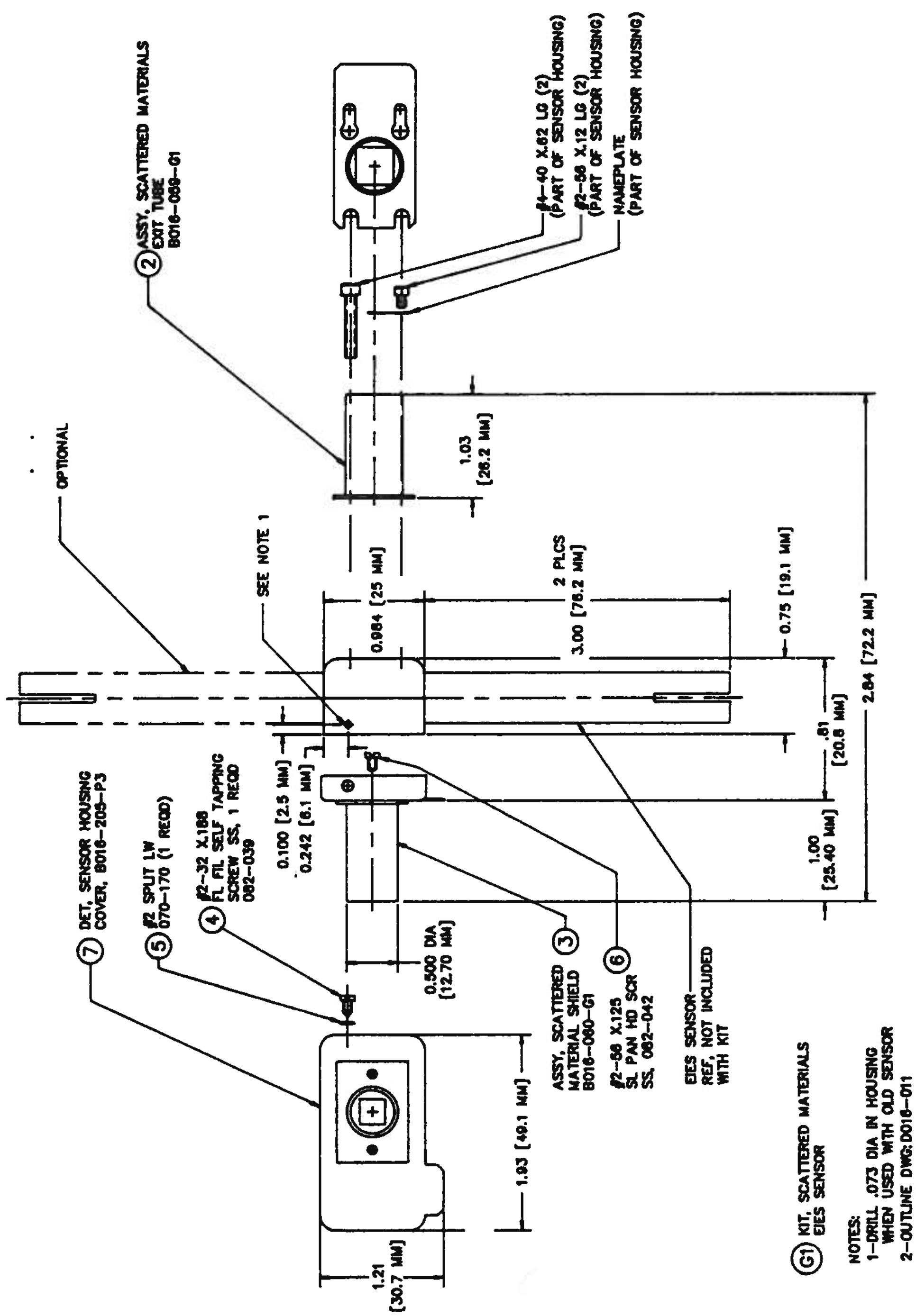


Figure 3.17 - EIES Sensor with Scattered Materials Shields

3.5 Grounding the Sentinel III

The ground connection on the Sentinel III Operator's Console is a threaded stud with a hex nut. On the SCU, one mounting bolt may be used for a ground connection. One suggestion is to connect a ring terminal to the ground strap, thus allowing a good connection, and easy removal and installation. See Figure 3.18 for the suggested method of grounding. When used near RF powered sputtering systems,the grounding method may have to be modified to the specific situation.*

> ***CAUTION:*** *The proper operation of the Sentinel III, as well as the safety of your operators and service people, depends on a low impedance earth ground. If you have not already done so, verify the quality of your system ground with your plant engineering department.*

> **NOTE:** If a ground must be established, several major power supply manufacturers recommend the following procedure:
>
> Where soil conditions allow, drive two ten foot copper clad steel rods into the ground six feet apart. Pour a copper sulfate or salt solution around them to improve the ground's conduction. Measure resistance between these rods. A near zero resistance measurement indicates earth ground is achieved.
>
> Keep connections to this grounding network as short as possible.

*An informative article on the subject of Grounding and RFI Prevention was recently published by H. D. Alcaide, in "Solid State Technology" P.117, April 1982.

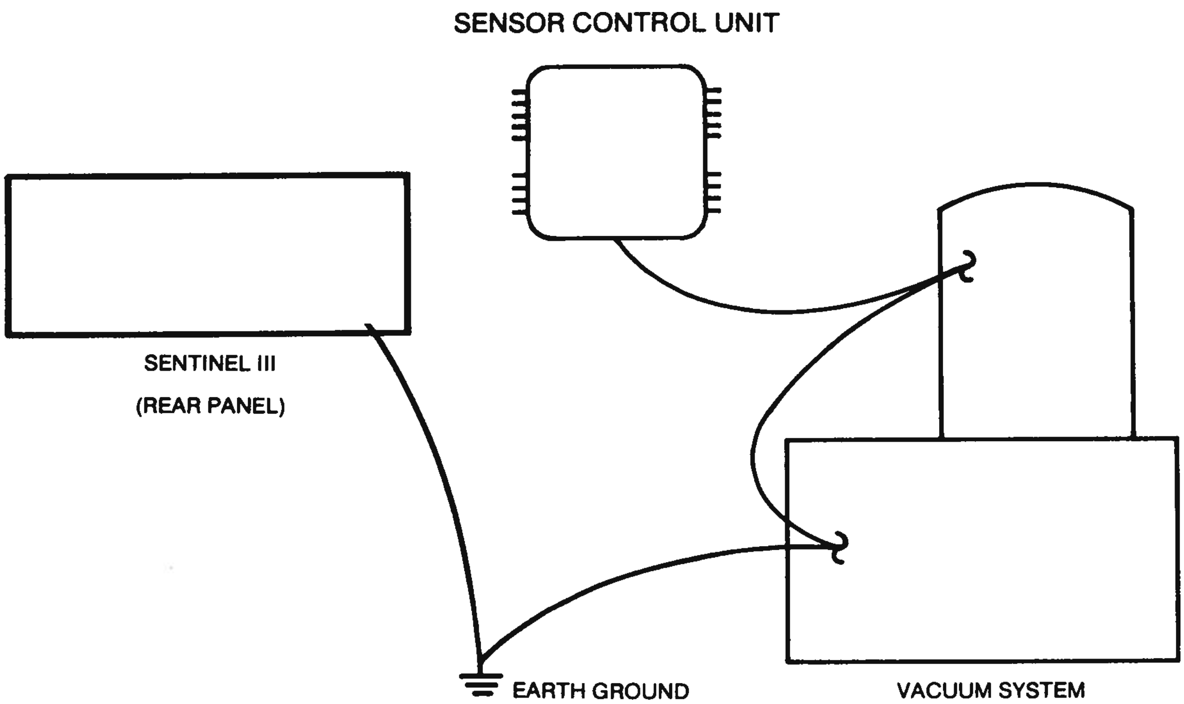


Figure 3.18 Typical System Ground Diagram

Section 4 of the Sentinel III Manual provides instructions for determining several of the Sentinel III program values. It also contains sections on measurement theory for those interested in the evolution of optical and quartz crystal monitors.

4.0 MEASUREMENT AND CALIBRATION THEORY

4.1 Theory of EIES Measurements

EIES (Electron Impact Emission Spectroscopy) is a system of evaporant excitation by electrons that uses the optical intensity of the subsequent de-excitation as a means of process control. It is based on statistical atomic processes and has the advantage of material selectivity by wavelength discrimination. It engenders a long life sensor due to the non-consumable nature of its operation. Some characteristics are further described below.

4.1.1 SENSOR PHYSICS AND CHARACTERISTICS

The EIES sensor shown in Figure 1.2 (Section 1) is a simple design that utilizes a single voltage electron gun that has an efficiency of driving 60% of the electrons emitted by the hot cathode filament through the interaction volume to the Faraday cup collector. The purpose of the Faraday cup is to eliminate the excitations caused by the low energy secondary electrons produced from primary electrons striking a flat surface. The sensor is installed so that a portion of the evaporant stream is allowed to pass through the interaction region and leave without accumulating on the structure. Within this interaction volume there is an exchange of energy from the primary electrons to the outershell electrons of the evaporant atoms. This excess energy is dissipated by the evaporant atoms so afflicted immediately emitting a photon. This photon is characterized by a wavelength specific to the material and the quantity of photons generated at any specific wavelength is governed by the following equation:

$J_{iJ} = (i/e)NQ_{iJ}$ Where

J_{iJ} = number of photons emitted at transition
= primary electron current density in Amps/cm
e = electronic charge
N = evaporant atom density
Q_{iJ} = excitation probability for the transition
to at a fixed primary electron energy for a given material.

The photon flux (J_{jk}) is directly proportional to the evaporant number density if the electron beam current and energy are held constant.

If the evaporant strikes a substrate at right angles, the mass deposition rate per unit area, D_m, is given by

$$D_m = mNV \text{ (assuming a unit accommodation coefficient)}$$

where V = average velocity of the particles directed toward the substrate

m = mass of the atom or molecule
N = evaporant density near the substrate

For an atomic or molecular beam generated from an ideal effusion source

$$V = 3/4 \left(\frac{2\pi KT}{m}\right)^{1/2}$$

where T is the absolute temperature and K is Boltzman's constant. Then

$$J_{jk} = 4/3 \left(\frac{D_m}{m}\right)\left(\frac{m}{2\pi KT}\right)^{1/2} Q_{jk} \frac{i}{e}$$

In general, only a small fraction of the photons generated in the sensor are collected by the optical pipe for detection. Losses also occur because of the conversion efficiency of the phototube and the optical filter transmission efficiency. These three factors may be lumped into a constant, (S), which varies from system to system. In general, $S<<1$.

Considering the above, an equation for the system may be written as

$$I = 4/3\, S\left(\frac{D_m}{m}\right)\left(\frac{m}{2\pi KT}\right)^{1/2} Q_{jk} \frac{i}{e}$$

Where I is the number of photons converted into an electrical signal.

Further simplification yields

$$I = G\, D_m/T^{1/2} \text{ where } G = 4/3\, S\left(\frac{1}{2\pi mK}\right)^{1/2} Q_{jk} \frac{i}{e}$$

Thus, the Sentinel signal is related to the deposition rate and the source temperature. However, for most metals a source temperature change of 20% will result in a deposition rate change of more than two orders of magnitude. A 20% change in T will result in a change of $T^{1/2}$ or approximately 10%. Therefore, over normally encountered changes in temperature, the $T^{1/2}$ dependence is usually included in the gauge constant (G). In general, the optical output signal can be considered linearly proportional to the deposition rate.

$$I = G'\, D_m.$$

Please note that the photons are emitted nearly without preference to direction, so only a small portion of them are collected for use in signal processing. It is also important to note that the electron beam is not run in a DC mode but is squarewave modulated at 500 Hz. This modulation is important in the elimination of any photons generated by thermal incandescence of the evaporation source or ambient background over the primary 200 to 500 nanometer wavelength range of interest.

The simplicity of this sensor is exemplified by the absence of moving mechanical parts, the existence of only two electrical connections and the simple hollow stainless steel tube used for sensor mounting and as a pathway for the pertinent photons.

EIES is not in any way connected to the measurement of ionization currents. Although ionization takes place it is an unnecessary and uninteresting process for the purposes of EIES. In this way it is distinctly different from the so called continuous monitors of the past.

These devices depended on the measurement of weak ionization currents which were often confused by the copious numbers of charged particles produced by the typical electron beam evaporator. Elimination of these spurious currents required an electrical element to strip away the charged particles before they entered the sensor. Because the ionization monitors do not discriminate among the various atomic species, there was no way to do direct composition monitoring. Even more difficult to deal with were the currents generated by the residual gasses. EIES generally is able to nearly eliminate the gas signals through wavelength discrimination. The ionization monitors required a mechanical chopper wheel in order to subtract the currents due to the gas from the currents due to the evaporants. This chopper was implemented utilizing a motor in the vacuum chamber and it could never achieve compatibility with the ultra high vacuum environment. The resulting complexity of these ionization apparatus consumed about ten times the volume necessary to execute the EIES technique.

Figure 4.1 shows the output of the EIES sensor for three very commonly evaporated materials; Al, Si and Cu; at a fixed rate of 30 angstroms per second. The sensor output is scanned slowly with a monochromator over the normally excited 200 to 500 nanometer wavelength region. Note the range of intensities; from the very strong copper transition at 324.7 nm to the group of weak silicon transitions centered around 252 nm, is nearly an order of magnitude. The other interesting feature is that although the potential for interference exists, as it does for any emission spectrometer, in general these spectra are simple enough that separation through practical wavelength discrimination is easily accomplished. The natural linewidths of these transitions (approximately 0.001 angstrom) are significantly narrower than the affordable pass-band used to select them.

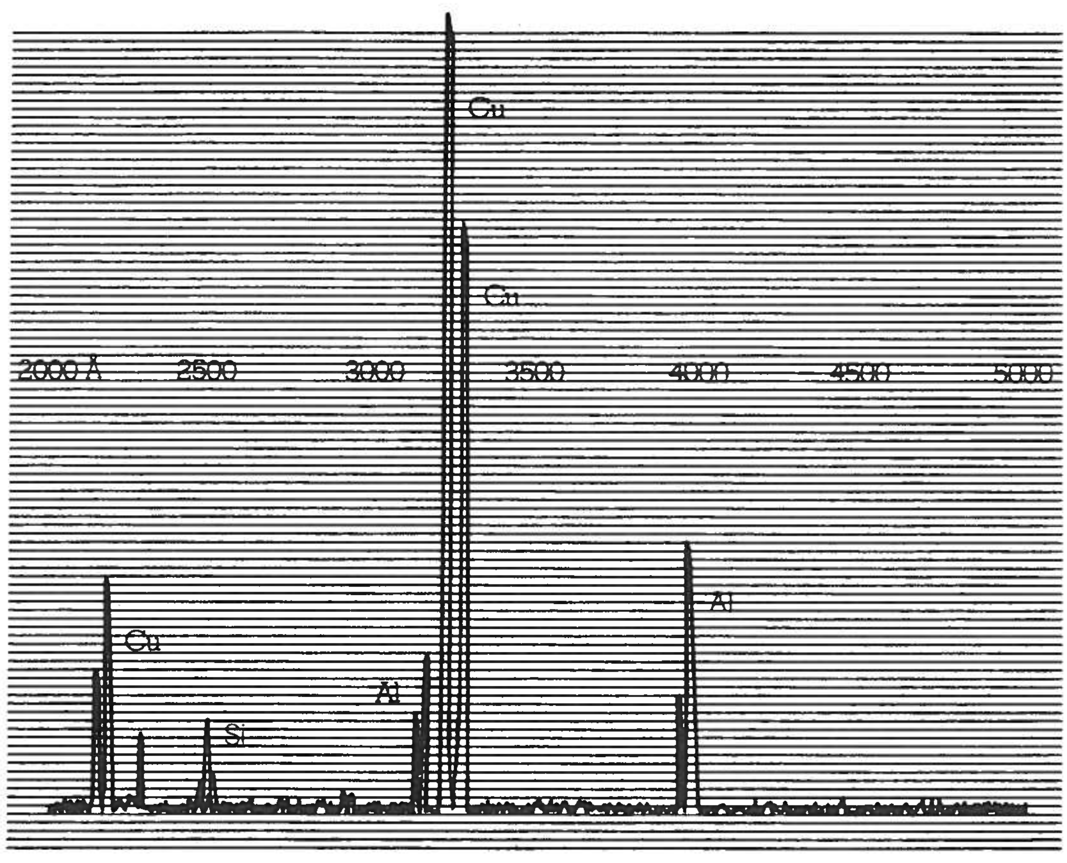


Figure 4.1 - Monochromator Scan

4.1.2 SENSOR STATISTICS

The operation of the Sentinel III is ultimately limited by the statistical fluctuations of the photons generated by the interaction of the electrons and the evaporant atoms. Although the absolute value of the excitation cross sections are not known, an analysis of the process may proceed using approximate values for the excitation cross sections.

In general, the statistical fluctuation is given by $(\frac{1}{NT})^{1/2}$

where N = number of events per unit time (1/sec)
T = measurement time (sec)

Estimating the number of events detected is really a series of estimations from the number of photons produced in the sensor, the collection efficiency and finally the detection efficiency down to the anode current of the photomultiplier.

The number of photons generated in the sensor is governed by the equation in Section 4.1.1. Typically the Sentinel operates with 4 mA peak electron current which yields

$i = 1.02 \times 10^{-2}$ amps-Sec $\qquad \frac{i}{e} = 6.38 \times 10^{16}$/Sec-cm^2

$e = 1.6 \times 10^{-19}$ amp-Sec

The atomic number density for copper accumulating at 10 Å/sec may be estimated at 9×10^{10} atoms/cm^3 based on growth rate and a velocity based on the melting temperature of the material.

The last factor in the equation is the excitation probability. Typical values range from 10^{-20} to as high as 10^{-16} -cm^2. If a value of 10^{-17} is used, the total number of excitations generated per cm^3 in the sensor is

$$J_{ij} = (6.38 \times 10^{16}/\text{Sec-cm}^2)\ (9 \times 10^{10}/\text{cm}^3)\ (10^{-17}\text{cm}^2)$$

$$J_{ij} = 5.74 \times 10^{10}/\text{Sec-cm}^3$$

The excitation volume in the sensor is not, however, 1 cm^3, but rather with dimensions of $1.1 \times 0.85 \times 0.4 = 0.37$ cm^3

$$J_{ij}\ (\text{sensor}) = 2.12 \times 10^{10}/\text{Sec}$$

The next thing to calculate is the collection efficiency. A typical value would be the light collected at a sensor to detector distance of 10 inches (25.4 cm).

The area of photo cathode exposed through the filter is 1.1 cm$\times$0.8 cm = 0.9 cm^2.

Since the optics used is non-focusing and the sensor radiation is near isotropic, the collection efficiency is approximately

$$\frac{0.9\ \text{cm}^2}{4 \cdot \pi (25.4)^2 \text{cm}^2} = \frac{0.9}{8.1 \times 10^3} = 1.11 \times 10^{-4}$$

Additionally, the filters used have a transmission efficiency of about 10% so the number of pertinent photons reaching the cathode is approximately

$$J_{ij}\ (\text{Cathode}) = 2.12 \times 10^{10}/\text{Sec} \quad (1.11 \times 10^{-4}) \quad (0.1)$$
$$= 2.35 \times 10^5/\text{Sec}$$

Since the photo cathode used has a conversion efficiency of about 20% at the 324.7 nm copper line, the anode statistics are as follows:

$$J_{ij}\ (\text{anode}) = 2.35 \times 10^5/\text{Sec} \ (0.2) = 4.7 \times 10^4/\text{Sec}$$

Since the measurement period of the Sentinel III is not 1 sec, but 125 ms, the expected fluctuation simply due to statistics is approximately

$$\left[\frac{1}{(4.7 \times 10^4 (0.125)}\right]^{1/2} = \left[\frac{1}{(5.88 \times 10^3)}\right]^{1/2} = 1.3 \times 10^{-2}$$

or simply ± 1.3%

These results may be scaled to obtain a similar result for the specific rates and apparatus of interest. These results ignore the fluctuations (noise) induced by photomultiplier dark current, source thermal fluctuations, source generated light and electronic noise and are the best results that could be expected.

4.1.3 OPTICAL DISCRIMINATION

The preferred means of wavelength discrimination for production use is the thin film optical filter. It has the advantage of being very small, without adjustments and very efficient in transmitting the desired wavelength at the exclusion of all others. The main disadvantages are that a special filter is required for each species and since the materials used in their construction are by necessity hygroscopic, long-term degradation and ultimately failures are experienced. The failure is characterized by a gradual drop in sensitivity (due to loss of transmission) and often an increase in the interference due to residual gasses and alloy materials. The unfortunate feature of this failure mode is that it takes place over several years and the degradation is not noted until it is severe. Typical specification of these filters are two cavity halfwidths of 10 to 30 angstroms, central passband transmissions of 5 to 30 percent and out of passband blockings of more than five absorbance units.

4.1.4 CONSTRUCTION OF THIN FILM FILTERS

The optical characteristics of thin film interference filters are defined by the ordered relationship of the thicknesses and indices of refraction of the materials used. The manufacture of filters with the characteristics required for trouble free operation of the Sentinel III often require one hundred or more individual coatings. In order to obtain the required passband and transmission, it is often necessary to use materials that are hygroscopic. The precise thickness and index of refraction relationships of these films should be preserved by minimizing their exposure to air, or more specifically, moisture.

To extend the useful life of the filters, the composite substrate and deposited films are placed in a structure that maximizes the path that moisture must travel to reach the sensitive films. This structure is shown in Figure 4.2. While this construction enhances the expected life, degradation may occur after long exposures in a high humidity/temperature environment. Optical filters are covered by warranty; see the Warranty Section for details.

CAUTION: *To insure a maximum shelf life for the optical filters it is recommended that they remain in their shipping bottles when not in use. The condition of the desiccant should be verified by periodically checking for a blue color. Desiccant that has turned pink should be regenerated or replaced immediately.*

You may find it convenient to keep large numbers of filters together in a large desiccator. By keeping the closed shipping bottles in a second humidity controlled container, you will greatly increase the time interval between regeneration or replacement of the desiccant. Desiccators and desiccant may be purchased from any of the major scientific supply companies.

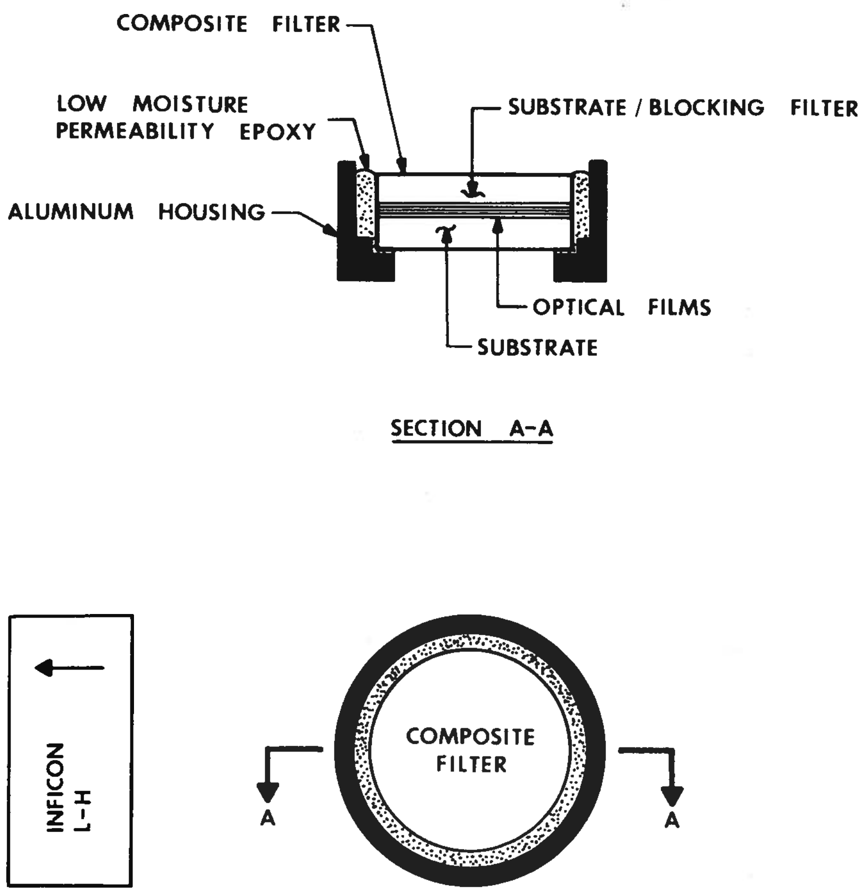


Figure 4.2 Optical Filter Construction

Cleaning and Maintaining Optical Filters

There is no need for periodic maintenance of optical filters. If a filter is accidentally soiled or finger printed on an optical surface, immediate cleaning is recommended. Soft, lint-free optical cloth and spectrographically pure isopropyl alcohol is suggested. In severe cases, the use of a mild detergent and a distilled water rinse is advisable prior to the alcohol. Finger prints should be removed as soon as possible because the residue can etch the substrates.

Since the optical films are not on the external surface of these assemblies, considerable force may be applied in the cleaning process.

Performance Verification

Despite the precautions taken in the manufacture of the films and filter assemblies, degradation of the optical performance can occur with time. Proper operation of the Sentinel III depends on separation of the emission line of the material of interest from lines belonging to coevaporated materials and residual gases. The operation of the Sentinel III will, therefore, be directly affected by a degradation in the filter performance.

The status of an optical filter must be determined with the use of a spectrophotometer to determine the central wavelength, the shape of the passband and the existence of any "light leaks" outside the passband.

To make the required measurements, the spectrophotometer must be able to measure the off-band transmission which normally exceeds 5 absorbance units and determine the central wavelength to ±3A.

Please contact Inficon's Service Department to verify filter performance at a nominal cost.

4.1.5 MONOCHROMATOR CHARACTERISTICS

An alternate means of wavelength discrimination is the tunable monochromator. It is efficient over the entire 180 to 500 nm range of interest, selectable for the wavelength of interest, and may be secured at that point. The bandwidth of the monochromator is also selectable from 1 to 5 nm (FWHM). The throughput of the monochromator varies approximately as the square of the bandwidth, so you may trade off sensitivity for selectivity, depending on the particular situation. The inherent scattered light specification of the double monochromator is even better than the blocking specification of the filters. Unfortunately, the real size of the source somewhat reduces the seven absorbance unit specification to a practical five absorbance units, which approximates the level achieved by the filters.

4.1.6 CONVERSION OF PHOTONS TO ELECTRICAL SIGNALS

The Sentinel III uses a highly select Hammatsu R106UH photomultiplier to convert the optical signal to an Electronic current. This PMT is selected for both high conversion gain and low fluctuation noise. Use of the standard manufacturer specifications will result in unsatisfactory performance in many cases.

4.1.7 CROSS-SENSITIVITY PARAMETER

The Sentinel III Cross-Sensitivity Parameters allow you to eliminate interference due to residual gasses and other materials. Interference occurs when an emission line of the interfering species occurs near the wavelength used to monitor the material being deposited.

The theory behind the cross sensitivity correction is expressed in the following equations which assume the interference is only due to a gas.

$$S1 = k1M1 + k2G$$

$$Sm = kmG + k3M1$$

where: S1 = total Signal at Channel 1
Sm = Total Signal at the Monitor Channel
M1 = Number Density of Material 1
G = Number Density of the interfering Gas.
k1, k2, k3, km = Instrument constants related to physical and optical considerations

Since the quantities of interest are M1 and G, we may solve the above equations as:

$$M1 = (S1 - k2G)/k1 \quad G = (Sm - k3M1)/km$$

Then substituting:

$$M1 = S1/k1 - (k2/k1km)(Sm - k3M1)$$

provided that k3M1 << kmG on the monitor channel, the term k2/k1km(Sm - k3M1) can be approximated to be CSm

where C can be determined by expressing the rate signal at Channel 1 due to the interfering gas as a percentage of the monitor channel signal.

To ensure the validity of the approximation, k2/k1km(Sm-k3M1) = CSm, the "suggested" range for the Cross sensitivity correction is 0 to 9.9%. Larger values are permitted. However, as the % increases the approximation degenerates.

Figure 4.3, shown on the following page, illustrates the cross-sensitivity correction parameter. The graph is a plot of the ratio of thickness accumulations (Optical channel divided by XTAL channel) vs. the rate at the monitor channel due to Nitrogen.

Controlling at 5 Å/s of Tin, it is seen that without the cross-sensitivity correction the optical signal due to Nitrogen interference increases with Nitrogen rate. Since the controller maintains constant optical signal, less material is required at higher Nitrogen pressure causing a decrease in the thickness accumulation on the crystal and an increase in the optical/crystal ratio. With the cross-sensitivity correction, the optical/crystal ratio equals 1 through the range of Nitrogen rate.

An easy method of determining this constant is to crystal calibrate at the lowest pressure using "0" for the cross-sensitivity constant. When the pressure increases to near maximum, increase the constant until the optical and crystal channels are equal again.

The cross-sensitivity correction can also be used during a co-deposition where cross talk occurs between the two materials. In this application the signal of the second material, M2, interfering with the signal of the first material, M1, can be eliminated at channel 1 using the cross-sensitivity Channel 2 correction. While at the same time interference at Channel 2 from M1 can be eliminated using the cross-sensitivity Channel 1 correction. This allows for accurate composition measurement and control for both materials.

As implemented in the Sentinel III the cross-sensitivity correction can be used to simultaneously correct at Channel 1, Channel 2, and the Monitor Channel.

4.2 Theory of Quartz Crystal Microbalance Measurements

The quartz crystal's use as a microbalance is an exact and highly refined technology. The Sentinel III uses the QCM (Quartz Crystal Monitor) as a means of rapid and accurate calibration of single materials. The basis of this procedure is outlined in the following paragraphs.

4.2.1 MEASUREMENT THEORY

Commercial quartz-crystal film thickness monitors have evolved in three distinct stages: (1) frequency measurement technique, (2) period measurement technique, and (3) z-match technique.

Sauerbrey[1] used the quartz-crystal resonator to measure deposited film thickness which was later developed into a commercial unit. The thickness frequency used is given by:

$$T_f = (N_q d_q / d_f f_q^2)(f_q - f_c) \qquad (1)$$

where

T_f = film thickness (cm)
d_q = density of quartz (2.648g/cm^3)
d_f = density of film (g/cm^3)
$N_q = f_q l_q$ = frequency constant for AT-cut quartz crystal (1.668×10^5 Hz/cm)
l_q = thickness of quartz crystal (cm)
f_q = resonant frequency of unplated crystal (6.050×10^6 Hz)
f_c = resonant frequency of loaded crystal (Hz)

Experiments have shown that in order to keep the thickness measurement reasonably accurate, the maximum frequency shift allowable is limited to about 2% of f_q.

The period measurement technique was used by the second generation quartz-crystal thickness monitors, with the following equation used for thickness computation:

$$T_f = (N_q d_q / d_f)(t_c - t_q) \qquad (2)$$

In this equation, $t_c = 1/f_c$ and $t_q = 1/f_q$ are the periods of oscillation for the loaded and original crystals, respectively. For a small frequency shift, Eq (1) becomes a good approximation of Eq (2).

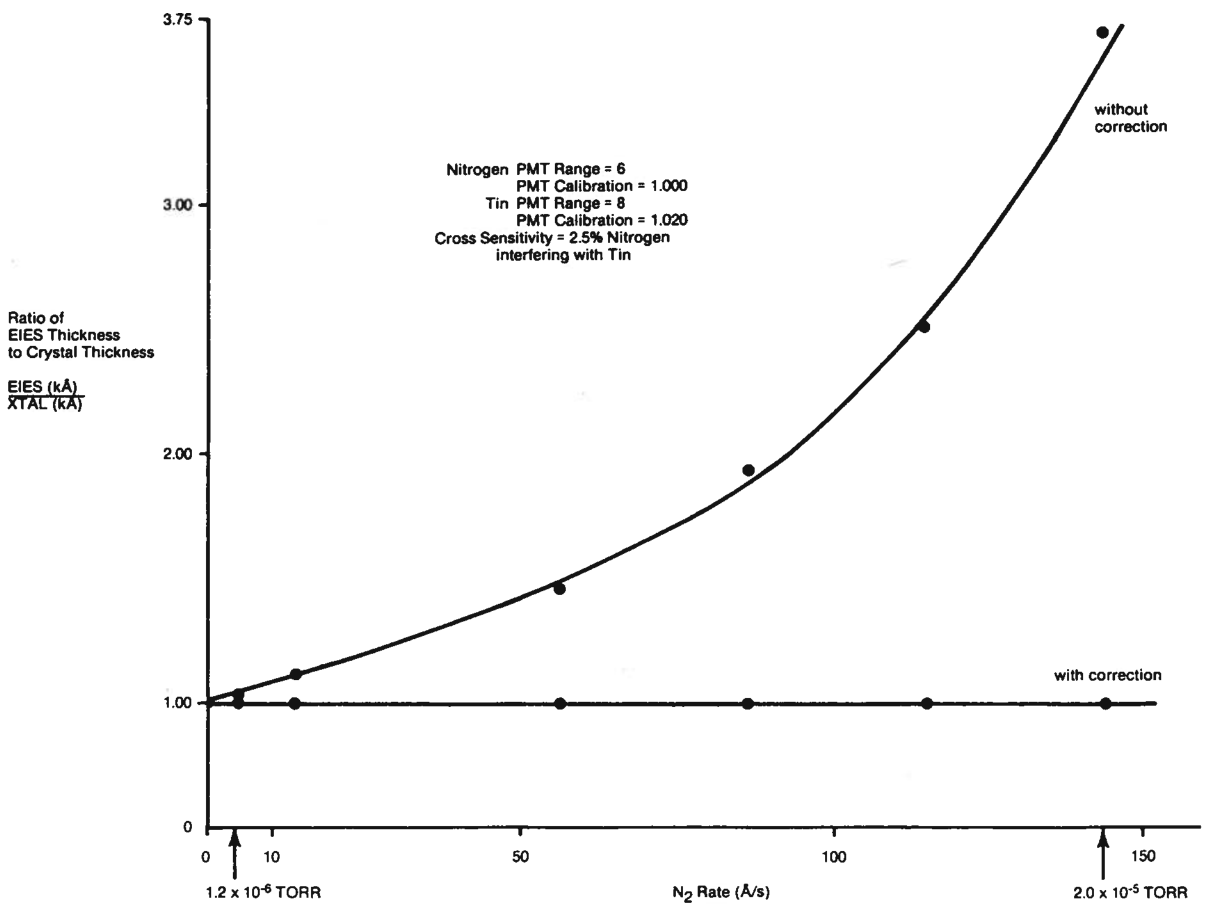


Figure 4.3 Graph of Cross-Sensitivity Correction (Tin vs Nitrogen)

Although experiments demonstrated that Eq (2) is reasonably accurate for selected materials with frequency shifts of up to 10% of f_q, the theoretical justification of using Eq (2) for thickness computation has been lacking. Tests on the validity of Eq (2) indicate that significant errors begin to appear for a majority of materials with crystal frequency shift as small as 5% of f_q. When the quartz crystal monitor is used to measure the rate of deposition, the errors in indicated time become even more serious, because the thickness error is a time-varying function, and rate is the derivative of thickness with respect to time.

Advances in crystal design and improved driving circuitry allow the quartz crystal to keep oscillating even with very large amounts of deposited material on it. In many cases it is possible to achieve frequency shifts of more than 20% of f_q. Also, complex and precise mathematical calculations can be easily performed with modern microcomputers.

Miller and Bolef[2] were the first to treat the quartz-film composite as a one-dimensional compound acoustical resonator. Their results indicated that the elastic properties of the deposited film should be related to the frequency shift. A further study on their original solution resulted in a simpler thickness frequency equation in the form of

$$T_f = (N_q d_q / \pi d_f f_c Z) \tan^{-1}(Z \tan[\pi(f_q - f_c)/f_q]) \quad (3)$$

where

$$Z = (d_q \mu_q / d_f \mu_f)^{1/2}$$

is the acoustic impedance ratio with μ_f and μ_q the shear moduli of deposited film and quartz crystal, respectively. Eq (3) shows that materials with different elastic properties will obey different thickness frequency relations. This phenomenon has been verified experimentally in our laboratory for a number of materials.[3] The experimental results demonstrated that if the density and Z-value of the deposited material are known, Eq (3) is remarkably accurate in determining film thickness.

Another significance of Eq (3) is that for the first time the validity of "period measurement" technique, or Eq (2), can be explained from a theoretical point of view. Through a simple algebraic exercise, one can easily show that Eq (2) is a special case of Eq (3) with Z = 1, or quartz-on-quartz.

The Sentinel III incorporates an approximated form of Eq (3) for thickness computation. The acoustic impedance ratio Z can be entered into the instrument as a separate material constant. A reproducibility of better than 2% for both thickness and rate can thus be achieved over a full 1 MHz shift in crystal frequency and Z ratios up to 1.99.

[1] Sauerbrey, G.Z., Physik 155, 206 (1959).

[2] Miller, J.G. and Bolef, D.I., J applied Phys 39, 4589 and 5815 (1968).

[3] Lu, Chih-Shun, J. Vac. Sci. Technology 12, (1975).

TABLE 4.1 Table of Bulk Densities And Z-Values For Common Materials

MATERIAL	SYMBOL	BULK DENSITY (g/cm3)	Z-RATIO
ALUMINUM ANTIMONIDE	AlSb	4.360	0.743
ALUMINUM	Al	2.70	1.08
ALUMINUM OXIDE	Al_2O_3	3.97	0.336
ANTIMONY	Sb	6.62	0.768
ARSENIC	As	5.73	0.966
BARIUM	Ba	3.5	2.1
BARIUM FLUORIDE	BaF	4.886	0.793
BARIUM NITRATE	BaN_2O_6	3.244	1.261
BARIUM TITANATE (CUBIC)	$BaTiO_3$	6.035	0.412
BARIUM TITANATE (TETR)	$BaTiO_3$	5.999	0.464
BERYLLIUM	Be	1.85	0.543
BISMUTH	Bi	9.8	0.079
BISMUTH OXIDE	Bi_2O_3	8.9	---
BORON	B	2.54	0.389
CADMIUM	Cd	8.64	0.682
CADMIUM SELENIDE	CdSe	5.81	---
CADMIUM SULFIDE	CdS	4.83	1.02
CADMIUM TELLURIDE	CdTe	5.85	0.98
CALCIUM	Ca	1.55	2.62
CALCIUM FLUORIDE	CaF_2	3.18	0.775
CALCIUM SULFATE	$CaSO_4$	2.962	0.955
CARBON (DIAMOND)	C	3.52	0.22
CARBON (GRAPHITE)	C	2.25	3.26
CERIUM (III) FLUORIDE	CeF_3	6.16	---
CERIUM (IV) OXIDE	CeO_2	7.13	---
CESIUM BROMIDE	CsBr	4.456	1.410
CESIUM CHLORIDE	CsCl	3.988	1.399
CESIUM IODIDE	CsI	4.516	1.542
CESIUM SULFATE	Cs_2SO_4	4.243	1.212
CHROMIUM	Cr	7.20	0.305
CHROMIUM (III) OXIDE	Cr_2O_3	5.21	---
COBALT	Co	8.71	0.343
COBALT OXIDE	CoO	6.440	0.412
COPPER	Cu	8.93	0.437
COPPER (I) SULFIDE (Alpha)	Cu_2S(Alpha)	5.6	0.69
COPPER (I) SULFIDE (Beta)	Cu_2S(Beta)	5.8	0.67
COPPER (II) SULFIDE	CuS	4.6	0.82
CRYOLITE	Na_3AlF_6	---	---
DYSPORSIUM	Dy	8.560	0.605
ERBIUM	Er	9.05	0.74
GADOLINIUM	Gd	7.89	0.67
GALLIUM	Ga	5.93	0.593
GALLIUM ARSENIDE	GaAs	5.31	1.59
GERMANIUM	Ge	5.35	0.516
GOLD	Au	19.3	0.381
HAFNIUM	Hf	13.09	0.36
HAFNIUM OXIDE	HfO_2	9.63	---
HOLNIUM	Ho	8.8	0.58
INDIUM	In	7.3	0.841
INDIUM ANTIMONIDE	InSb	5.789	0.767

MATERIAL	SYMBOL	BULK DENSITY (g/cm3)	Z-RATIO
INDIUM OXIDE	In_2O_3	7.18	---
IRIDIUM	Ir	22.4	0.129
IRON	Fe	7.86	0.349
LANTHANUM	La	6.17	0.92
LANTHANUM FLUORIDE	LaF_3	5.94	---
LANTHANUM OXIDE	LaO_3	6.51	---
LEAD	Pb	11.3	1.13
LEAD FLUORIDE	PbF_2	7.790	0.661
LEAD SULFIDE	PbS	7.50	0.566
LEAD TELLURIDE	PbTe	8.160	0.651
LITHIUM	Li	0.53	5.9
LITHIUM BROMIDE	LiBr	3.470	1.230
LITHIUM FLUORIDE	LiF	2.638	0.778
LITHIUM NIOBATE	$LiNbO_3$	4.700	0.463
MAGNESIUM	Mg	1.74	1.61
MAGNESIUM FLUORIDE	MgF_2	3.18	0.637
MAGNESIUM OXIDE	MgO	5.390	0.467
MANGANESE	Mn	7.20	0.377
MANGANESE (II) SULFIDE	MnS	3.99	0.94
MERCURY	Hg	13.46	0.74
MOLYBDENUM	Mo	10.2	0.257
NEODYNIUM FLUORIDE	NdF_3	6.506	---
NEODYNIUM OXIDE	Nd_2O_3	7.24	---
NICKEL	Ni	8.91	0.331
NIOBIUM	Nb	8.578	0.492
NIOBIUM (V) OXIDE	Nb_2O_5	4.47	---
PALLADIUM	Pd	12.038	0.370
PLATINUM	Pt	21.4	0.245
POTASSIUM BROMIDE	KBr	2.750	1.893
POTASSIUM CHLORIDE	KC_1	1.98	2.05
POTASSIUM IODIDE	KI	3.128	2.077
RHENIUM	Re	21.04	0.15
RHODIUM	Rh	12.41	0.21
RUBIUM	Rb	1.53	2.54
RUTHENIUM	Ru	12.362	0.182
SAMARIUM	Sm	7.54	.089
SCANDIUM	Sc	3.0	0.91
SELENIUM	Se	4.82	0.864
SILICON	Si	2.32	0.712
SILICON (II) OXIDE	SiO	2.13	0.87
SILICON DIOXIDE (Fused Quartz)	SiO_2	2.20	1.07
SILVER	Ag	10.5	0.529
SILVER BROMIDE	AgBr	6.47	1.18
SILVER CHLORIDE	AgCl	5.56	1.32
SODIUM	Na	0.97	4.8
SODIUM CHLORATE	$NaClO_3$	2.164	1.565
SODIUM CHLORIDE	NaCl	2.17	1.57
SODIUM FLUORIDE	NaF	2.799	0.949
SODIUM NITRATE	$NaNO_3$	2.270	1.194
STRONTIUM FLUORIDE	SrF_2	4.277	0.727
STRONTIUM OXIDE	SrO	4.990	0.517
SULFUR	S	2.07	2.29

MATERIAL	SYMBOL	BULK DENSITY (g/cm3)	Z-RATIO
TANTALUM	Ta	16.6	0.262
TANTALUM (IV) OXIDE	Ta_2O_5	8.2	0.30
TELLURIUM	Te	6.25	0.9
TELLURIUM OXIDE	TeO_2	5.990	0.862
TERBIUM	Tb	8.27	0.66
THALLIUM	Tl	11.85	1.55
THORIUM	Th	11.694	0.484
THORIUM DIOXIDE	ThO_2	9.991	0.284
THORIUM (IV) FLUORIDE	ThF_4	6.32	---
TIN	Sn	7.30	0.724
TITANIUM	Ti	4.50	0.628
TITANIUM (IV) OXIDE	TiO_2	4.26	0.40
TITANIUM OXIDE	TiO	4.9	N/A
TUNGSTEN	W	19.3	0.163
TUNGSTEN CARBIDE	WC	15.6	0.151
URANIUM	U	18.7	0.238
URANIUM DIOXIDE	UO_2	10.970	0.286
URANIUM OXIDE	U_4O_9	10.969	0.348
VANADIUM	V	5.96	0.530
YTTERBIUM	Yb	6.98	1.13
YTTRIUM	Y	4.34	0.835
YTTRIUM OXIDE	Y_2O_3	5.01	---
ZINC	Zn	7.04	0.514
ZINC OXIDE	ZnO	5.61	0.556
ZINC SELENIDE	ZnSe	5.26	0.722
ZINC SULFIDE	ZnS	4.09	0.775
ZINC TELLURIDE	ZnTe	5.636	0.770
ZIRCONIUM	Zr	6.51	0.60
ZIRCONIUM CARBIDE	ZrC	6.606	0.264
ZIRCONIUM OXIDE	ZrO_2	5.600	0.95

Inficon welcomes information from our customers on any Z-Ratios that they may have, both from a theoretical or empirical basis. Contact our Field Service or Engineering Departments for inclusion of your information in future printings of the list.

4.2.2 DETERMINING DENSITY

NOTE:	Bulk density values are sufficiently accurate for most applications (see Table 4.1).

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 the 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 new density value with the following equation:

$$\text{Density (g/cm}^3\text{)} = D_1 \frac{T_x}{T_M}$$

where D_1 = Initial density setting
T_x = Thickness reading on Sentinel III
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 has not been zeroed between the test deposition and the entering of calculated density.

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

4.2.3 DETERMINING Z-RATIO

A list of Z-values for materials commonly used is given in Table 4.1. For other materials, Z can be calculated from the following formula:

$$Z = (d_q \mu_q / d_f \mu_f)^{1/2}$$

$$= 8.834 \times 10^5 (d_f \mu_f)^{-1/2}$$

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

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

d_q = density of quartz (crystal) (2.60g/cm^3)

μ_q = shear modulus of quartz (crystal) (2.94×10^{11} dynes/cm^2)

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

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

1. Using the calibrated density and 100% tooling, make a deposition such that the percent crystal life display will read approximately 50%, or near the end of crystal life for the particular materials, whichever is smaller.

2. Place a new substrate next to the sensor and make a second, short deposition (1000-5000Å).

3. Determine the actual thickness on the substrate (as suggested in density calibration).

4. Adjust Z-ratio value in the Sentinel III to bring thickness reading in agreement with actual thickness.

For multiple layer deposition (for example, two layers), the Z-value used for 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.

4.2.4 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:

$$\text{Tooling (\%)} = TF_I \times \frac{T_M}{T_X}$$

where T_M = Actual thickness at substrate holder

T_X = Thickness reading in the Sentinel III

TF_I = Initial tooling factor

4. Round off percent tooling to the nearest %

5. When entering this new value for tooling into the program, T_M will equal T_X if calculations are done properly.

> **NOTE:** When calibrating tooling, we recommend that you make a minimum of three separate runs. Variations in source distribution and other system factors will contribute to slight thickness variations from run to run. An average value tooling factor should be used for final calibrations.

4.3 Theory of EIES Calibration

The Sentinel III converts an optical signal generated in the sensor and then transmitted and filtered, into a digital readout which is displayed on the front panel. Because of the uniqueness of each system in providing quantitative data, the instrument must be calibrated to a known reference. The parameters which affect the optical output from the sensor until it is finally converted into a digital signal, are the following:

a. Strength of the emission transition(s) (Q_{ij})
b. Length of the optical couplings
c. Variations in mirror reflectivity with optical wavelength
d. Differences in transmission efficiencies for various optical filters
e. Variations in monochromator throughput with wavelength
f. Variations in monochromator throughput with variations in slit-width (bandwidth)
g. Variation in overall conversion efficiency of the photo cathode and electron gain of the electron multiplier in the photomultiplier tubes
h. Overall mechanical and electrical component tolerances

SECTION 4
MEASUREMENT & CALIBRATION

General Considerations

Since the Sentinel's sensor has access to only a small portion of the vapor system, be sure that this portion is indicative of the total process. Do not place the sensor at high angles to the source normal, or where it may be screened or shuttered by moving components. See Section 3.1.

When calibrating, be sure you understand the following items and their effects on calibration:

a. Large variations in pressure can affect calibration. The signals produced by the residual gasses can add to the material signal; thus, the Sentinel signal can vary slightly as the material rate stays constant. This variance can be minimized by the proper choice of filters, or by choosing an emission line far removed from the primary residual gas bands. (Contact Leybold Inficon for applications assistance.) See 4.1.7 for correction.

b. Many times changes in gain which appear to be calibration drift are actually due to source distribution changes. Distribution of most evaporators varies with both the input power and the material level. To minimize these effects the following rules should be followed:

   1. Minimize the distance between crystal sensor and the Sentinel sensor (if you are using a quartz crystal monitor).

   2. Keep fluctuations of the evaporation pool height to a minimum by using a wire feeder for a continuous process, or by maintaining the starting charge volume by weighing for a batch process.

   3. Keep the beam spot position and size constant when using electron beam evaporators.

c. Before starting the actual calibration, be sure that the Sentinel has good source control. Widely varying evaporator power levels change the source distribution and will affect the calibration. Refer to Section 2.6.4 for establishing rate control. Make sure the beam sweep frequency is not close to the Sentinel III's measurement frequency (8Hz).

d. The required frequency of recalibration is process dependent. Calibration stability of $\pm 3.5\%$ has been demonstrated over many days for both continuous and batch coating. However, each process is different and only the user can determine the frequency of calibration necessary for a reliable product.

e. The calibration of displayed rate to actual rate does not have to be a direct one-to-one correlation. It may be beneficial, in processes depositing low rates, to calibrate the instrument so that the following relation is satisfied:

   $N \times \text{Actual Rate} = \text{Displayed Rate}$

   where N is any convenient number. The added resolution will provide tighter rate control and improved thickness accuracies.

f. In processes where the Sentinel III is controlling alloy depositions, calibration is best achieved by evaporating each element individually. Calibration Methods #1A and #1B (below) incorporate this approach. Method #1B requires analytic laboratory facilities to determine film composition.

CALIBRATION METHODS

The methods of calibration are the following:

1. Auto calibrate with crystal monitor. (See Section 2.7.3)

2. Witness slide analysis following the deposition.

The method used depends on available equipment and the nature of the process. For batch processes involving high-product cost and requiring a high degree of reliability, the ability to occasionally verify calibration on a batch basis is best provided by a shuttered quartz crystal monitor. For continuous or load-locked processes, an occasional calibration verification of the product is sufficient if it can be done within a reasonable time in relation to the evaporation; otherwise a shuttered crystal is suggested.

Method 1A - Witness Slide Correlation (when individual species may be evaporated)

This method is the most time-consuming, as well as the most variable. Any method of thickness determination in which you have confidence may be used, such as step analysis, Eddy currents, interferometry or weight change. (Be sure of the technique's repeatability prior to starting, to avoid confusion.)

In order to accurately calibrate the system by this method, you will need the following (Fig. 4.1):

1. A shutter installed between evaporant source and sensor/slide location.

2. Automatic shutter control to insure that the thickness reading on the Sentinel is zeroed at the time of shutter opening.

3. Smooth rate control by the Sentinel during the time the deposition is proceeding.

The procedure for calibration is as follows:

1. From the trial deposition determine:

    a. Process time
    b. Sentinel thickness accumulation
    c. Actual coating thickness from one of the above methods

2. Calculate

   a. Actual rate by dividing the actual thickness by the process time

   b. Apparent (Sentinel) rate by dividing the Sentinel thickness accumulation by the process time

3. Perform the calibration by noting coarse and fine optical gains and adjust using a linear assumption - Gain changes between PMT Ranges are as follows:

Range		Gain
1	-	1
1	-	3.3
1	-	10
1	-	33
1	-	100
1	-	330
1	-	1000
1	-	3300

If the initial adjustment is small, the procedure need only be followed once. However, if the initial mismatch is greater than 50%, the calibration procedure should be repeated.

Example:

If the Sentinel III reads 2000Å when the standard reads 2500Å and the PMT range is 3 and fine gain is 1.200, the new gain is obtained as follows:

$$\text{New gain} = 1.200 \left(\frac{2500}{2000}\right) = 1.500$$

Method #1B - Witness Slide Correlation (where only the alloy is available)

When it is not feasible to evaporate the individual elements of an alloy, an indirect method of chemical correlation must be substituted. In addition to knowing the total accumulated thickness, you must have information describing the relative portions of each species.

The problem of calibration in this case is that adjustment becomes very dependent on the accuracy and repeatability of the analytic technique. The best results are obtained when the technique has been used consistently and reasonable bounds have been established for its accuracy. Even the most consistent analytic techniques can have inaccuracies in excess of 5% for each material.

In the following calibration procedure, the symbols used are as follows:

CH 1 - Apparent Sentinel accumulation for Material 1 (A)
CH 2 - Apparent Sentinel accumulation for Material 2 (A)
M1 - Mass of Material 1 as analyzed (g)
M2 - Mass of Material 2 as analyzed (g)
D1 - Density of Material 1 (g/cm^3)
D2 - Density of Material 2 (g/cm^3)
A - Total deposited area analyzed (cm^2)

Using the set up as in Method #1A, conduct a trial deposition.

1. Determine

   a. process time from a stopwatch of the time elapsed indication from Sentinel
   b. apparent thickness accumulations on CH 1 and CH 2
   c. the true mass of each component (M1 and M2) as measured by the other analytic technique

2. Convert the mass (M1, M2) of each component to a thickness by

   a. dividing the mass of each component by the areas analyzed
   b. dividing the result by the density of each component. This gives an answer which is in units of thickness, d (cm)

$$d = \frac{M1}{AD1} \text{ [multiply by } 1 \times 10^8 \text{ to convert to (Å)]}$$

   c. dividing the result (b) by the process time to determine a true rate for Material 1

   d. repeating steps (a) through (c) for Material 2

The Sentinel may now be calibrated using the technique for individual elements.

Converting Thickness Indications to Other Useful Quantities

Common vacuum metallurgical practice dictates the expression of a film coating thickness in units of angstroms (Å). This naturally leads to expression of rates in units of angstroms per seconds (Å/s). However, there are other common expressions for these parameters, such as microns per minute (μ/min) or thousandths of an inch per minute (mil/min).

Conversion formulas useful for the Sentinel III:

Thickness

1μ	=	10,000 Å
1 mil	=	2.54 × 10^5Å
1μ	=	3.95 × 10^{-2} mil

Rate

1μ/min	=	166.7 Å/s
1 mil/min	=	4.23 × 10^4 Å/s
1μ/min	=	3.95 × 10^{-2} mil/min

It is sometimes necessary to relate a thickness ratio on the Sentinel to other material parameters such as atomic percent or mass percent. Atomic percent may be defined as follows:

$$\text{Atomic percent of Material 1} = \frac{N1}{N1 + N2} \times 100\%$$

where:

N1 = number of atoms per unit volume of Material 1
N2 = number of atoms per unit volume of Material 2

The atomic percent of a Sentinel-produced binary alloy which has been calibrated in common units may be computed quickly if the density and molecular weight of the two materials are known.

The average composition may be computed by the following method:

$$\text{Atomic percent Material}_1 = \frac{\dfrac{T1\,D1}{M1}}{\dfrac{T1\,D1}{M1} + \dfrac{T2\,D2}{M2}} \times 100\%$$

where:

T1, T2 = Sentinel accumulated thickness for each material
D1, D2 = density of Material 1 and 2 respectively in gm/cm^3
M1, M2 = molecular weight of Material 1 and 2 respectively in gm-mole

4.4 Procedure for Zeroing the EIES Sensor Signal in the Sentinel III

The following procedure is for zeroing the Rate display for Channels 1 and 2 and the Monitor Channel of the Sentinel III when using the EIES sensor.

NOTE:	The instrument should be turned on and warmed up for 15 minutes.

As there may be a slight offset between PMT RANGEs (calibration gain parameter located in the film program), the instrument should be calibrated to the correct PMT RANGE prior to zeroing the unit. It may be beneficial to short the unused signal inputs also, as this will reduce noise entering the SCU.

All the potentiometers referenced in this procedure will decrease the rate on the display when turned clockwise and increase the rate when turned counter-clockwise.

1. Before applying high voltage to the photomultiplier tube (PMT), block off all light entering the PMT. This can be accomplished by placing an opaque material in front of the optical filter and threading the PMT back onto the optical feedthrough.

2. Connect the cable from the Sentinel III Console to the SCU and all the signal and high voltage cables from the SCU to the photomultiplier tubes. (Note: if you have only a single material Sentinel III it is not necessary to connect a photomultiplier tube to the unused signal inputs.)

3. With the emission off, adjust potentiometer R88 until the display reads zero on the Rate display. Potentiometer R88 is located in the SCU on board number 753-310. If all three channels do not read the exact same rate, make the adjustment so that the Monitor Channel reads zero. If you are not using the Monitor Channel make the adjustment so that Channel 1 reads zero.

NOTE:	In some newer model Sentinel SCU's the potentiometer R88 is accessible via a hole in the SCU box. To access this pot, remove the cap plug closest to the top of the SCU, (i.e, the top is the side with the Console Interface connector, J3). If it is necessary to remove the sides of the SCU, care must be taken to shield the electronics from stray electromagnetic fields, which may cause a small voltage on the signal input.

4. If the Rate displays are not all zero, each individual channel can be adjusted. If you are using the Monitor Channel as your reference zero, you may have to adjust Channels 1 and 2. If you are using Channel 1 as your reference you may only need to adjust Channel 2. Potentiometers R24 (CH. 1) and R46 (CH. 2) are located in the SCU near the location of R88. Again, these pots may be accessed by removing the cap plugs located in the vicinity of the cap plug for R88. The potentiometer for Channel 2 lies closest to R88, while the pot for Channel 1 is immediately to the right of the pot for Channel 2.

5. Next, with the emission on , adjust potentiometer R11 on the SCU CNTL board, located in the Sentinel III Console, until the appropriate channel reads zero.

6. If a very accurate zero is required (usually only if depositing at very low rates) it is best to take thickness accumulations of 1 to 2 minutes. As the thickness is the integral of rate, very fine adjustments can be made by also ensuring that thickness is zero over time. With care it should be possible to achieve a thickness accumulation of 1 or 2 Angstroms in 2 minutes.

4.5 Theory of Quartz Crystal Calibration of EIES

In Figure 3.1 (Section 3) a shuttered QCM is shown near to the sensor and is used for calibration of the instrument. In this newer generation of instrumentation the calibration of the optical signal may be automatic. The Sentinel III is capable of exchanging information from the crystal and EIES sensors. The crystal provides absolute measure of the deposition rate; the EIES provides a relative measure of the deposition rate. This information exchange is used by the Sentinel III to determine the calibration factors (fine and coarse gains) allowing the instrument to be used quantitatively. The shutter that is placed over the crystal is open only as long as is necessary to gather sufficient frequency shift to allow computations to the required accuracy. This procedure need take only a few seconds at deposition rates of 4 angstroms per second or more but for maximum accuracy a 5 second period of thermal stabilization of the crystal is allowed prior to the data taking interval. This procedure is able to be initiated at any point of the deposition so that it may be used to verify the calibration. For co-depositions from separate sources, the QCM is unfortunately not material selective and is thereby not useful for alloy determinations, except prior to the combined evaporation. Prior to the combined evaporation each material's EIES signal may be separately calibrated to the crystal. Then during a co-deposition the EIES sensor, which is material specific, can control both materials simultaneously. Since the vapor densities of the co-deposited materials are sufficiently dilute that matrix effects are not present, the only interference which may occur is from optical interferences. These simple optical interferences are directly proportional to the vapor densities and therefore are easily subtracted using the cross sensitivity parameters.

Once the optical signal is extracted, converted to an electrical signal, and quantified through calibration, the instrument performs the important task of rate control. One of the inherent advantages of EIES is that it is a rate sensing type of instrument. Unlike the QCM which is a thickness sensing instrument that differentiates the successive thickness to derive rate, the Sentinel integrates the rate to determine thickness.

4.6 Calibration Algorithm

The following algorithm is used by the Sentinel III to do the Quartz Crystal Calibration:

1. Open crystal shutter.

2. Delay 5 seconds. (Wait for crystal reading to stabilize.)

3. Set counter to zero.

4. Accumulate optical thickness and crystal thickness until
   crystal thickness > (300Å/TOOLING)/(DENSITY x CAL ACCURACY)

5. If

   ABS[(crystal thickness - optical thickness)
   /crystal thickness] < CAL ACCURACY

   and

   counter < 2, exit.

   (Optical sensor already in calibration - won't change.)

6. Increment counter.

7. If counter = 1, go to 4. (Try again.)

8. If

   ABS[(previous optical thickness - optical thickness)/
   previous optical thickness] > CAL ACCURACY, go to 4.

   (Not getting consistent optical readings so keep trying.)

9. Calibration value = fine gain x (crystal thickness/optical thickness).

10. If

    .5 < = calibration value < = 2.5

    then

    fine gain = calibration value. Exit.

11. If calibration value < .5, decrement PMT range. Go to 3.

12. If calibration value > 2.5, increment PMT range. Go to 3.

5.0 MAINTENANCE AND REPAIR

WARNING!!!
POTENTIALLY LETHAL VOLTAGES ARE PRESENT WITHIN THE SENTINEL III WHEN THE LINE CORD IS CONNECTED. CERTAIN CONTROL VOLTAGES MAY ALSO BE PRESENT AT THE I/O RELAY MODULE CONNECTOR. DISCONNECT THE LINE CORD WHEN REMOVING, INSTALLING, OR SERVICING ANY COMPONENT OF THE SENTINEL III INSTRUMENT. REFER ALL MAINTENANCE TO QUALIFIED PERSONNEL.

CAUTION: *The Sentinel III contains delicate circuitry which is susceptible to shock caused by electrical shorting. Disconnect the line cord when making any interface connections or performing any internal service on the Sentinel III. Refer all maintenance to qualified personnel.*

Sensors which may be used with the Sentinel III include:

Standard (w/wo Shutter)
Compact (w/wo Shutter)
UVH Bakeable (w/wo Shutter)
EIES

5.1 Crystal Calibration System

5.1.1 TROUBLESHOOTING

STANDARD, COMPACT, AND BAKEABLE SENSORS

SYMPTOM	CAUSE	REMEDY
1. large jumps of thickness reading during depositon	a. mode hopping due to defective crystal	a. replace crystal
	b. crystal near the end of its life	b. replace crystal
	c. scratches or foreign particles on the crystal holder seating surface	c. clean or polish the crystal seating surface on the crystal holder

NOTE: Crystal life is highly dependent on process conditions of rate, power radiated from source, location, material, and residual gas composition

SYMPTOM	CAUSE	REMEDY
2. crystal ceases to oscillate during deposition before it reaches its "normal" life	a. crystal is being hit by small droplets of molten material from the evaporation source	a. use a shutter to shield the sensor during initial period of evaporation; move the sensor further away
	b. defective crystal	b. change crystal
	c. built-up material on edge of crystal holder touching crystal	c. clean the crystal holder
	d. material on crystal holder partially masking full crystal area	d. clean crystal holder
3. crystal does not oscillate or oscillates intermittently (both in vacuum and in air)	a. defective or damaged crystal	a. replace crystal
	b. existence of electrical short or poor electrical contacts	b. check for electrical continuity and short in-sensor cable connector, contact springs, and the connecting wire inside the sensor; check for electrical continuity in feedthroughs
4. crystal oscillates when 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 accumulation on the crystal	b. turn off cooling water to sensor before opening it to air
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. crystal is not properly seated	a. check and clean crystal seating surface of the crystal holder

(continued...)

SYMPTOM	CAUSE	REMEDY
5. ...continued	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; if the crystal heating is due to energetic secondary electrons, change regualr sensor to a sputtering sensor
	c. no cooling water	c. check cooling water flow rate (refer to specifications Section 1, for the type of sensor used)
6. poor thickness reproducibility	a. erratic source emission characteristics	a. move sensor to a different location; check the evaporation source for proper operating conditions; insure relatively constant pool height and avoid tunneling into the melt
	b. material does not adhere to the crystal	b. check the cleanliness of the crystal surface; evaporate a layer of proper material on the crystal to improve adhesion. Use silver coated sputtering crystals for better adhesion of Dielectrics

5.1.2 REPLACING THE CRYSTAL

The procedure for replacing the crystal is basically the same with either the standard, compact, or bakeable sensor. Before you begin, please observe the following precautions:

> ***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 it can be broken.*

NOTES:	Certain materials, especially dielectrics, may not adhere strongly to the crystal surface and may cause erratic readings.
	Thick deposits of some materials, such as SiO, Si, and Ni will normally peel off the crystal when it is exposed to air, as a result of changes in film stress caused by gas absorption. When you observe peeling, change the crystals.

STANDARD AND COMPACT SENSORS

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

1. Gripping the crystal holder with your fingers, pull it straight out of the sensor body.
2. Gently pry the crystal retainer from the holder (or use crystal snatcher; see Figure 5.4).
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.

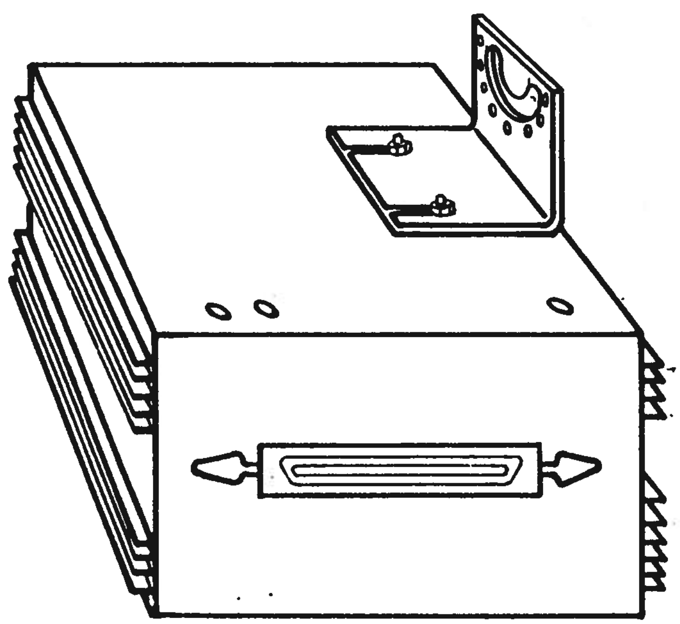


Figure 5.1 Standard Crystal Sensor (Exploded)

SHUTTERED SENSORS

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

BAKEABLE SENSOR

The procedure is the same for the Bakeable sensor as the regular crystal, except that you must first unlock the cam assembly by flipping it up. Once the crystal has been replaced, place a flat edge of the holder flush with the cam mechanism and lock it in place with the cam (Figure 5.2).

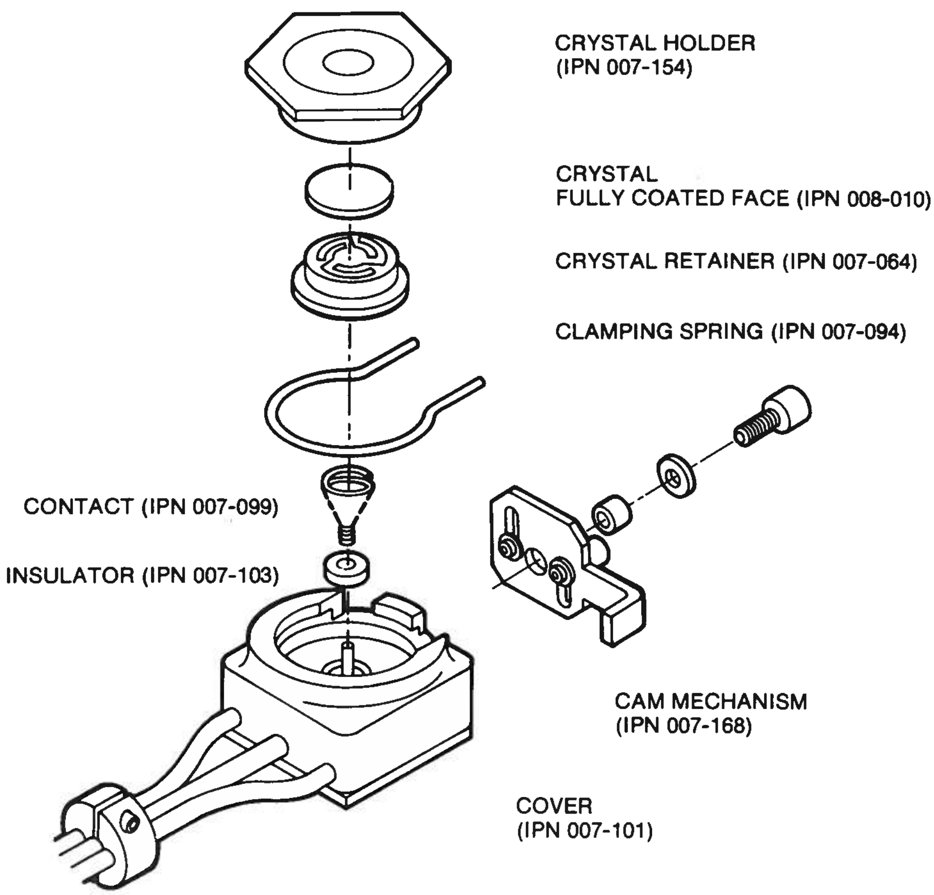


Figure 5.2 Bakeable Crystal Sensor (Exploded)

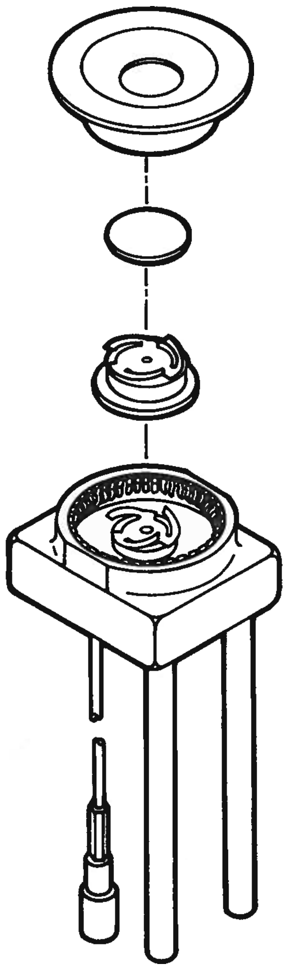


Figure 5.3 Compact Crystal Sensor (Exploded)

If you wish to use the crystal snatcher supplied with the sensor, follow the instructions below:

1. Insert crystal snatcher into ceramic retainer (1) and apply a small amount of pressure. This locks the retainer to the snatcher and allows the retainer to be pulled straight out (2).

2. Re-insert the retainer into the holder after the crystal has been changed.

3. Release the crystal snatcher with a slight side-to-side motion.

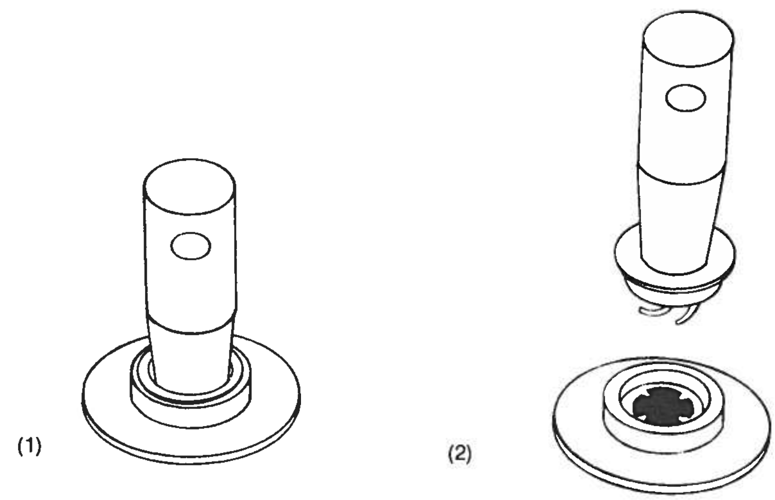


Figure 5.4 Replacing the Crystal

5.1.3 DUAL STANDARD CRYSTAL SENSOR ASSEMBLY INSTRUCTIONS

Minor disassembly of the Actuator Assembly is required to adjust the Shutter Module.

1. Disassemble existing assembly.

2. Lubricate .125 diameter shaft hole in sensor body with molybdenum disulfide or equivalent lubricant.

3. Mount piston support assembly in bore of actuator assembly, utilizing two (2) #4-40x.38 long stainless steel hardware.

4. Place two (2) stainless steel spacers on to shaft assembly.

5. Pass shaft assembly through .125 hole from backside of sensor body.

6. Position roll pin that protrudes from piston support assembly into .086 diameter hole on backside of sensor body.

7. Rotate actuator assembly until the .062 diameter pin of shaft assembly engages the noncountersunk side of hole in piston support assembly. Secure actuator assembly to sensor body utilizing two (2) #4-40x.625 long stainless steel hardware.

8. Attach shutter to end of shaft assembly. Position shutter for proper coverage of crystal nearest waterline. Actuate shutter to determine coverage of second crystal; readjust shutter if necessary to obtain optimum coverage for both positions.

Reference Figures 5.5, 5.6, and 5.7

NOTE:	Lubrication procedure should be repeated after approximately 2,000 shutter actuations. Failure to lubricate may significantly reduce life of operation or cause assembly to become totally inoperative.

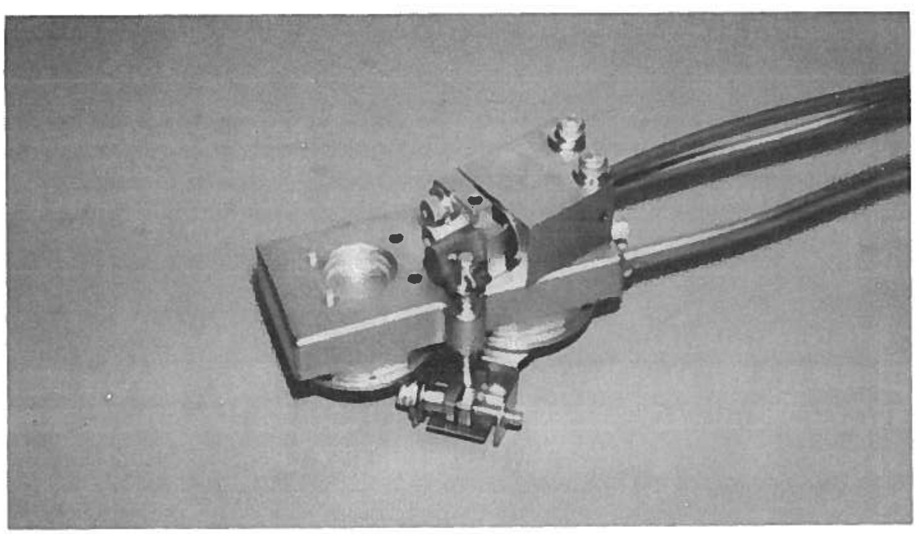


Figure 5.5 Dual Sensor

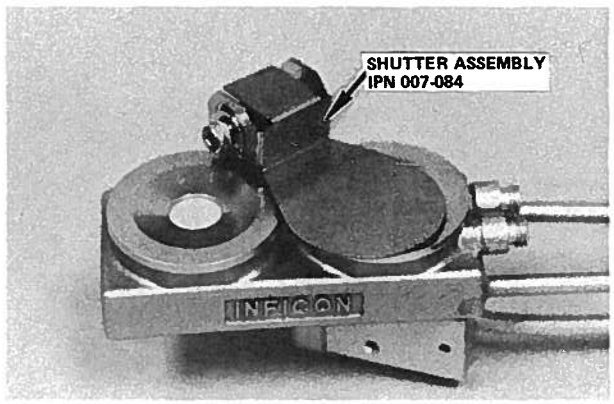


Figure 5.6 Dual Crystal Sensor

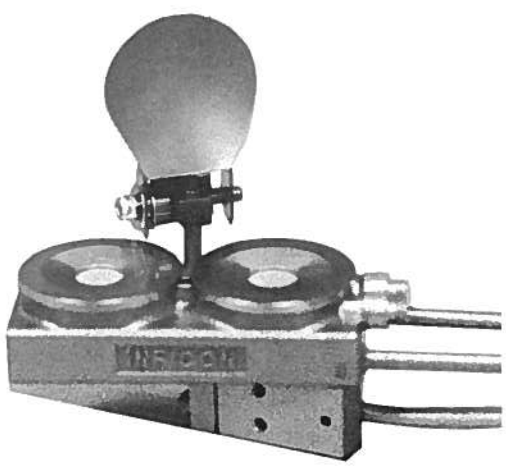


Figure 5.7 Dual Crystal Sensor (Open)

5.2 EIES Sensing System

The need for periodic maintenance is generally restricted to the sensor emitter assembly and the optical window located in the feedthrough. The need for maintenance is highly dependent on process specifics and must be established in the field.

5.2.1 EMITTER ASSEMBLY REPLACEMENT

> **NOTE:** The emitter assembly itself is not considered a repairable item due to the necessity for special tooling and fixtures.

While average filament life is approximately 1000 hours, process parameters can affect this figure; therefore, a routine service schedule should be established for each installation. Before you replace the emitter assembly, please read the general precautions listed below:

1. Turn the instrument power off before removing the sensor from the vacuum system.
2. Be sure the sensor is replaced in the exact location and orientation as before its removal. (This will minimize the calibration error experienced on the first run after the replacement.)
3. Put a light, fresh coating of graphite (IPN 009-175) on all screws removed from the sensor before replacing them.
4. Follow standard vacuum procedures to prevent emitter contamination by improper handling.

Follow the steps below to replace the emitter assembly:

1. Unplug the in-vacuum cable from the sensor connector pins by grasping the connector body and pulling with a slight rocking motion.
2. If necessary, loosen the clamping ring at the end of the optical tube to remove the sensor from the vacuum system.
3. Carefully pry the cover off the sensor housing.
4. Remove the two #2-56 hex screws which hold the emitter assembly and name plate in place.
5. Check the general mechanical condition of the assembly before you install the new emitter assembly. Remove excess evaporant and flaking if necessary.
6. Install the new emitter such that the connector pins are centered in the housing slot and the aperture plate is parallel with the Faraday collector.
7. Replace the sensor cover.

8. Check the resistance between the emitter connector pins (approximately 1 ohm), and between one pin and the sensor base assembly (-). Use the highest resistance range when checking between a connector pin and the base. Use the lowest when checking between connector pins.

   If there is continuity between the base and the connector pins, check the position of the emitter assembly.

   If there is no continuity between the connector pins, the filament is open.

5.3 Optical Windows

In some deposition processes, material may diffuse or migrate up the optical coupling and deposit on the window located in the feedthrough. This results in a gradual loss of sensitivity and a corresponding calibration drift. If a noticeable loss of sensitivity is evident after a long period of heavy evaporation, and this is not restored after the emitter is replaced, cleaning may be necessary.

1" Bolt Feedthrough (016-230-G2) - This uses a fused, UV GRADE Quartz disk that is sealed by Viton O-Rings. The window may be cleaned by acid etching or polishing. A replacement window may be ordered under IPN 016-252-P1.

1-2/3" ConFlat Feedthrough (016-390-G1) - This uses a UV GRADE Sapphire window that is high temperature bonded into a 1.33" ConFlat flange. The suggested cleaning method is polishing. The replacement window may be ordered under IPN 009-067.

CAUTION: *Be careful not to scratch or chip windows, or a resultant loss in transmission may occur. In all cases, the final cleaning should be done in extremely high-purity solvent to prevent attenuation of shorter wavelengths.*

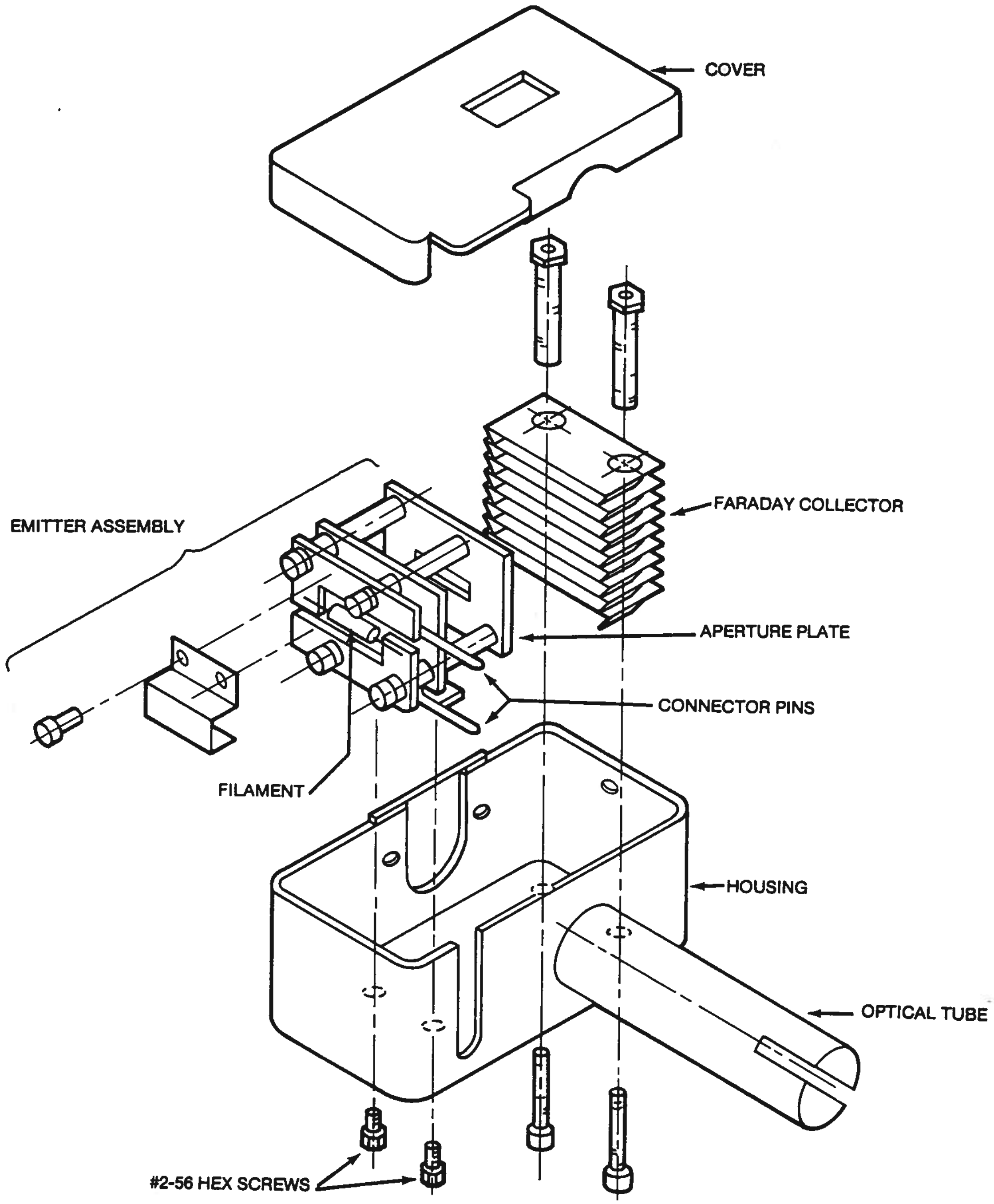


Figure 5.9 Sentinel III Sensor

5.4 Optical Filters

Refer to Section 4.1.4 (pg. 4-8) for details pertaining to cleaning and maintaining optical filters.

5.5 EIES Sensor Troubleshooting Guide

SYMPTOM	CAUSE	REMEDY
Emission Error Message	Electrical "short" or "open" condition	Check continuity or isolation for EIES sensor and In-Vacuum Cable
Max leak or 50% leak message	Insulators in the EIES assembly are coated	Replaced or rebuild emitter assembly
	In-Vacuum Cable is not isolated from GND	Check isolation of cable
No signal at maximum gain	Material not passing through sensor	Check placement of sensor and possible masking. See Section 3.1
	PMT Signal Cable not on correct channel on SCU	Check signal cable
	Incorrect wavelength being monitored	Check Thin Film Filter placement and wavelength—see chart p.1-13 or adjust monochromator
	Optical window coated	Clean window see Section 5.3
	Signal attenuation too great	See Section 3.1.2 and Section 3.2.2b
	Fiberoptic is broken	See Section 3.3.2
	Quartz light guide broken	Replace quartz light guide
Noisy Signal	Control loop is not optimized or control loop output voltage not optimum	Tune control loop, see Section 2.6.4
	PMT Range = 8	See Section 3.1.2 and 3.3.2 for optimizing EIES signal
	Melt not conditioned properly	Condition melt to reduce oxides or eliminate trapped gases

SYMPTOM	CAUSE	REMEDY
		Eliminate thermal shorts
	Depositing a refractory metal	Use optical light shield. See Section 3.1.5
	Wrong Thin Film Filter or no Filter	Check Thin Film Filter
	Large Dither or slow sweep on e-beam source which is causing beating with measurement frequency	Reduce Dither or increase sweep frequency
	Room light entering photomultiplier tube or entering EIES sensor light pipe	Check for light leaks around EIES sensor and PMT Check for an opening around the light pipe
Inconsistent Calibration with respect to XTAL	Gas interference	Use cross-sensitivity correction
	Material pool height variations	Replenish source to maintain pool height
	Beam position moved	Recalibrate/keep beam position and sweep frequency constant

5.6 Zero Offset Drift

If you experience a zero rate offset problem, make the following adjustments while the PMT signal cable is disconnected.

1.With the emission off, adjust potentiometer R5 (on Z-24, which functions as a differential amplifier) until the zero offset on the screen is eliminated.

2.With the emission on, a small zero offset may once again be observed. Adjusting R11 will change the bias on the amplifier inputs and will consequently enable you to eliminate the rate offset caused by the emission current.

6.0 SCHEMATICS AND MODULE THEORY

Section 6 includes detailed information and schematics for the Sentinel III electronic circuitry.

Modules are discussed in the following order:

Sentinel III Interconnection Diagram
SCU Interconnection Diagram
CPU Board (753-362)
Video Board (017-322-G1)
Relay I/O Board (017-442-G1)
Power Supply Board (017-382)
Deposition Control Board (753-332-G1)
System Control Board (753-342-G1)
Preamps and Detectors Board (753-312)
AE Sensor Regulator (753-322-G1)
IEEE-488 Communications Board (017-430) (Optional)
Filter Changer Controller Board (753-352) (Optional)
Interconnecting Cables

The Sentinel III System Diagram illustrates the basic relationship of modules within the system.

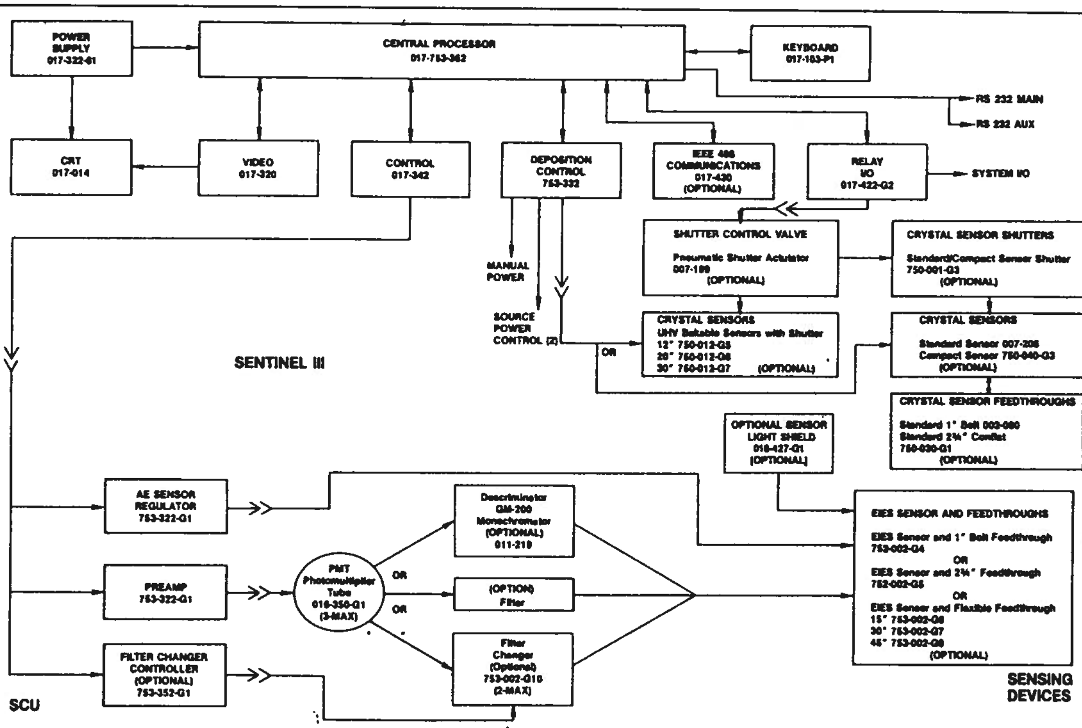


Figure 6.1 Sentinel III Block Diagram

6.3 Central Processor Board (017-332-G1)

The CPU board controls the entire operation of the Sentinel III. The program contained in ROMs Z2 through Z5 is interpreted by the Z80 CPU, which directs the instrument's activity. Static RAMs Z6 and Z7 are the operating system's variable storage area ("scratchpad RAM"). CMOS static RAM Z8 has battery backup to maintain program variables and data during power off conditions.

Address, control and data buffers Z21, Z25, Z32 and Z33 provide isolation between the CPU and the other boards in the unit. Z14 provides the CPU and Baud Rate Generator clocks. Memory address decoding is done by Z16 and Z17, while I/O decoding is accomplished by chips Z9 and Z17.

Serial communications are handled by Z22, which provides two RS-232 ports. The main port (A) is used for two-way communications, while the auxiliary port (B) is used for a serial plotter. Interrupt control and system timing are performed by Z31, which is a Z80 Counter Timer Circuit (CTC). Keyboard entries are handled by Z28 and Z29 which are 74C923 keyboard decoders.

Three power supplies are used on the CPU board, they are +5, +18, and -18 volts. The +18 and -18 volts are regulated down to +15 and -15 volts by VR1 and VR2 for the RS-232. The +5 volts is used for Vcc and to charge the CMOS RAM backup battery.

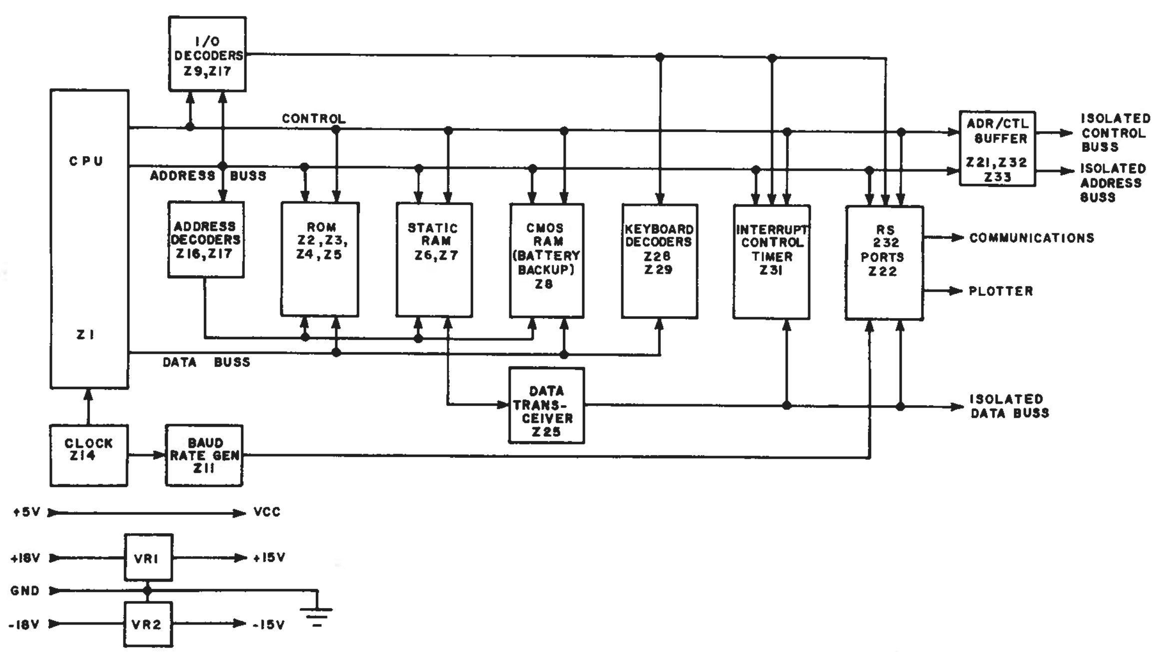


Figure 6.4 Central Processor

6.4 Video Generator (017-322-G1)

The Video board contains its own Z80 CPU and memory, which allows it to free run without the CPU board. In order for the CPU board to communicate with the Video board, a DMA (Direct Memory Access) mode has been established using a common RAM called the "Video Mailbox". Since the main CPU does not have to control the video functions, it is free to perform other tasks faster and more efficiently. ROM Z14 contains all the video operating firmware.

The "Video Mailbox" is contained in a single CMOS static RAM (Z19) which can be accessed by both the Video CPU and the Central Processor CPU with different addresses.

Most of the Video display is performed by Z2, which is a CRTC (CRT Controller). This chip generates the vertical sync (V SYNC), horizontal (H SYNC), and blanking (BLNK) pulses.

The data to be displayed is stored in dynamic RAMs Z3, Z7, Z10, Z16, Z23, Z24, Z28 and Z34. This data can be accessed by both the CPU and CRTC by controlling address multiplexers Z20, Z21, Z22 and Z27. The dynamic memory timing is provided by Z25, Z26, Z32 and Z33. Video data is converted to dots and shifted out by Z15. These dots are combined with the sync pulses by Z18 and sent out through Q1 and Q2 as a composite video signal.

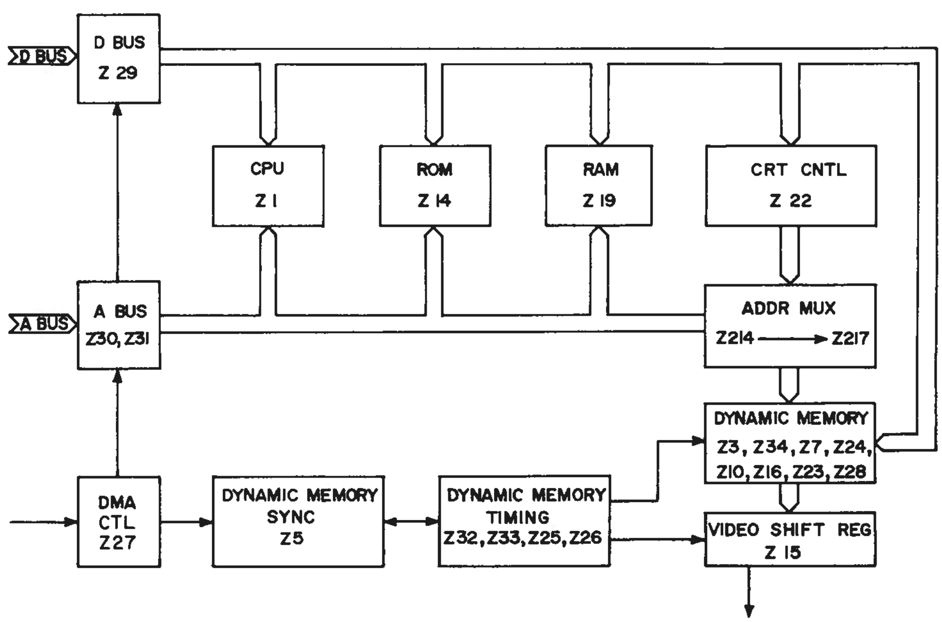


Figure 6.6 Video Generator

6.5 Relay I/O Board (017-422-G1)

The Relay I/O board provides you with a means of obtaining data from, and remotely controlling the Sentinel III.

The Instrument Status relay (K11) is energized when all conditions are met for making valid data measurements.

The Relay I/O board has twelve (12) inputs used for controllable functions.

The electronic circuitry consists of the following: The inputs are isolated from the system by twelve (12) optocouplers, Z12 through Z23. These isolators require an AC or DC voltage between 8 and 24 VRMS to be activated. These couplers are read by octal latches Z4 and Z8. Relays K1 through K12 provide output information, and are controlled by relay drivers Z3 and Z6, and octal latches Z2 and Z5. The data is read to and from the board via octal bus transceiver Z1, which isolates the board from the system data bus. Address decoding and bus control are handled by chips Z9 and Z7 respectively. An on board 10 volt DC ground referenced supply consisting of Q1 and Q2 is provided for use when an external power source is not available.

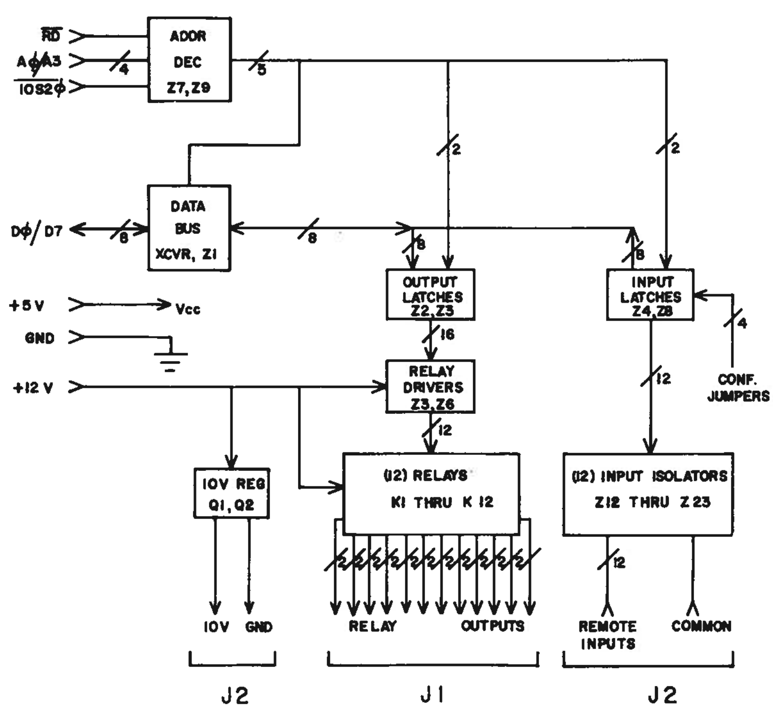


Figure 6.8 Relay I/O Board

6.6 Power Supply Board (017-382-G2)

The power supply generates the 5 voltages needed for proper operation of the Sentinel III.

1. 5V @ 4 amps for Logic
2. 12V @ 2.5 amps for the CRT
3. 24V @ 2.5 amps for the Emission Regulation Circuitry
4. +18V @ 350 ma for the Linear Circuits
5. -18V @ 350 ma for the Linear Circuits

The 5, 12, and 24 volt regulators all are driven from an unregulated 28V dc Bus. The 5 volt switching regulator consists of control circuit Z3, power switching network Q5, and inductor L2. Output voltage is determined by the internal 5V reference of Z3 and divider network R36 and R38. Current limit protection is accomplished by comparing the voltage across current sense resistor R34 to the fixed voltage drop of diode CR12. Output noise is limited by L4 and C21.

Operation of the 12 volt switcher is similar to the 5 volt switcher with the exception of the voltage and current sensing element values. The 12 volt control circuit Z4 is also slaved to the 5 volt control circuit Z3 such that they both operate at the same frequency and phase. This ensures consistent noise and regulation performance from both regulators. Both regulators also employ slow start networks R39-C29 and R46-C35 to reduce current surges on power turn on.

The 24 volt regulator VR4 is a linear regulator whose output voltage is determined by the ratio of R21 to R22. This regulator is switched to approximately 1.2V (EMISSION OFF) by shorting R22 with control transistor Q4. Transistor Q4 is driven by control logic Z2. This logic requires that a watchdog pulse train be present (10 p.p.s.) and the 24VON signal be present in order to turn Q4 off and cause regulator VR4 to operate at 24 volts. The watchdog feature affords protection of the electronics if the software or CPU fails to operate properly. The 24 volt regulator is only operational when the emission switch on the front panel is activated. Any system malfunctions will cause the 24 volts to be turned off, thus protecting the sensor and electronics.

Linear regulators VR1 and VR2 supply the q18 volts for the Analog sections of the instrument. These regulators are driven from a 36V CT bridge rectifier and filter. The negative full wave rectified ac is sampled via CR2 to provide a line voltage failure indication. Z2 (along with Q3) is both a threshold and pulse omission detector. If line voltage pulses don't occur for a duration longer than 100 ms or the line voltage falls below 85V rms a power fail signal is sent to the CPU via Z2 pin 6.

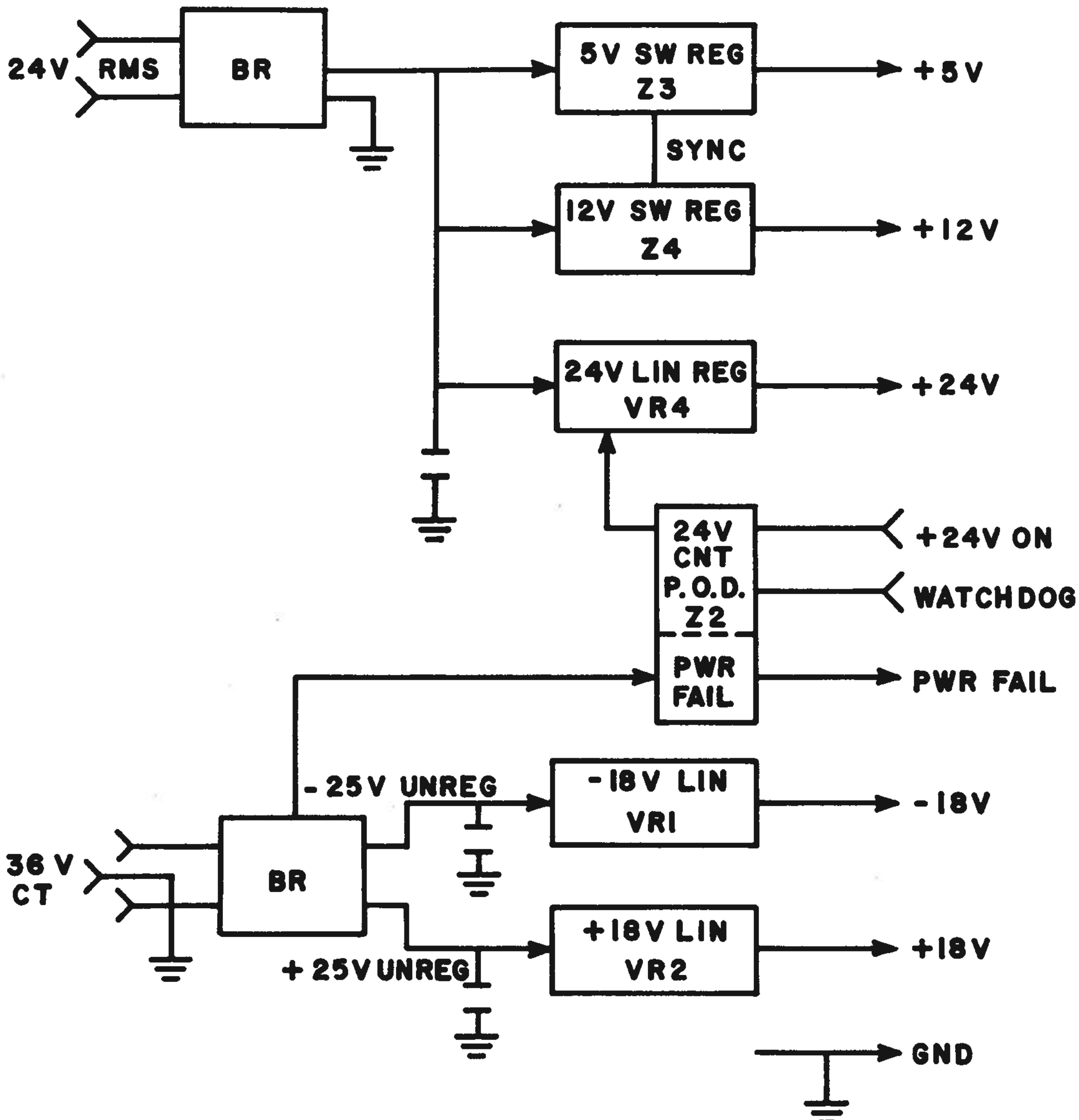


Figure 6.10 Power Supply

6.7 Deposition Control Board (753-332-G1)

The Deposition Control board contains the necessary circuitry to generate the analog control signals. These signals are sent to the deposition power supplies to control rate for two independent channels. Also contained on this board is measurement circuitry needed to accurately measure the crystal sensor period.

Programmable Counter Timer chip Z4 contains three independent counters. Counter 1 is used as a prescaler counter and generates the DAC Time Base signal (DTB), which is derived from the system clock. This DTB is then used to gate two other counters in Z4. Counters 2 and 3 generate a pulse width modulated signal, in which the ON time to OFF time ratio represents the digital value of the desired power control analog signal for channels 1 and 2 respectively. The PWM signals are filtered by RC networks and operational amplifier Z16 to produce a DC voltage proportional to the digital value. Both outputs are normally -10 volts full scale, unless shorting jumpers J1 and J2 are removed. The outputs are then -5 volts full scale. RC networks Z6-Z5 along with Zener diodes CR1 and CR2 provide transient voltage protection for the electronics.

The remote sensor oscillator is interfaced to the Deposition Control board through the BNC connector on the back panel. DC power is supplied through this connector as well as providing a means of sending the high frequency information to amplifier Z10. This is done by RF choke L1, which provides a DC path while being a high impedance for the high frequency. The sensor measurement starts with the positive going edge of the start measurement pulse which toggles the output of D flip-flop Z8-5 from low to high. This output is then used as the input to another D flip-flop. The next positive going edge of the active crystal signal toggles D flip-flop Z8-9 to provide a synchronized Gate signal. This gate signal is used to gate 2 counters in Programmable Counter Chip Z3 and counter Z7. These three counters serve as an accumulator for the measurement word. As long as the gate line is high, the high frequency reference clock (39.3216 MHz) is provided by oscillator Y1, is accumulated. The measurement gate time is set by the sensor operating frequency, prescaler Z9 and the prescaler in Timer chip Z3. When the prescaler in Z3 reaches its final count, its output Z3-10 goes low resetting D flip-flop Z8-5, 9 and the gate line which stops the accumulation of the reference clock. The processor then reads the measurement word through port Z2 and counters 1 and 2 in Timer chip Z3. The processor makes four sensor period measurements per second.

Adjustment of the Offset voltage is performed on this board. Before adjustment can be done, the GAIN must be set to 8 on the FILM display. Next, with the DATA display in the READY mode, monitor the RATE A/S for a reading of 0.0. Adjust R5 for the optimum reading of 0.0.

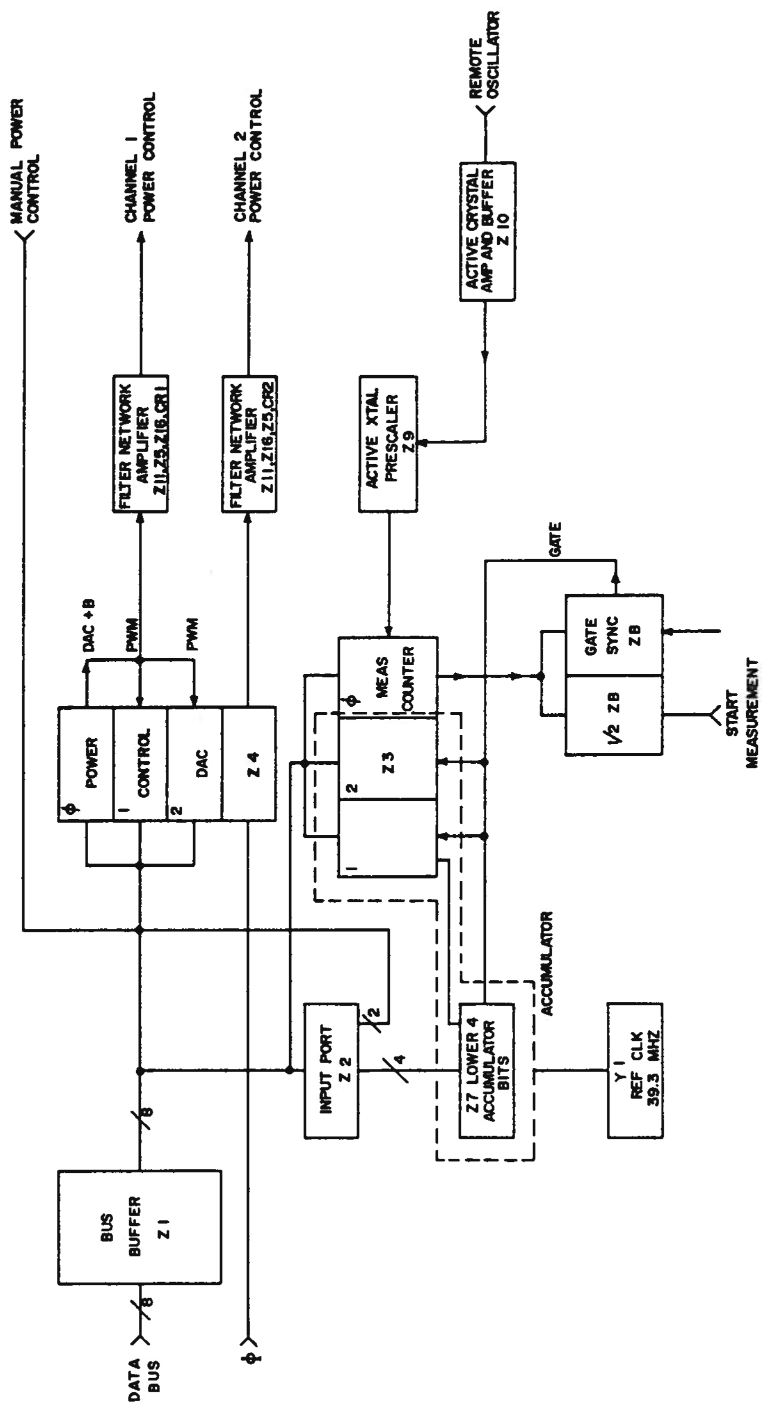


Figure 6.12 Deposition Control Board

6.8 System Control Board (753-342-G1)

The system control card has all the circuitry necessary to operate the sensor control unit (SCU). It also has three DACs that generate the analog recorder output for each of the three preamp channels.

Output port Z11 generates the Data Mux control signals, and the gain control lines for preamp channels 1 and 2. Output port Z15 generates the gain control signals for preamp channel 3, test signal control and the filter select codes for the optional Filter Changer. Input port Z19 monitors the status of the SCU. Port Z10 generates the WATCH DOG and the EMISS ON signals that control the +24 volts.

Buffer Z24 allows any needed offset adjustment of the Mux analog data from the preamp board. Sample and Hold Z23, upon command of the Hold line from Z10, holds the analog signal while 12 bit A/D converter Z22 makes the conversion. The processor then reads the 12 bit digital value from converter Z22.

Programmable Counter Timer chip Z1 provides three pulse Width Modulated (PWM) signals that correspond to the three preamp channels, in which the OFF time to ON time ratio represents a 12 bit digital value. These PWM signals are then filtered by RC networks Z5-Z8 and buffer Z6 to produce a DC value proportional to the digital value. All three converted signals are 10 volts full scale. The time base signal that is used to gate the three counters is derived from the system clock and 1/2 JK flip-flop Z3 and counter Z2. The other half of Z3 is used to provide the 500 Hz chopping signal for use by the modulator and demodulator circuitry. Z14 is a bus buffer. Z17 and Z9 provide the address and I/O decoding for the converters and I/O ports.

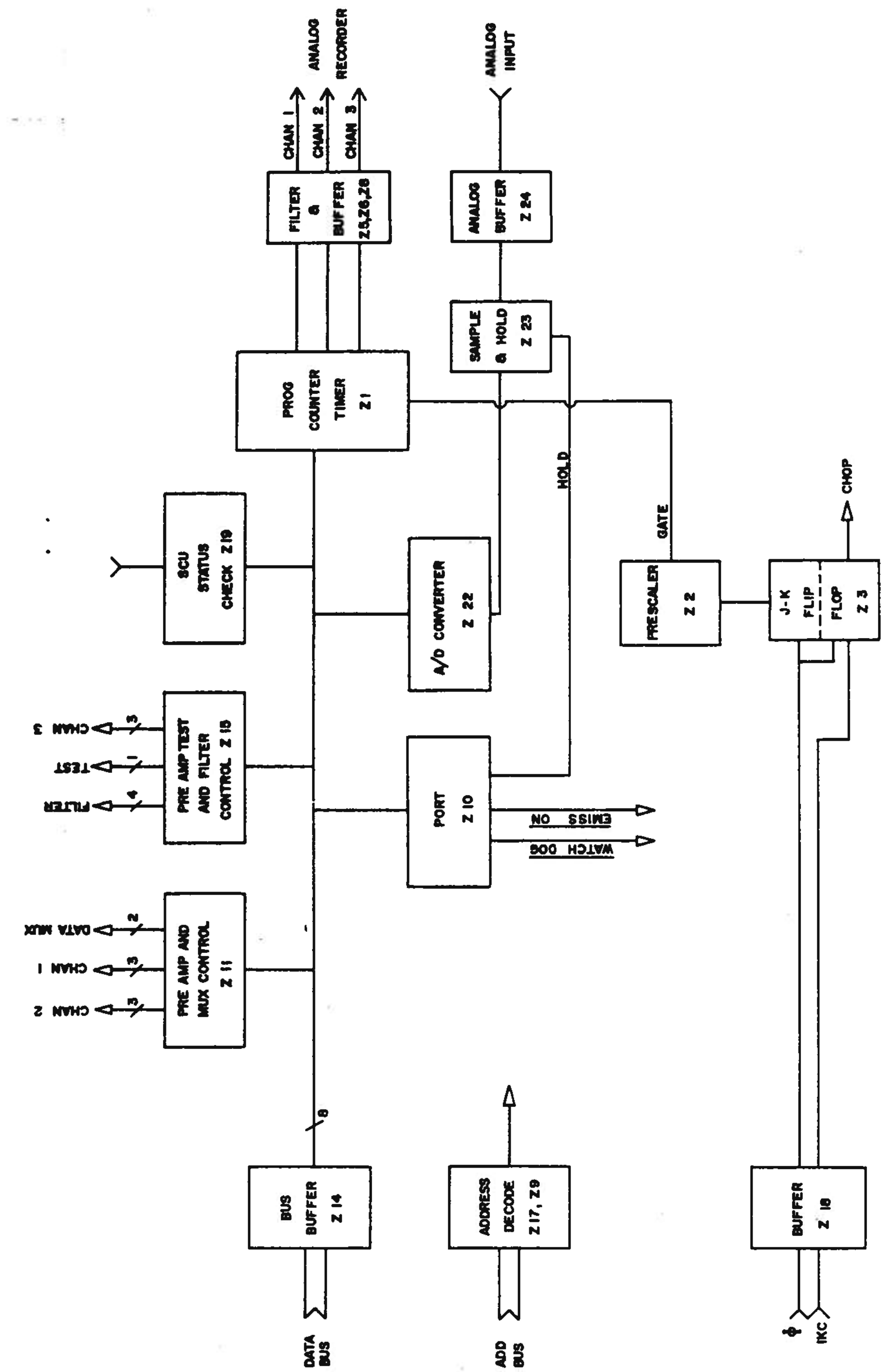


Figure 6.14 System Control Board

6.9 Preamps and Detectors Board (753-312-G1)

This board contains the circuitry needed to convert the low level optical signal into a measurable voltage and synchronously demodulate it into a dc level.

Low noise operational amplifiers Z7, Z16, and Z25 convert the input currents to voltages with a gain of .1 volt/uamp. Programmable state amplifiers Z6-Z5, Z15-Z14, and Z24-Z23, under selection of the System Control board, amplify the signals further with a gain of 1, 3.3, 10, 33, 100, 330, 1000 or 3300. Phase Lock Loop (PLL) Z1, driven by the 500 Hz along with the divide by 8 counter Z2, provide the synchronous sampling count rate (4MHz) required by the narrow bandpass Comb filter (Z4-Z3-Z8, Z12-Z13-Z10, Z22-Z21-Z17) for each of the three channels.

The modulated 500Hz signal is then synchronously demodulated into a dc signal via Z9-Z8, Z11-Z10, and Z18-Z17. Multiplexer Z20, under control of the system control board, then sends the requested channel data to buffer Z19.

The other half of buffer Z19 attenuates the 500Hz square wave signal to a usable voltage level test signal. Under control of the System Control board, this test signal is injected into the first stage of the programmable amplifiers for testing the circuitry.

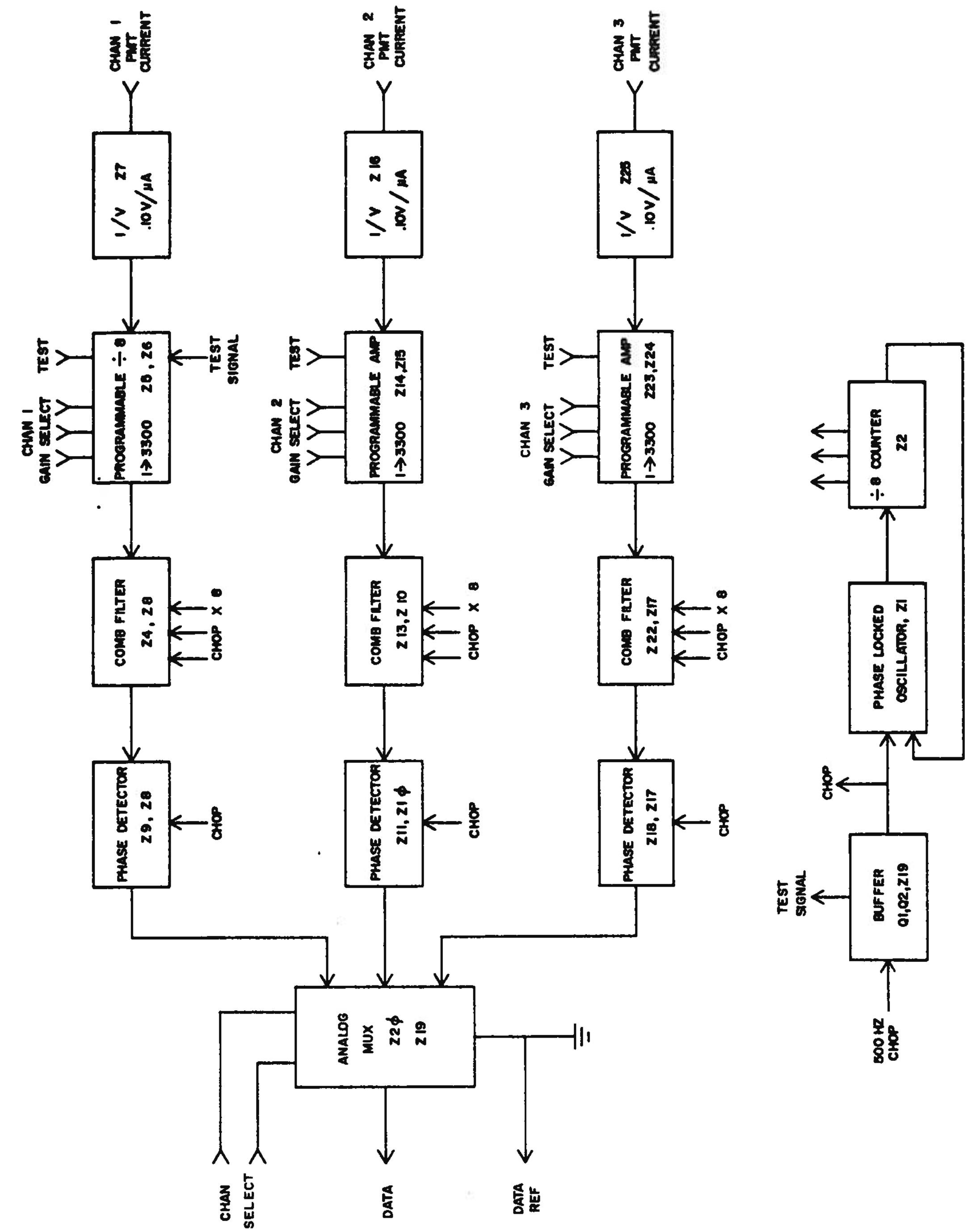


Figure 6.16 Preamps and Detectors Board

6.10 AE Sensor Regulator Board (753-322-G1)

This board contains the circuitry needed to independently drive two sensor heads. The requirements are q180 volts chopped at 500 Hz, (cathode bias), two filament supplies, and two emission regulators. The 750 VDC required by the photomultiplier tube (PMT) is also supplied by this board.

The 180 volts is a switching type supply that runs off the 24 volts. It consists of switching regulator Z11, drive transistors Q12 and Q13, and inductor T3. T3 provides isolation from ground and its dual secondary provides two isolated 180 volt supplies. Comparator Z13 provides feedback to switching regulated Z11. R79 provides for adjustment of the 180 VDC. Opto-isolator Z12 limits the maximum voltage. A bipolar modulator consisting of Q2-Q5, and Q6-Q1 for channel 1, and Q4, Q7, and Q8, Q3 for channel 2 driven by the buffered 500 Hz chopped signal from Z13, provides the q180 chop signal that is needed to turn the sensor head on and off.

During the conducting half of the cycle (-180 volts), a two phase sensitive discriminator (Z1, Z6 Pin 1 and Z1, Z5 Pin 1) measures the emission and leakage currents of the two sensors, across 100 ohm sensing resistors R3 and R4. During the non-conducting half of the cycle (+180 volts), just the leakage current is measured (Z6 Pin 14, Z6 Pin 2). These two signals are then summed at the inputs of the emission control integrators (Z6 Pin 6, Z5 Pin 6) along with an offset current. The emission current for both sensor drives is factory set at 4mA. For an emission current of 2mA at sensor drive 2, remove jumper J3 and connect jumper J4. For an emission current of 2mA at sensor drive 1, remove jumper J1 and connect jumper J2. The outputs of these two integrators are then fed back to the corresponding filament supply switching regulator (Z2 Pin 4 or Z7 Pin 4), to control the power to filament 1 and filament 2 respectively.

The filament supplies are switching supplies, driven by the +24 volts. The two supplies are identical supplies, consisting of a switching regulator (Z2, Z7), drive circuitry (Z3, Z8), and inductor (T1, T2). The isolated secondary of each of these inductors, is then referenced to the corresponding chopped q180 volts. The actual filament drive is app. 5 Vdc (pulsed at a frequency of 20KHz), capable of delivering 15 watts. Opto-isolator (Z4, Z9) limits the maximum filament voltage. Switch SW1 enables or disables the second filament supply (Sensor Drive 1). Comparator Z10 monitors the emission control and buffered leakage lines for errors.

The high voltage required by the PMT of the module is provided by the PS1 integrator Z13 Pin 14 and the drive transistors Q9 and Q10. The high voltage output is sampled by R76 and fed back to the input of the integrator. The integrator then increases or decreases the transistor drive accordingly to maintain the proper output voltage. Trim-pot R102 provides adjustment for the -750 volts.

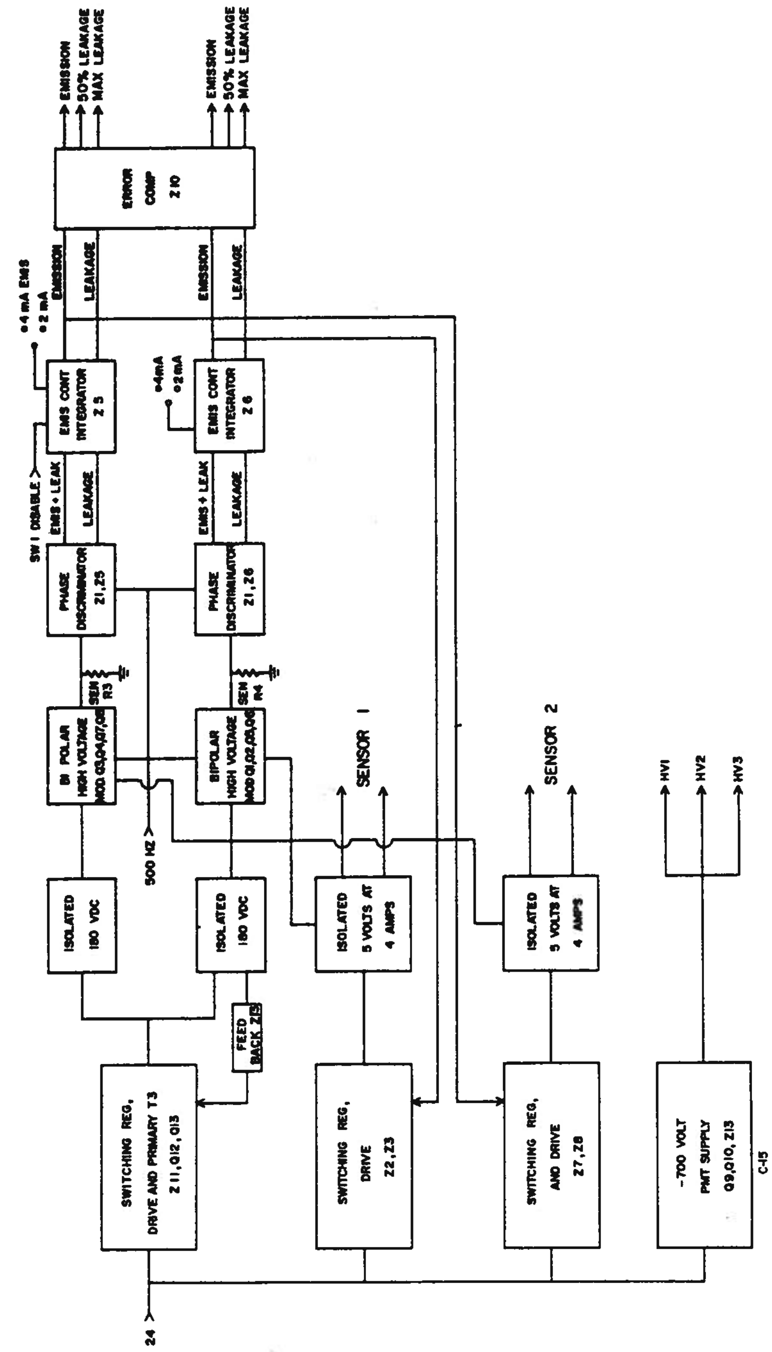


Figure 6.18 AE Sensor Regulator (753-322-G1)

6.11 IEEE 488 (017-432) (Optional)

The IEEE 488 board contains all the hardware necessary to interface a Sentinel III to the IEEE 488, 1975 communications bus as a Talker/Listener device. However, this module does not provide capabilities for it to be used as an IEEE 488 control device.

The Sentinel III 488 bus address is selected via the switches on the rear panel of the board. The IEEE 488 option and serial RS-232 software may be installed simultaneously. If this is done the IEEE 488 option disables the RS-232 computer communications capability. The device configuration switches on the back panel employ positive logic, which means that when in the off position, the Sentinel interprets a switch as a logical 1. Switches 1 through 5 determine the device address (0 to 30 may be selected). Switch 8 is the 488 enable.

The electronics consists of the following: Programmable I/O Z2 provides interrupt vectoring, and reads the device configuration switches (S1) on the back panel of the board. Z3 is a GPIB Talker/Listener, which provides communication control between the CPU and the 488 bus. Z4 and Z8 are GPIB Transceivers that provide proper voltage and timing during data transfers.

Z9 operates as a data bus transceiver, which effectively isolates the CPU and on board data buses. Z10, Z11, and Z12 are all buffers, with the first two for address lines and the last for control lines. Z5 provides I/O port decoding, while Z6 and Z7 handle interrupt and bus control timing.

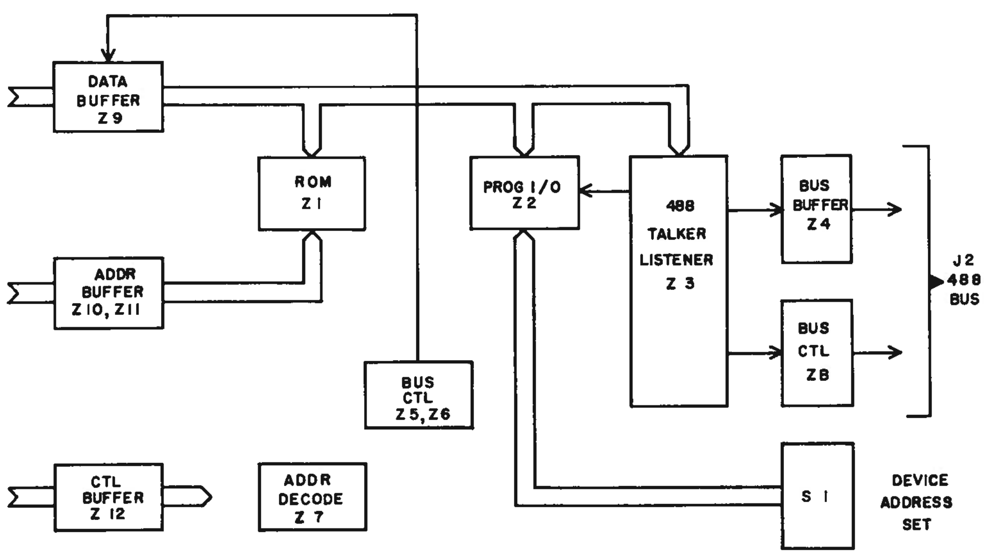


Figure 6.20 IEEE-488 Board

6.12 Filter Changer Controller Board (753-352) (Optional)

This board provides the drive and position control for two Filter Changers. Each channel has a comparator that verifies the desired filter position code, provided by the System Control board, with the actual position code from the Filter Changer. When these codes are not equal, the comparator output goes low triggering one shot Z3. These two signals are then connected via an NOR circuit (Z4) to produce a noise discriminator. This prevents false actuation of the changer due to switch bounce or noise. This buffered signal then drives the solid state relay in the filter changer. Each control channel has a position valid line that is monitored. When a new filter position is selected, this line must become valid after approximately 15 seconds, or a filter error is generated.

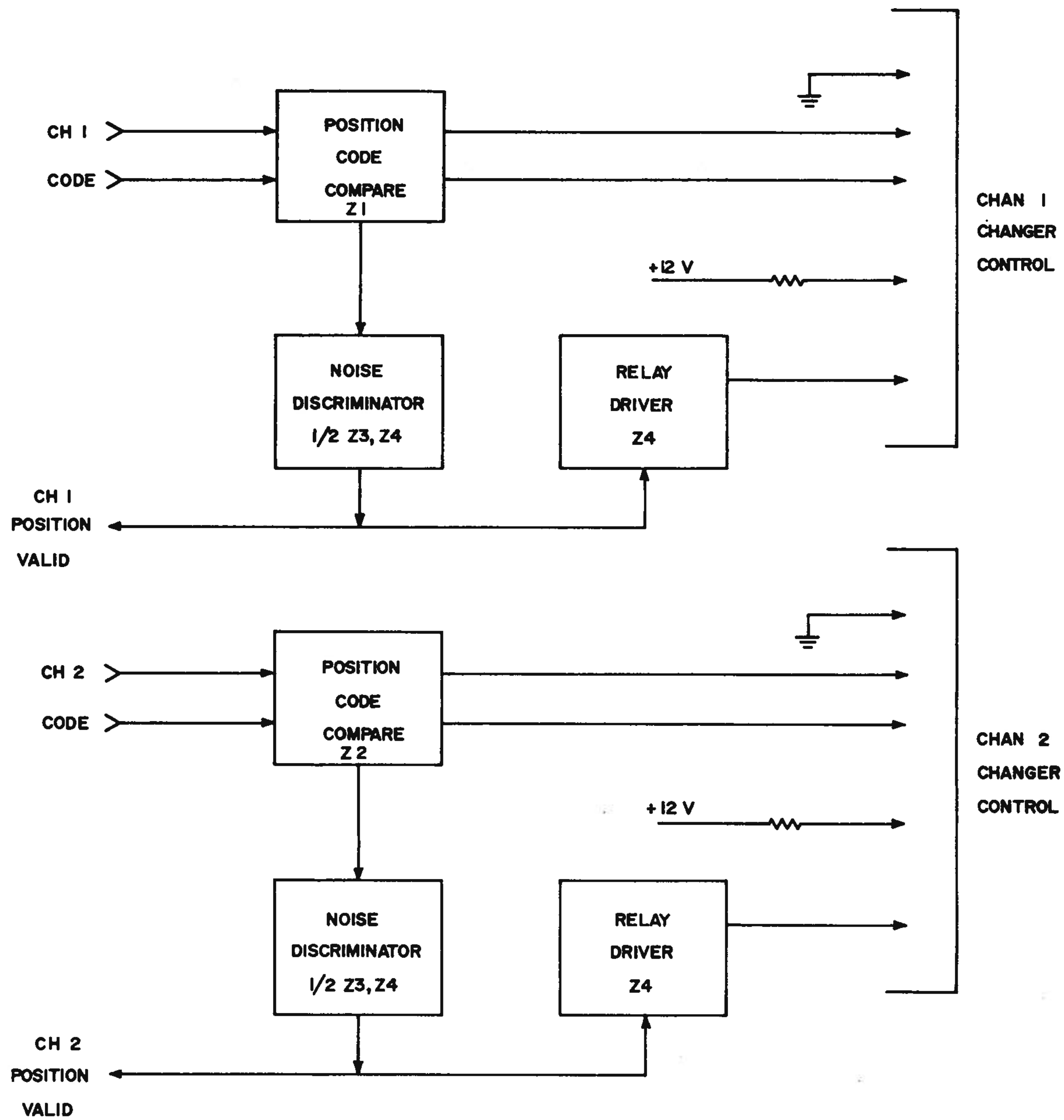


Figure 6.22 Filter Changer Board

7.0 COMMUNICATIONS

7.1 Communications Overview

Any function that can be done via front panel entry or remote input can be accomplished through the communications interface. This gives you total automation capabilities.

The communications for the Sentinel III consists of three types of interfaces; Semi Equipment Communications Standard (SECS), RS-232 and IEEE-488. Also included is an RS-232 interface for automatic data logging of process information. The IEEE-488 communications is optional.

The RS-232 and IEEE-488 interfaces both use the same language to communicate with an external computer. The difference lies in how they originate messages.

The SECS interface uses the languages as specified in the "1984 SEMI STANDARDS for EQUIPMENT" manual. The SECS interface should not be used unless you are familiar with this standard. Consult the SEMI standards book if you plan to use SECS.

Semiconductor Equipment and Materials Institute, Incorporated
625 Ellis Street
Mountain View, California 94043 U.S.A.

7.1.1 DEFINITION OF TERMS

Serial Communication

The individual bits of information that make up a command or data message are sent in series on a single wire. In an actual communications link between a host computer and the Sentinel III, at least three wires are used, more typically five, to provide two-way communication, a common ground, and preferably, some control signals.

Bits, Bytes, and Characters

The minimum unit of information in computers is called a bit (binary digit); a bit has one of two values, usually denoted as 0 and 1, are electrically distinguished as two voltage levels. A byte is a group of 8 bits normally handled as a unit. In the Sentinel III communication system, a byte represents one character, which is a letter, numeral, punctuation mark or control character.

Control Characters

In addition to letters, numerals and punctuation marks, the ASCII character set includes 32 codes that can be recognized by computer equipment for special purposes. Some of these are assigned as communications controls, such as indicating the end of messages. The control codes will be discussed in detail in the communications discussion sections.

Baud

The rate, in bits per second, at which information is sent is called the baud rate. In order for information to be receive correctly, the host computer and Sentinel III must operate at the same baud rate. A variety of commonly used baud rates are available. Selection of the desired rate is accomplished with internal switches located on the CPU board.

Start, Parity, and Stop Bits

The RS-232 Standard defines an asynchronous form of communication, in which characters are sent one at a time with no fixed interval. Since the group of 8 bits used to identify a character may start with a 1 or 0, the group is preceded by a start bit which is always 0 and followed by one or more stop bits which are always 1's. The transition from the 1 level to the 0 level signals the receiver that a character follows.

Handshaking

Handshaking is used to prevent the transmitting device from sending characters when the receiving device is "busy" and the message would not be received correctly. The Sentinel III supports software and hardware handshaking. Software handshaking is accomplished between the host computer and the Sentinel III by using the echo mode of operation and programming the host so that it does not send a character until the Sentinel III has responded (echoed) to indicate the preceding character has been received and processed. Hardware handshaking is accomplished with three additional wires by which the host computer and the Sentinel III signal that they are ready to receive the next character.

7.1.2 CONFIGURATION FOR SECS, RS-232, IEEE-488

To access the CPU board:

1. Remove the two screws in the upper corners of the rear panel so that the top of the Operator's Console can be removed by sliding it to the rear. Take the top completely off. (See Figure 7.1).

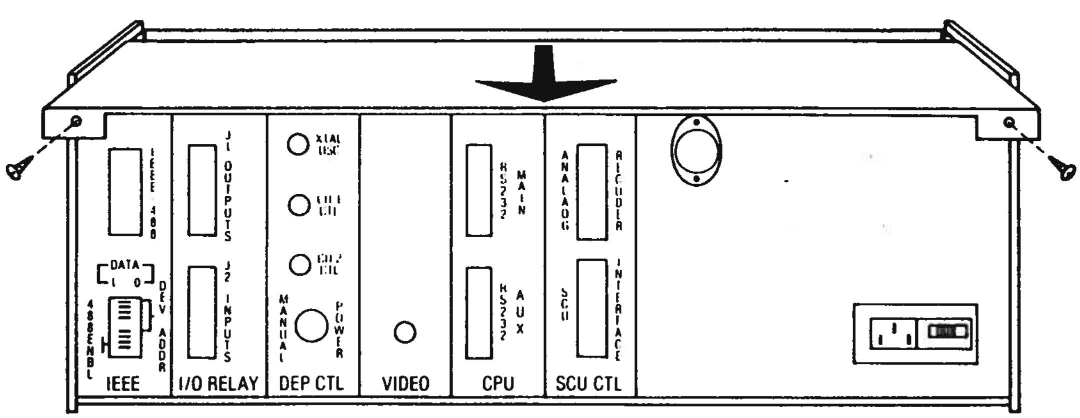


Figure 7.1 Operator's Console Cover

2. Remove the CPU board (No. 017-332) which is the long printed circuit board in the middle of the unit Figure 7.2). To remove this board, take out the three screws on the rear of the panel holding it in place - then lift the board straight out of its socket.

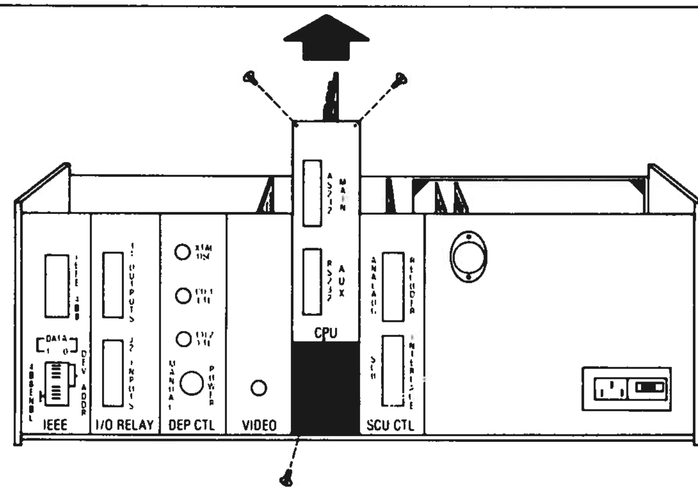


Figure 7.2 CPU Board Removal

3. To change the settings on the communications configuration switches, refer to Figure 7.3 for connection locations.

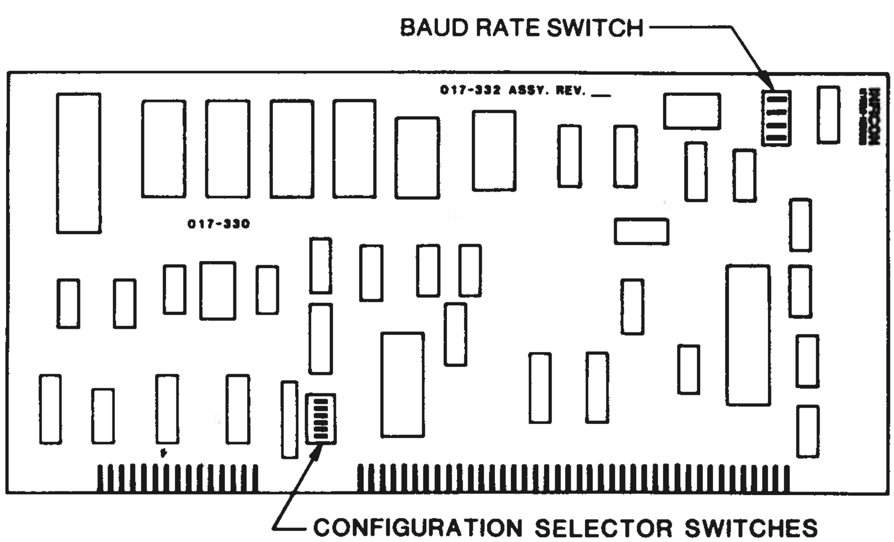


Figure 7.3 Configuration Selector Switch

Configuration of the communications is determined by switches 2 and 3 on the CPU board. Set switches as shown in Table 7.1.

Table 7.1 - Configuration

Switch 2	Switch 3	Configured
0=on	0=on	SECS
1=off	1=off	RS-232
0=on	0=on	IEEE-488[1,2]
1=off	1=off	RS-232

[1]Refer to section 7.1.6 ADDRESS SWITCH for enabling and disabling settings.

[2]If IEEE-488 board is installed

7.1.3 PORT TEST PROCEDURE

The Interface software includes an optional self-test procedure which may be used to check the RS-232 ports of the Sentinel III for basic operational status. Without following the procedure outlined, no self-test of the ports is carried out. It is recommended that the operator perform this procedure before interfacing the Sentinel III with a host computer, and any time thereafter when such troubleshooting is necessary.

The interface test consists of transmitting the message "SENTINEL III SELF TEST" to the RS-232 port. This message is checked and must be received within a set amount of time. The Test result then appears on the Sentinel III display screen.

Either of the two RS-232 ports, A or B (Main or Auxiliary, respectively) may be tested with this procedure:

1. Sentinel III Power off.

2. Connect the self-loop connector to the port to be tested. This connection is supplied with the Sentinel III.

3. The right and left cursor keys on the Sentinel III front panel are used in the test. The right cursor key is associated with Port B, or the Auxiliary RS-232 port. The left cursor key is associated with Port a, or the Main RS-232 port. Press and hold the appropriate cursor key and turn Sentinel III power on.

4. The following display will appear briefly on the Sentinel III screen:

```
                    INFICON VIDEO SYSTEM V.#


BEGIN COM TEST
```

5. A successful test of the port will be indicated by the message "A-PORT OK" or "B-PORT OK" in the lower left-hand corner of the screen, replacing the original message "BEGIN COM TEST."

6. An unsuccessful test of a given port will be indicated by the message "A-PORT FAIL" or "B-PORT FAIL" in the lower left-hand corner of the screen, replacing the original message "BEGIN COM TEST." If the "BEGIN COM TEST" message remains on the screen, the Sentinel III transmit enable line (CTS) is disabled, which is also an error condition. If any indication of failure is observed, contact the Inficon Service Department.

7.1.4 CONNECTIONS

The Sentinel III incorporates a standard 25 pin female connector for connection to the host computer, and is wired as a DTE (Data Terminal Equipment) device. Note that the CTS (Clear to Send) line must be driven to Binary 0 (positive voltage >3 volts and <15 volts) in order for the Sentinel III to transmit to the host. In a hardware handshaking system, the CTS line should be used by the host computer to control the activity of the Sentinel III transmitter. In a similar manner, the RTS (Request to Send) output from Sentinel III is intended to control the host transmitter. For successful hardware handshaking the transmitter of the host device must be controllable on a character-by-character basis.

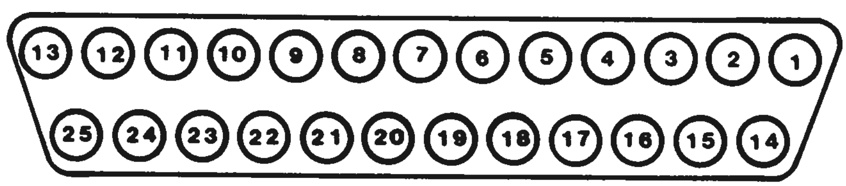


Figure 7.4 Pin Connection Diagram

7.1.5 RS-232C COMMUNICATIONS DISCUSSION

The RS-232C Interface provides a means of electronic communication with the Sentinel III. Using suitable equipment, the Sentinel III can be operated from a remote location, controlled without operator intervention and integrated into computer controlled instrumentation systems. Data from the Sentinel III can also be acquired, manipulated and stored by computer equipment.

When communicating with an external device through the RS-232 interface, the external device is required to assume the role of the "host" and the Sentinel III acts as the "peripheral" device. The host issues commands to the Sentinel III to change mode or to respond with data to be read by the host. The host device will normally be a computer which has been programmed to issue suitable commands to the Sentinel III.

SECTION 7
COMMUNICATIONS

Every command sent from the host to the Sentinel III must be terminated with an ASCII (ACK). This is an indication to the Sentinel III that this is the end of the present command and to being interpreting that command. ACK is the Control F(^F) character and is usually suppressed from the display.

Upon successful completion of the current command, the Sentinel III will return data if the current command includes a request for data plus an ASCII (ACK). The (ACK) is an indication to the host computer that the command transmitted to the Sentinel III was completed successfully and the data preceding it, if any, is the data the host computer requested.

NACK is the Control U (^U) character and is usually suppressed from the display. If an ASCII (NACK) is received this is an indication to the host computer that the command it just transmitted is somehow in error. The ASCII character preceding the (NACK) is the error code indicating the type of error that occurred (see the Error code listing in Section 7.3.3).

From the time the (ACK) is received by the Sentinel III until the (ACK/NACK) is received by the host computer, any data that the Sentinel III receives will be read but will not be stored or acted upon in any way. No indication or response is sent to the host computer that this has occurred.

Below is a typical communications sequence:

1 - Sentinel III is running - There are no messages being handled.

2 - Host originates a command message - The host sends a character by character message followed by an ACKnowledge (^F) to the Sentinel III.

3 - The command is then processed and the resultant data (if any) is sent to the host one character at a time. The command is then terminated by an ACKnowledge (^F) or,

4 - If the command message is invalid, the Sentinel III sends an NACK (^U not acknowledge) to the host. Preceded by an error code.

7.1.6 IEEE-488 COMMUNICATIONS DISCUSSION

The IEEE-488 Interface provides the capability for a variety of devices to communicate with each other and to share the resources of a single bus.

This means that the entire system can share one printer or one computer instead of each instrument having a computer and printer dedicated specifically for its use alone.

In the IEEE-488 Communications discussion the "Computer" will be referred to as the Controller since all communications in IEEE-488 systems are handled by one main Controller (computer).

Every command sent from the Controller to the Sentinel III must be terminated with the ASCII (ACK). This is an indication to the Sentinel III that this is the end of the present command and to begin interpreting that command. The controller has the option of asserting the EOI line on transmission of the (ACK), since the Sentinel III checks each received character for the (ACK). ACK is often the control F (^F) character and is usually suppressed from the display.

Upon successful completion of the current command the Sentinel III will return any data, if the current command includes a request for data, plus an ASCII (ACK). The (ACK) is an indication to the Controller computer that the command it just transmitted to the Sentinel III was completed successfully and the data preceding it, if any, is the data the Controller computer requested.

If an ASCII (NACK) is received this is an indication to the Controller computer that the command it just transmitted is in error. The ASCII character preceding the (NACK) is the error code indicating the type of error that occurred. NACK is often the U (^U) character and is usually suppressed from the display.

Upon transmission of either the (ACK) or (NACK), the Sentinel III also asserts the EOI line.

From the time the (ACK) is received by the Sentinel III until the (ACK/NACK) is received by the Controller computer, any data that the Sentinel III receives will be read but will not be stored or acted upon in any way. No indication or response is sent to the Controller computer that this has occurred.

ADDRESS SWITCH

An eight segment switch is located on the IEEE-488 Module rear panel. This switch sets the Sentinel III bus address. Switches 1 through 5 are used to select an address of 0 to 30. Switches 6 and 7 are not used. Switch 8, when set t0 (1) enables IEEE-488 communications; when set to (0) it disables IEEE-488 communications. [Settings on CPU board must also be set as shown in Table 7.1.]

Address selection is as follows: 1 = On
0 = Off

Address	Switch Numbers #54321	Address	Switch Numbers #54321
0	00000	16	10000
1	00001	17	10001
2	00010	18	10010
3	00011	19	10011
4	00100	20	10100
5	00101	21	10101
6	00110	22	10110
7	00111	23	10111
8	01000	24	11000
9	01001	25	11001
10	01010	26	11010
11	01011	27	11011
12	01100	28	11100
13	01101	29	11101
14	01110	30	11110
15	01111		

The IEEE-488 Module connector is shown below along with associated pin information.

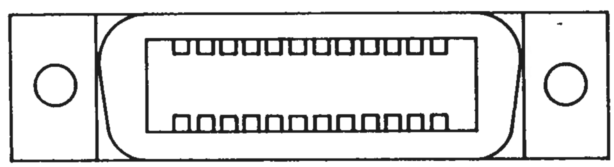


Figure 7.5 IEEE-488 Interface Module Connector

7.2 Interface Connections

7.2.1 AUTOMATIC DATA LOGGING INTERFACE CONNECTION

The AUX PORT uses an RS-232 interface to provide data logging to an external printer.

The AUX PORT is fixed at 2400 baud and implements hardware handshaking to guarantee data transfer. If no hardware handshaking is required simply connect pins 5 and 20 of the AUX PORT together. The AUX PORT DATA LOGGING equipment constant (Communications Menu) must be set to YES in order to enable automatic data logging. If no data logging is wanted, or in the data logging port is not connected, then the AUX PORT DATA LOGGING equipment constant must be set to NO. Failure to do this will cause the AUX PORT DATA LOGGING to prevent the MAIN COMMUNICATIONS from originating PROCESS DONE messages and the new process information will not be saved.

Example of data log dump:

" START RUN #0001 "
PROCESS 1

FILM #1
RATE=+0040.0 Å/s
THICK=+0000250 Å
TIME= 00:07 min:s
AVG POWER= 00%

"END RUN #0001 "

<u>Sentinel III Pin Descriptions for Aux Port</u>

2 - Transmit data; data sent form the Sentinel III.
5 - Clear to send; input low to Sentinel III enables transmitter.
7 - Signal ground; common between user and Sentinel III.
20 - Data terminal ready; output logic low when Sentinel III is turned on.

7.2.2 RS-232 AND SECS INTERFACE CONNECTIONS

The RS-232 interface implements hardware handshaking to guarantee data transfer. If no hardware handshaking is required, simply connect pins 5, 8 and 20 of the main part together. The SECS interface does not use pins 5 and 8 (no hardware handshaking). The baud rate is programmable by internal DIP switches on the CPU board in the range from 150 to 19,200 baud. The character word consists of one start bit, eight data bits and one stop bit. No parity bit is implemented.

Pin 1 (shield ground), pin 18 (+12 to +15 volts) and pin 25 (-12 to -15 volts) are not implemented by this connection.

<u>Sentinel III Pin Descriptions for Main Port</u>

2 - Transmit data; data sent form the Sentinel III.
3 - Receive data; data received by Sentinel III.
4 - Request to send; output logic low when Sentinel III's receive is empty.
5 - Clear to send; input low to Sentinel III enables transmitter.
7 - Signal ground; common between user and Sentinel III.
8 - Data carrier detect; input low to Sentinel III enables receiver.
20 - Data terminal ready; output logic low when Sentinel III is turned on.

7.3 RS-232 and IEEE-488

7.3.1 RS-232 AND IEEE-488 - DEFINITION OF TERMS

All names between < > signify an ASCII code used in messages. All names between () signify ASCII numbers used as ID's, values or command codes.

<ACK> -	ASCII code 06 hex, 06 decimal.
<NAK> -	ASCII code 15 hex, 21 decimal.
<CTL-X> -	ASCII code 18 hex, 24 decimal.
<SPACE> -	ASCII code 20 hex, 32 decimal.
(SVID) -	Status variable ID, defined towards end of manual.
(ECID) -	Equipment constant ID, defined towards end of manual.
(VALUE) -	New equipment constant value. Same format as that sent by Equipment Constant Request command. The format for values are described in ECID section.
(RCMD) -	Remote command codes, defined towards end of manual.

7.3.2 RS-232 AND IEEE-488 COMMANDS

The first character of each command is an ASCII character. The last character sent <ACK> tells the Sentinel III to interpret the command and act accordingly. There may also be ID's or VALUE's associated with certain commands. These are sent after the command character and before the <ACK>. Below is a description of each command. If the command you send has an error in it, the Sentinel III will respond with a negative response. These are defined after the communications commands.

H<ACK> ARE YOU THERE?
This command tells the host what the equipment model is and its version #.

S(SVID)<ACK> SELECTED EQUIPMENT STATUS SEND
This command is used to request status information from the equipment.

Q(ECID)<ACK> EQUIPMENT CONSTANT REQUEST
This command is used to request equipment constant values from the equipment.

P(ECID)<SPACE>(VALUE)<ACK> EQUIPMENT CONSTANT SEND
This command is used to change equipment constant VALUEs in the equipment. All equipment constant VALUEs are sent as ASCII items with the same format as the EQUIPMENT CONSTANT REQUEST command sends. The exception begin string type equipment constant ID's that must be less than or equal to their maximum length which is specified in the ECID section. To nul out a string type equipment constant send P(ECID)<SPACE><ACK>. The range of the VALUes are given in Section 2.3.

R(RCMD)<ACK> REMOTE COMMAND SEND
This command is used to do remote key events or remote inputs.

K(44 BYTE BINARY STRING)<ACK> LOOPBACK BINARY STRING
This command echoes back the same binary information it received. Used for testing interface.

T(0-36 ASCII CHARACTERS)<ACK> TERMINAL DISPLAY
This command is used to send a message to the equipment which is displayed in the COMMUNICATIONS display. To erase the message send T<ACK>.

<CTL-X> ABORT
This command aborts a command if the <ACK> hasn't been sent yet. There is no response from an ABORT command.

7.3.3 RS-232 AND IEEE-488 NEGATIVE RESPONSES

Negative responses will result if the command sent has one of the errors listed below.

A<NAK> ILLEGAL COMMAND

B<NAK> ILLEGAL VALUE

C<NAK> ILLEGAL ID

D<NAK>	ILLEGAL COMMAND FORMAT
E<NAK>	NO DATA TO RETRIEVE
F<NAK>	CAN NOT CHANGE VALUE NOW

7.3.4 RS-232 AND IEEE-488 ORIGINATED MESSAGES

These commands will only be sent if the MAIN COMMUNICATIONS ORIGINATE ECID is set to YES. If the IEEE-488 communications is selected then the alarm codes below will be the service request codes. If the PROCESS DONE originated message is sent by the Sentinel III the new process information will overwrite any older process information.

U<ACK>	PROCESS DONE (When this is received, do command S04<ACK> to retrieve process information.)
V<ACK>	EQUIPMENT STOPPED
W<ACK>	PROCESS STARTED or RE-STARTED after a STOP.

7.4 Semiconductor Equipment Communications Standard (SECS)

7.4.1 SECS GENERAL INFORMATION

Manufacturer - Leybold Inficon Inc.

Product # - Sentinel III (SNTIII)

Equipment Function - Dual channel thin film deposition controller/ monitor

Interface Function - Interface used to gather information or for automated control of the instrument.

Software Revision Code - Version number 2

Changes from Previous Levels - No changes because this is first version of instrument.

7.4.2 SECS MESSAGES

a. STREAM 1: EQUIPMENT STATUS

S1, F0	ABORT TRANSACTION (S1F0) This command does nothing.
S1, F1	ARE YOU THERE REQUEST (R) This is used to establish whether the equipment is on-line.

S1, F2 — ON LINE DATA (D)
This is the response to indicate that the equipment is on-line.

S1, F3 — SELECTED EQUIPMENT STATUS REQUEST (SSR)
This command is used to read status variables from the equipment.

S1, F4 — SELECTED EQUIPMENT STATUS DATA (SSD)
The equipment reports the value of the status variable requested.

b. STREAM 2: EQUIPMENT CONTROL AND DIAGNOSTICS

S2, F10 — ABORT TRANSACTION (S2F0)
This command does nothing

S2, F13 — EQUIPMENT CONSTANT REQUEST (ECR)
This command is used to read equipment constants from the equipment.

S2, F14 — EQUIPMENT CONSTANT DATA (ECD)
The equipment sends the value for the equipment constant requested.

S2, F15 — EQUIPMENT CONSTANT SEND (ECS)
This command is used to change equipment constants in the equipment.

S2, F16 — EQUIPMENT CONSTANT ACKNOWLEDGE (ECA)
Acknowledge equipment constant change or error.

S2, F21 — REMOTE COMMAND SEND (RCS)
Used to perform an activity like key events or remote inputs.

S2, F22 — REMOTE COMMAND ACKNOWLEDGE (RCA)
Acknowledge remote command or error.

S2, F25 — LOOPBACK DIAGNOSTIC REQUEST (LDR)
The binary string sent to the equipment is echoed back.

S2, F26 — LOOPBACK DIAGNOSTIC DATA (LDD)
The echoed binary string.

c. STREAM 5: EXCEPTION REPORTING

S5, F0 — ABORT TRANSACTION (S5F0)
This command does nothing

S5, F1 — ALARM REPORT SEND (ARS)
This message reports a change in equipment status to the host.

S5, F2 — ALARM REPORT ACKNOWLEDGE (ARA)
This command does nothing.

d. STREAM 9: SYSTEM ERRORS

S9, F0 — ABORT TRANSACTION (S9F0)
This command does nothing

S9, F1 — UNRECOGNIZED DEVICE ID (UDN)
This message to the host indicates the device ID in the message block header did not match equipment's device ID.

S9, F3 — UNRECOGNIZED STREAM TYPE (USN)
This message to the host indicates the equipment does not recognize the stream type in the message block header.

S9, F5 — UNRECOGNIZED FUNCTION TYPE (UFN)
This message to the host indicates the equipment does not recognize the function type in the message block header.

S9, F7 — ILLEGAL DATA (IDN)
This message to the host indicates that the stream and function were recognized but the associated data format could not be interpreted.

S9, F11 — DATA TOO LONG (DLN)
This message to the host indicates the equipment has been sent more data than it can handle. The message being received has been aborted.

e. STREAM 10: TERMINAL SERVICES

S10, F0 — ABORT TRANSACTION (S10F0)
This command does nothing.

S10, F9 — BROADCAST (BCN)
This command is used by the host to send a message to an operator at the equipment.

7.4.3 SECS MESSAGE SUMMARY - DIRECTION OF MESSAGE

a. STREAM 1: EQUIPMENT STATUS - DIRECTION OF MESSAGE

HOST	EQUIPMENT	EQUIPMENT	HOST
Send	Respond	Send	Respond
S1, F0 >	—		
S1, F1 >	< S1, F2		
S1, F3 >	< S1, F4		

b. STREAM 2: EQUIPMENT CONTROL AND DIAGNOSTICS - DIRECTION OF MESSAGE

HOST	EQUIPMENT	EQUIPMENT	HOST
Send	Respond	Send	Respond
S2, F10 >	—		
S2, F13 >	< S2, F14		
S2, F15 >	< S2, F16		
S2, F21 >	< S2, F22		
S2, F25 >	< S2, F26		

c. STREAM 5: EXCEPTION REPORTING - DIRECTION OF MESSAGE

HOST	EQUIPMENT	EQUIPMENT	HOST
Send	Respond	Send	Respond
S5, F0 >	—		
		S5, F1 >	< S5, F2

d. STREAM 9: SYSTEM ERRORS - DIRECTION OF MESSAGE

HOST	EQUIPMENT	EQUIPMENT	HOST
Send	Respond	Send	Respond
S9, F0 >	—		
		S9, F1 >	—
		S9, F3 >	—
		S9, F5 >	—
		S9, F7 >	—
		S9, F11 >	—

e. STREAM 10: TERMINAL SERVICES - DIRECTION OF MESSAGE

HOST	EQUIPMENT	EQUIPMENT	HOST
Send S10, F9 >	Respond —	Send	Respond

7.4.4 SECS MESSAGE DETAIL

a. STREAM 1: EQUIPMENT STATUS

HOST QUERY: S1, F0 — ABORT TRANSACTION (S1F0)
This command does nothing.

RESPONSE: — None expected.

HOST QUERY: S1, F1 — ARE YOU THERE REQUEST (R)
This command is used to establish whether the equipment is on-line.

RESPONSE: — No response within host timeout:
Line is disconnected.
Power off.

S1, F2 — ON LINE DATA (D)
Equipment is on-line.
Data sent: a list of 2 ASCII items
Model name: SNTIII (6 ASCII bytes)
Version #: 00 (2 ASCII bytes)

HOST QUERY: S1, F3 — SELECTED EQUIPMENT STATUS REQUEST (SSR)
A request to the equipment to report selected values of its status. All status variable ID's are ASCII items of 2 bytes. Only 1 status variable ID per message. A zero length ASCII item sent will respond with a zero length list.

RESPONSE: S1, F4 — SELECTED EQUIPMENT STATUS DATA (SSD)
The equipment reports the value of the status variable requested.
All values are sent as ASCII items.
A zero length list means no response can be made.
A zero length ASCII item means that status variable ID does not exist.

b. STREAM 2: EQUIPMENT CONTROL AND DIAGNOSTICS

HOST QUERY:	S2, F0	ABORT TRANSACTION (S2F0) This command does nothing.
RESPONSE:		None expected.
HOST QUERY:	S2, F13	EQUIPMENT CONSTANT REQUEST (ECR) This command reads all the equipment constant values from the equipment. All equipment constant ID's are ASCII items of 4 bytes. Only 1 equipment constant ID per message. A zero length ASCII item will respond with a zero length list.
RESPONSE:	S2, F14	EQUIPMENT CONSTANT DATA (ECD) The equipment reports the value of the equipment constants requested. All values are sent as ASCII items. A zero length list means no response can be made. A zero length ASCII items means that status ID does not exist.
HOST QUERY:	S2, F15	EQUIPMENT CONSTANT SEND (ECS) This command is used to change equipment constant values in the equipment. All equipment constant ID's are ASCII items of 4 bytes. Only 1 equipment constant change per message. All equipment constant values are sent as ASCII items with the same format as the S2, F14 message. The exception being string type equipment constant ID's that must be less than or equal to their maximum length which is specified in the ECID section. To nul out a string type equipment constant send a zero length for the equipment constant value. The range of the values are given in Section 2.
RESPONSE:	S2, F16	EQUIPMENT CONSTANT ACKNOWLEDGE (ECA) Acknowledge equipment constant change or error. Acknowledge code: binary item of 1 byte 0 - Acknowledge. 1 - Constant does not exist. 2 - Cannot change constant now. 64 - Bad equipment constant value.
HOST QUERY:	S2, F21	REMOTE COMMAND SEND (RCS) This command is used to perform an activity like key events and remote inputs. Remote command codes are ASCII items 2 characters long. Only 1 remote command code per message.
RESPONSE:	S2, F22	REMOTE COMMAND ACKNOWLEDGE (RCA) Acknowledge remote command or error. Acknowledge code: 1-byte integer (unsigned) 0 - Completed or done. 1 - Command does not exist.

HOST QUERY:	S2, F25	LOOPBACK DIAGNOSTIC REQUEST (LDR) The binary string sent to the equipment is echoed back to the host. Binary string's maximum length is 44.
RESPONSE:	S2, F26	LOOPBACK DIAGNOSTIC DATA (LDD) The binary string received S2, F25 is echoed back.

c. STREAM 5: EXCEPTION REPORTING

HOST QUERY:	S5, F0	ABORT TRANSACTION (S5F0) This command does nothing.
RESPONSE:		None expected.
EQUIP. QUERY:	S5, F1	ALARM REPORT SEND (ARS) This message reports a change in equipment status such as PROCESS STARTED, STOP or PROCESS DONE. If the ALID is PROCESS DONE (55H), an (S1F3) with SVID equal to 04 must be sent to retrieve the process information. If this is not sent, then newer process information will overwrite the older process information.
RESPONSE:	S5, F2	ALARM REPORT ACKNOWLEDGE (ARA) This command does nothing.

d. STREAM 9: SYSTEM ERRORS

HOST QUERY:	S9, F0	ABORT TRANSACTION (S9F0) This command does nothing.
RESPONSE:		None expected.
EQUIP. QUERY:	S9, F1	UNRECOGNIZED DEVICE ID (UDN) This message to the host indicates that the device ID in the message block header did not match equipment's device ID.
RESPONSE:		None expected.
EQUIP. QUERY:	S9, F3	UNRECOGNIZED STREAM TYPE (USN) This message to the host indicates that the equipment does not recognize the stream type in the message block header.
RESPONSE:		None expected.
EQUIP. QUERY:	S9, F5	UNRECOGNIZED FUNCTION TYPE (UFN) This message to the host indicates that the equipment does not recognize the function type in the message block header.
RESPONSE:		None expected.

EQUIP. QUERY:	S9, F7	ILLEGAL DATA (IDN) This message to the host indicates that the stream and function were recognized but the associated data format could not be interpreted.
RESPONSE:		None expected.
EQUIP. QUERY:	S9, F11	DATA TOO LONG (DLN) This message to the host indicates that the equipment has been sent more data than it can handle. The message being received has been aborted. Maximum message length including lists and items excluding the header is 44 bytes.
RESPONSE:		None expected.

e. STREAM 10: TERMINAL SERVICES

HOST QUERY:	S10, F0	ABORT TRANSACTION (S10F0) This command does nothing
RESPONSE:		None expected.
HOST QUERY:	S10, F9	BROADCAST (BCN) This command is used by the host to send a message to an operator at the equipment. The host sends an ASCII item up to 36 characters long. Valid characters are from 20Hex to 5FHex. An ASCII '+' is replaced by an 'Å'. 5EHex is an up arrow symbol and 5FHex is a down arrow symbol. All invalid ASCII characters are replaced by an ASCII space. To erase the message send an ASCII item of zero length.
RESPONSE:		None expected.

7.5 Communications ID's and Codes

7.5.1 EQUIPMENT CONSTANT ID'S (ECID)

All equipment constant ID's are 4 ASCII digits long; the first digit is for films 1 through 6 or 0 for non-film constant. Below is a list of specific equipment constant ID's for each display. Along with the ECID's are the formats or values of each ECID given as an example. When changing values, the same number of digits given in the example must be sent along with decimal point and colon information. The range of the VALUEs are given in Section 2.3.

a. DATA DISPLAY EQUIPMENT CONSTANT ID'S

104 = PLOT DWELL 1	Ex. = 12
105 = PLOT DWELL 2	Ex. = 12
108 = PROCESS BUFFER "STRING TYPE, 32 CHARACTERS MAX"	
132 = RATE DEVIATION NUMBER, CHANNEL 1	Ex. = 1
133 = RATE DEVIATION NUMBER, CHANNEL 2	Ex. = 1

b. <u>FILM DISPLAY EQUIPMENT CONSTANTS ID'S</u>

099 = FILM # (1ST DIGIT IS 0)	Ex. = 1
064 = SOAK 1 POWER SET POINT	Ex. = 12
065 = RISE 1 TIME	Ex. = 12:34
066 = SOAK 1 TIME	Ex. = 12:34
067 = SOAK 2 POWER SET POINT	Ex. = 12
068 = RISE 2 TIME	Ex. = 12:34
069 = SOAK 2 TIME	Ex. = 12:34
070 = RATE RAMP TIME	Ex. = 12:34
071 = RATE BEGIN	Ex. = 123.4
072 = RATE NEW	Ex. = 123.4
073 = FALL TIME	Ex. = 12:34
074 = IDLE POWER	Ex. = 12
075 = MAX POWER LIMIT	Ex. = 12
076 = CONTROL DAMP	Ex. = 12
077 = CONTROL GAIN	Ex. = 12
078 = FINAL THICKNESS LIMIT	Ex. = 123.456
079 = SETPOINT THICKNESS LIMIT	Ex. = 123.456
080 = RATIO	Ex. = 123.4
081 = SHUTTER DELAY	Ex. = 1
082 = STOP ON MAX POWER	Ex. = 1
083 = CHANNEL #	Ex. = 1
084 = SETPOINT TIMER	Ex. = 12:34
085 = SETPOINT RAMP	Ex. = 123.456
086 = FILTER NUMBER	Ex. = 1
087 = COMPLETE ON TIME POWER	Ex. = 1
088 = AUTO CALIBRATION ON START	Ex. = 1
089 = CALIBRATION INTERVAL	Ex. = 123
090 = CALIBRATION ACCURACY	Ex. = 12
091 = XTAL Z-RATIO	Ex. = 1.234
092 = XTAL DENSITY	Ex. = 12.34
093 = XTAL TOOLING	Ex. = 123
098 = XTAL MEASUREMENT	Ex. = 1

c. <u>FILM DISPLAY AND MONITOR DISPLAY EQUIPMENT CONSTANT ID'S</u>

094 = PMT RANGE	Ex. = 1
095 = PMT CALIBRATION	Ex. = 1.234
096 = CROSS SENSITIVITY CHANNEL 1	Ex. = 12.3
097 = CROSS SENSITIVITY CHANNEL 2	Ex. = 12.3

d. EXECUTIVE DISPLAY EQUIPMENT CONSTANT ID'S

101 = ACTIVE PROCESS	Ex. = 1
102 = POSITION TO START	Ex. = 12
103 = RUN NUMBER SET	Ex. = 1234
106 = PROCESS BUFFER 1 "STRING TYPE, 32 CHARACTERS MAX"	
107 = PROCESS BUFFER 2 "STRING TYPE, 32 CHARACTERS MAX"	
109 = XTAL DISABLE FLAG	Ex. = 1
110 = TEST ON	Ex. = 1
111 = TEST TIME COMPRESSED	Ex. = 1
112 = FINAL THICKNESS OVERRIDE 0 (PROCESS 1)	Ex. = 123.456
113 = FINAL THICKNESS OVERRIDE 1 (PROCESS 1)	Ex. = 123.456
114 = FINAL THICKNESS OVERRIDE 2 (PROCESS 1)	Ex. = 123.456
115 = FINAL THICKNESS OVERRIDE 3 (PROCESS 1)	Ex. = 123.456
116 = FINAL THICKNESS OVERRIDE 4 (PROCESS 1)	Ex. = 123.456
117 = FINAL THICKNESS OVERRIDE 5 (PROCESS 1)	Ex. = 123.456
118 = FINAL THICKNESS OVERRIDE 6 (PROCESS 1)	Ex. = 123.456
119 = FINAL THICKNESS OVERRIDE 7 (PROCESS 1)	Ex. = 123.456
120 = FINAL THICKNESS OVERRIDE 8 (PROCESS 1)	Ex. = 123.456
121 = FINAL THICKNESS OVERRIDE 9 (PROCESS 1)	Ex. = 123.456
122 = FINAL THICKNESS OVERRIDE 0 (PROCESS 1)	Ex. = 123.456
123 = FINAL THICKNESS OVERRIDE 1 (PROCESS 1)	Ex. = 123.456
124 = FINAL THICKNESS OVERRIDE 2 (PROCESS 1)	Ex. = 123.456
125 = FINAL THICKNESS OVERRIDE 3 (PROCESS 1)	Ex. = 123.456
126 = FINAL THICKNESS OVERRIDE 4 (PROCESS 1)	Ex. = 123.456
127 = FINAL THICKNESS OVERRIDE 5 (PROCESS 1)	Ex. = 123.456
128 = FINAL THICKNESS OVERRIDE 6 (PROCESS 1)	Ex. = 123.456
129 = FINAL THICKNESS OVERRIDE 7 (PROCESS 1)	Ex. = 123.456
130 = FINAL THICKNESS OVERRIDE 8 (PROCESS 1)	Ex. = 123.456
131 = FINAL THICKNESS OVERRIDE 9 (PROCESS 1)	Ex. = 123.456

e. COMMUNICATIONS DISPLAY EQUIPMENT CONSTANT ID'S

134 = MAIN COMMUNICATIONS ORIGINATE	Ex. = 1
135 = DEVICE ID	Ex. = 12345
136 = RETRY COUNT	Ex. = 12
137 = RECEIVE TIMEOUT	Ex. = 12
001 = DUPLICATE EQUIPMENT CONSTANT ID FOR ID 137	Ex. = 12
138 = PROTOCOL TIMEOUT	Ex. = 12.3
139 = AUTOMATIC DATA LOG CONFIGURATION	Ex. = 1

f. EXTERNAL I/O DISPLAY EQUIPMENT CONSTANT ID'S

140 = EXTERNAL OUTPUT 7 "STRING TYPE, 11 CHARACTERS MAX"
141 = EXTERNAL OUTPUT 8 "STRING TYPE, 11 CHARACTERS MAX"
142 = EXTERNAL OUTPUT 9 "STRING TYPE, 11 CHARACTERS MAX"
143 = EXTERNAL OUTPUT 10 "STRING TYPE, 11 CHARACTERS MAX"
144 = EXTERNAL OUTPUT 11 "STRING TYPE, 11 CHARACTERS MAX"
145 = EXTERNAL OUTPUT 12 "STRING TYPE, 11 CHARACTERS MAX"
154 = EXTERNAL INPUT 7 "STRING TYPE, 11 CHARACTERS MAX"
155 = EXTERNAL INPUT 8 "STRING TYPE, 11 CHARACTERS MAX"
156 = EXTERNAL INPUT 9 "STRING TYPE, 11 CHARACTERS MAX"
157 = EXTERNAL INPUT 10 "STRING TYPE, 11 CHARACTERS MAX"
158 = EXTERNAL INPUT 11 "STRING TYPE, 11 CHARACTERS MAX"
159 = EXTERNAL INPUT 12 "STRING TYPE, 11 CHARACTERS MAX"
168 = EXTERNAL OUTPUT TYPE 7 Ex. = 1
169 = EXTERNAL OUTPUT TYPE 8 Ex. = 1
170 = EXTERNAL OUTPUT TYPE 9 Ex. = 1
171 = EXTERNAL OUTPUT TYPE 10 Ex. = 1
172 = EXTERNAL OUTPUT TYPE 11 Ex. = 1
173 = EXTERNAL OUTPUT TYPE 12 Ex. = 1

g. INTERNAL I/O DISPLAY EQUIPMENT CONSTANT ID'S

146 = INTERNAL OUTPUT 1 "STRING TYPE, 11 CHARACTERS MAX"
147 = INTERNAL OUTPUT 2 "STRING TYPE, 11 CHARACTERS MAX"
148 = INTERNAL OUTPUT 3 "STRING TYPE, 11 CHARACTERS MAX"
149 = INTERNAL OUTPUT 4 "STRING TYPE, 11 CHARACTERS MAX"
150 = INTERNAL OUTPUT 5 "STRING TYPE, 11 CHARACTERS MAX"
151 = INTERNAL OUTPUT 6 "STRING TYPE, 11 CHARACTERS MAX"
152 = INTERNAL OUTPUT 7 "STRING TYPE, 11 CHARACTERS MAX"
153 = INTERNAL OUTPUT 8 "STRING TYPE, 11 CHARACTERS MAX"
160 = INTERNAL INPUT 1 "STRING TYPE, 11 CHARACTERS MAX"
161 = INTERNAL INPUT 2 "STRING TYPE, 11 CHARACTERS MAX"
162 = INTERNAL INPUT 3 "STRING TYPE, 11 CHARACTERS MAX"
163 = INTERNAL INPUT 4 "STRING TYPE, 11 CHARACTERS MAX"
164 = INTERNAL INPUT 5 "STRING TYPE, 11 CHARACTERS MAX"
165 = INTERNAL INPUT 6 "STRING TYPE, 11 CHARACTERS MAX"
166 = INTERNAL INPUT 7 "STRING TYPE, 11 CHARACTERS MAX"
167 = INTERNAL INPUT 8 "STRING TYPE, 11 CHARACTERS MAX"

174 = INTERNAL OUTPUT TYPE 1	Ex. = 1
175 = INTERNAL OUTPUT TYPE 2	Ex. = 1
176 = INTERNAL OUTPUT TYPE 3	Ex. = 1
177 = INTERNAL OUTPUT TYPE 4	Ex. = 1
178 = INTERNAL OUTPUT TYPE 5	Ex. = 1
179 = INTERNAL OUTPUT TYPE 6	Ex. = 1
180 = INTERNAL OUTPUT TYPE 7	Ex. = 1
181 = INTERNAL OUTPUT TYPE 8	Ex. = 1

7.5.2 STATUS VARIABLE ID'S (SVID)

All status variable ID's are ASCII items 2 characters long.

01 = INPUTS
20 ASCII CHARACTERS: 0 = ACTIVE, 1 = NOT ACTIVE.
1ST 12 SENT ARE EXTERNAL 1 > 12 THEN INTERNAL 1 > 8.

02 = OUTPUTS
20 ASCII CHARACTERS: 0 = RELAY OPEN, 1 = CLOSED.
1ST 12 SENT ARE EXTERNAL 1 > 12 THEN INTERNAL 1 > 8.

03 = LOGICAL OUTPUTS
20 ASCII CHARACTERS: 0 = FALSE, 1 = TRUE.
1ST 12 SENT ARE EXTERNAL 1 > 12 THEN INTERNAL 1 > 8.

04 = DUMP PROCESS INFORMATION
POSSIBLE 34 BLOCKS OF ASCII TEXT.

05 = XTAL LIFE
2 ASCII CHARACTERS:
EX. 03

06 = STATUS MESSAGES
16 ASCII CHARACTERS: 0 = FALSE, 1 = TRUE.
1ST CHARACTER = STOPPED
NEXT CHARACTER = MAX POWER CHANNEL 1
NEXT CHARACTER = MAX POWER CHANNEL 2
NEXT CHARACTER = CALIBRATING CHANNEL 1
NEXT CHARACTER = CALIBRATING CHANNEL 2
NEXT CHARACTER = CALIBRATION ERROR CHANNEL 1
NEXT CHARACTER = CALIBRATION ERROR CHANNEL 2
NEXT CHARACTER = XTAL FAIL
NEXT CHARACTER = SHUTTER DELAY 1
NEXT CHARACTER = SHUTTER DELAY 2
NEXT CHARACTER = TEST MODE
NEXT CHARACTER = EMISSION OFF
NEXT CHARACTER = 50% LEAK
NEXT CHARACTER = MAXIMUM LEAK
NEXT CHARACTER = EMISSION ERROR
NEXT CHARACTER = CABLE ERROR

07 = STOPPED STATUS MESSAGES
2 ASCII CHARACTERS:
00 = PROGRAM LOSS
01 = POWER LOSS
05 = BAD POSITION
07 = EMISSION OFF
08 = XTAL FAIL
09 = MAX POWER CHANNEL 1
10 = MAX POWER CHANNEL 2
11 = FILTER CHANGER ERROR
12 = NO FILTER CHANGER
13 = XTAL CONFLICT
14 = EXTERNAL
15 = SENSOR FAIL
16 = RATIO ERROR
32 = NOT STOPPED

10 = RATE CHANNEL 1
5 OR 6 ASCII CHARACTERS: UNITS IN angstroms.
EX. +999.0 (6 CHARACTERS)
EX. +1000 (5 CHARACTERS)

11 = POWER CHANNEL 1
2 ASCII CHARACTERS:
EX. 50

12 = THICKNESS CHANNEL 1
5 or 6 ASCII CHARACTERS: UNITS IN k angstroms.
EX. +999.0 (6 CHARACTERS)
EX. +1000 (5 CHARACTERS)

13 = PHASE MESSAGE CHANNEL 1
2 ASCII CHARACTERS:
00 = READY
01 = FILTER DELAY
02 = RISE 1
03 = SOAK 1
04 = RISE 2
05 = SOAK 2
06 = SHUTTER DELAY
07 = DEPOSIT
08 = RATE RAMP
09 = TIME POWER
10 = FALL
11 = IDLE
12 = MANUAL

7.5.3 REMOTE COMMAND CODES (RCMD)

Remote command codes are ASCII items 2 characters long.

00 = CHANGE DISPLAY TO MENU
01 = CHANGE DISPLAY TO DATA
02 = CHANGE DISPLAY TO FILM
03 = CHANGE DISPLAY TO MONITOR
04 = CHANGE DISPLAY TO EXECUTIVE
05 = CHANGE DISPLAY TO COMMUNICATIONS
06 = CHANGE DISPLAY TO EXTERNAL I/O
07 = CHANGE DISPLAY TO INTERNAL I/O
08 = REMOTE LOCK ON
09 = REMOTE LOCK OFF
10 = DO START
11 = DO STOP
12 = DO RESET
13 = ZERO THICKNESS CHANNEL 1
14 = ZERO THICKNESS CHANNEL 2
15 = DO CALIBRATION CHANNEL 1
16 = DO CALIBRATION CHANNEL 2
17 = INTERLOCK ON
30 = INTERLOCK OFF
18 = TURN EMISSION ON
19 = TURN EMISSION OFF
20 = FINAL THICKNESS ALL
21 = FINAL THICKNESS CHANNEL 1
22 = FINAL THICKNESS CHANNEL 2
23 = XTAL INHIBIT ON
31 = XTAL INHIBIT OFF
24 = SOAK HOLD CHANNEL 1 ON
32 = SOAK HOLD CHANNEL 1 OFF
25 = SOAK HOLD CHANNEL 2 ON
33 = SOAK HOLD CHANNEL 2 OFF
51 = CLOSE USER RELAY 1
52 = CLOSE USER RELAY 2
53 = CLOSE USER RELAY 3
54 = CLOSE USER RELAY 4
55 = CLOSE USER RELAY 5
56 = CLOSE USER RELAY 6
61 = OPEN USER RELAY 1
62 = OPEN USER RELAY 2
63 = OPEN USER RELAY 3
64 = OPEN USER RELAY 4
65 = OPEN USER RELAY 5
66 = OPEN USER RELAY 6

14 = PHASE TIME CHANNEL 1
5 ASCII CHARACTERS: UNITS IN min:sec.
EX. 99:59
15 = ACTIVE FILM CHANNEL 1
1 ASCII CHARACTER:
EX. 6
16 = FILM TIME CHANNEL 1
5 ASCII CHARACTERS: UNITS IN min:sec.
EX. 99:59
17 = RATE DEVIATION CHANNEL 1
5 ASCII CHARACTERS PER RATE DEVIATION: POSSIBLE 2 BLOCK RESPONSE, UNITS IN angstroms.
EX. -40.0

VALUES SAME FORMAT AS CHANNEL 1
20 = RATE CHANNEL 2
21 = POWER CHANNEL 2
22 = THICKNESS CHANNEL 2
23 = PHASE MESSAGE CHANNEL 2
24 = PHASE TIME CHANNEL 2
25 = ACTIVE FILM CHANNEL 2
26 = FILM TIME CHANNEL 2
27 = RATE DEVIATION CHANNEL 2

VALUES SAME FORMAT AS CHANNEL 1
30 = RATE MONITOR

7.5.4 ALARM ID'S (ALID)

Alarm ID is a 1-byte integer (unsigned).

55H = ASCII U = PROCESS DONE
56H = ASCII V = EQUIPMENT STOPPED
57H = ASCII W = PROCESS STARTED