# Cygnus®2

## Thin Film Deposition Controller

PN 074–545–P1H

INFICON

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### DECLARATION
### OF
### CONFORMITY

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**INFICON Inc.**
**Two Technology Place**
**East Syracuse, NY  13057**
**USA**

Meets the essential safety requirements of the European Union and is placed on the market accordingly.  It has been constructed in accordance with good engineering practice in safety matters in force in the Community and does not endanger the safety of persons, domestic animals or property when properly installed and maintained and used in applications for which it was made.
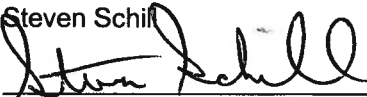
**Equipment Description:**   IC6/Cygnus 2 Deposition Controller (including all options).

**Applicable Directives:**   2014/35/EU (LVD)

2014/30/EU (General EMC)

2011/65/EU (RoHS)

**Applicable Standards:**

Safety:   EN 61010-1: 2010 Safety Requirements for Electrical Equipment For Measurement, Control, And Laboratory Use.
PART 1: General Requirements

Emissions:   EN 61326-1: 2013 (Radiated & Conducted Emissions)
(EMC – Measurement, Control & Laboratory Equipment)
CISPR 11/EN 55011 Edition 2009-12 Emission standard for industrial, scientific, and medical (ISM) radio RF equipment

FCC Part 18 Class A emissions requirement (USA)

Immunity:   EN 61326-1: 2013 (Industrial EMC Environments)
(EMC – Measurement, Control & Laboratory Equipment)

RoHS2:   Fully Compliant

**CE Implementation Date:**   June 2010 (Revised August, 2015)

**Authorized Representative:** Steven Schill

Thin Film Business Line Manager
INFICON, Inc.

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

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# *Chapter 1*
# *Introduction and Specifications*

## *1.1  Introduction*

Cygnus 2 is a closed loop process controller designed for use primarily in physical vapor deposition. Cygnus 2 monitors and/or controls the rate and thickness of the deposition of thin films. Deposition rate and thickness are inferred from the frequency change induced by mass added to a quartz crystal. This technique positions sensors in the path between or to the side of the source of the vaporized material and the target substrate. The sensor incorporates an exposed oscillating quartz crystal whose frequency decreases as material accumulates. The change in frequency provides information to determine rate and thickness and to continually control the evaporation power source. With user programmed time, thickness and power limits and with desired rates and material characteristics, Cygnus 2 is capable of automatically controlling the process in a precise and repeatable manner. User interaction is accomplished via Cygnus 2 front panel or remote communication and consists of selection or entry of parameters to define the process.

A complete system consists of a main electronics unit also called Cygnus 2, sensor heads and a crystal interface unit (XIU) for each attached sensor. These items are generally bundled at the factory and are also sold separately.

This Cygnus 2 Operating Manual provides user information for installing, programming and operating the main electronics unit.

When reading Cygnus 2 Operating Manual, please pay particular attention to the Notes, Cautions, and Warnings found throughout the text. The Notes, Cautions, and Warnings are defined in section 1.2.1 on page 1-2.

You are invited to comment on the usefulness and accuracy of this manual by visiting our website at www.inficon.com.

## *1.2  Cygnus 2 Safety*
### *1.2.1  Definition of Notes, Cautions and Warnings*

When using this manual, please pay attention to the Notes, Cautions, and Warnings found throughout. For the purposes of this manual they are defined as follows:

**NOTE:** Pertinent information that is useful in achieving maximum Cygnus 2 efficiency when followed.

### ⚠ CAUTION

**Failure to heed these messages could result in damage to Cygnus 2.**

### ⚠ WARNING

**Failure to heed these messages could result in personal injury.**

### ⚡ WARNING - Risk Of Electric Shock

**Dangerous voltages are present which could result in personal injury.**

## *1.2.2  General Safety Information*

⚠️ **WARNING - Risk Of Electric Shock**

> **Do not open the Cygnus 2 case! There are no
> user-serviceable components within the Cygnus 2 case.
> Dangerous voltages may be present whenever the power
> cord or external input/relay connectors are present.
> Refer all maintenance to qualified personnel.**

⚠️ **CAUTION**

> **Cygnus 2 contains delicate circuitry which is susceptible
> to transient power line voltages. Disconnect the line cord
> whenever making any interface connections. Refer all
> maintenance to qualified personnel.**

## *1.2.3  Earth Ground*

Cygnus 2 is connected to earth ground through a sealed three-core
(three-conductor) power cable, which must be plugged into a socket outlet with a
protective earth terminal. Extension cables must always have three conductors
including a protective earth terminal.

⚠️ **WARNING - Risk Of Electric Shock**

> **Never interrupt the protective earth circuit.**
>
> **Any interruption of the protective earth circuit inside or
> outside Cygnus 2, or disconnection of the protective
> earth terminal is likely to make Cygnus 2 dangerous.**
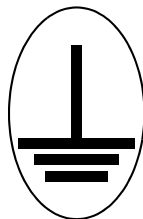


> **This symbol indicates where the protective earth ground
> is connected inside Cygnus 2. Never unscrew or loosen
> this connection.**

### 1.2.4 Main Power Connection

**WARNING - Risk Of Electric Shock**

**This Cygnus 2 has line voltage present on the primary circuits whenever it is plugged into a main power source.**

**Never remove the covers from Cygnus 2 during normal operation.**

**There are no operator-serviceable items within Cygnus 2.**

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

**In order to comply with accepted safety standards, Cygnus 2 must be installed into a rack system which contains a mains switch. This switch must break both sides of the line when it is open and it must not disconnect the safety ground.**

## 1.3  How To Contact INFICON

Worldwide customer support information is available under Support at www.inficon.com where you can contact:

- a Technical Support Engineer with questions regarding applications for and programming Cygnus 2.

- a Service Engineer with questions regarding troubleshooting, diagnosing or repairing a defective Cygnus 2.

- Sales and Customer Service, to find the INFICON Sales office nearest to you.

- Repair Service, to find the INFICON Service Center nearest to you.

If you are experiencing a problem with your Cygnus 2, please have the following information readily available:

- the serial number and firmware version for your Cygnus 2,

- a description of your problem,

- an explanation of any corrective action that you may have already attempted,

- and the exact wording of any error messages that you may have received.

### 1.3.1  Returning Your Cygnus 2

Do not return any component of your Cygnus 2 to INFICON without first speaking with a Customer Support Representative. You must obtain a Return Material Authorization (RMA) number from the Customer Support Representative.

If you deliver a package to INFICON without an RMA number, your package will be held and you will be contacted. This will result in delays in servicing your Cygnus 2.

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

## *1.4  Cygnus 2 Specifications*

### *1.4.1  Measurement*

Crystal Frequency . . . . . . . . . . . . . . . . . . . . 6.0 MHz (new crystal) to 4.5 MHz

Internal Precision . . . . . . . . . . . . . . . . . . . . . ±0.0035 Hz over 100 ms sample for fundamental and anharmonic frequencies

Thickness & Rate Resolution . . . . . . . . . . . . 0.0042 Å (new crystal);
0.0076 Å (crystal @ 4.5 MHz) over 100 ms sample for material density = 1.0,
Z-Ratio = 1.0

Thickness Accuracy . . . . . . . . . . . . . . . . . . . 0.5% typical, (dependent on process conditions, especially sensor location, material stress, temperature and density)

Frequency Accuracy . . . . . . . . . . . . . . . . . . . ±2 ppm 0-50°C

Measurement Frequency . . . . . . . . . . . . . . . 10 Hz

Measurement Technique . . . . . . . . . . . . . . . ModeLock with Auto-Z

User Interface . . . . . . . . . . . . . . . . . . . . . . . . LCD and limited membrane keypad. All parameters accessible through computer communications. Multiple message areas for indication of states and detailed indication of abnormal and stop conditions.

### *1.4.2  Screens and Hierarchy*

a) Navigation . . . . . . . . . . . . . . . . . . . . . . . . . Menu driven, four soft keys

b) Structure . . . . . . . . . . . . . . . . . . . . . . . . . . Separate screens dedicated to
1) Operate
2) Sensor Information
3) Sensor Parameters
4) Source Parameters
5) Material Parameters
6) General Parameters
7) Digital I/O Display
8) Logic
9) Maintenance
10) Counter/Timer
11) USB Storage

### 1.4.3  Cygnus 2 Features

#### 1.4.3.1  Recipe Storage and Datalogging

USB Memory Device

#### 1.4.3.2  Sensor Parameters

(Sensor) Shutter Output . . . . . . . . . . . . . . . . 0 to 38

Sensor Type . . . . . . . . . . . . . . . . . . . . . . . . . Single, XtalTwo, XtalSix, Xtal12, Generic

(Sensor) Switch Output . . . . . . . . . . . . . . . . 0 to 38

Auto-Z  . . . . . . . . . . . . . . . . . . . . . . . . . . . . Yes/No

# of Positions (for Generic Sensor type)  . . . 1 to 12

# of Pulses (for Generic Sensor type) . . . . . 1 to 10

Pulse On (Time for Generic Sensor type)  . . 0.1 to 9.9 s

Pulse Off (Time for Generic Sensor type)  . . 0.1 to 9.9 s

Recorder Output. . . . . . . . . . . . . . . . . . . . . . 0 to 12

Recorder Function . . . . . . . . . . . . . . . . . . . . Rate, Thickness, RateDeviation

Recorder Range. . . . . . . . . . . . . . . . . . . . . . 0 to 99999

#### 1.4.3.3  Source Parameters

Up to 6 Sources may be controlled at the same time

DAC Output . . . . . . . . . . . . . . . . . . . . . . . . . 0 to 12

(Source) Shutter Output . . . . . . . . . . . . . . . . 0 to 38

Crucible Selection  . . . . . . . . . . . . . . . . . . . . Turret is indexed to selected position on a Start. Turret feedback is checked whenever a Source is started. Range is from 1 to number of crucibles.

Number of Crucibles. . . . . . . . . . . . . . . . 1, 4, 8, 16, 32 or 64

Crucible Output  . . . . . . . . . . . . . . . . . . . 0 to 38

Turret Feedback . . . . . . . . . . . . . . . . . . . Yes / No

Turret Input. . . . . . . . . . . . . . . . . . . . . . . 0 to 28

Turret Delay . . . . . . . . . . . . . . . . . . . . . . 2 to 180 s (Time-out period with feedback, delay time without feedback)

### *1.4.3.4  Material Parameters*

6 Materials can be specified and given unique names (15 character max.).

Density . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 0.100 to 99.999 g/cc

Z-ratio . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 0.100 to 15.000

Master Tooling . . . . . . . . . . . . . . . . . . . . . . . 1.0 to 999.9%

Control Loop types . . . . . . . . . . . . . . . . . . . . Non-PID, PI, PID

Process Gain . . . . . . . . . . . . . . . . . . . . . . . . . 0.01 to 999.99 Å/s/%Power

Time Constant . . . . . . . . . . . . . . . . . . . . . . . . 0.010 to 9999.99 s

Dead Time . . . . . . . . . . . . . . . . . . . . . . . . . . . 0.010 to 9999.99 s

Maximum Source Power . . . . . . . . . . . . . . . 0.01 to 99.99%

Minimum Source Power . . . . . . . . . . . . . . . . 0.00 to 99.98%

Maximum Power Option . . . . . . . . . . . . . . . Continue, Post-Dep(osition), Stop All, Stop Mat(erial)—can be selected for each Material individually

Power Ramps . . . . . . . . . . . . . . . . . . . . . . . . 3 per Material

    Power Level . . . . . . . . . . . . . . . . . . . . . . . 0.00 to 99.99%

    Rise Time . . . . . . . . . . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

    Soak Time . . . . . . . . . . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

Auto Soak 2 . . . . . . . . . . . . . . . . . . . . . . . . . Yes / No

Deposit After Pre-Deposit . . . . . . . . . . . . . . Yes / No
                                Yes = go to Deposit
                                No = go to Non-Deposit Rate Control

(Control) Delay Option . . . . . . . . . . . . . . . . . None, Shutter, Control, Both

Control Delay Time . . . . . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

Shutter Delay Accur(acy) . . . . . . . . . . . . . . . 1 to 99%

Feed Power . . . . . . . . . . . . . . . . . . . . . . . . . 0.00 to 99.99%

Feed Ramp Time . . . . . . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

Feed Time . . . . . . . . . . . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

Idle Ramp . . . . . . . . . . . . . . . . . . . . . . . . . . 1 per Source

    Idle Power . . . . . . . . . . . . . . . . . . . . . . . . . 0.00 to 99.99%

    Idle Ramp Time . . . . . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

Rate . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 0.000 to 999.9 Å/s

Time Limit (in Deposit) . . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

Rate Filter Time . . . . . . . . . . . . . . . . . . . . . . 0.1, 0.4, 1.0, 4.0, or 10.0, 20.0, 30.0 s

Time Power Averaging Time . . . . . . . . . . . . 0 to 30 minutes

Ion Assist Deposit. . . . . . . . . . . . . . . . . . . . . Yes/No

On Final Thickness. . . . . . . . . . . . . . . . . . . . Continue, Post-Dep(osit), NonDep(osit)Cont(rol)

New Rate while in Deposit . . . . . . . . . . . . . . 2 Rate Ramps per Material

    New Rate 1 or 2 . . . . . . . . . . . . . . . . . . . 0.000 to 999.9 Å/s

    Start Ramp 1 or 2. . . . . . . . . . . . . . . . . . 0.000 to 999.9 kÅ

    Ramp Time 1 or 2. . . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

RateWatcher$^{®}$ . . . . . . . . . . . . . . . . . . . . . Sample and Hold Feature

    (RateWatcher) Option. . . . . . . . . . . . . . . Yes/No

    (RateWatcher) Time . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

    (RateWatcher) Accuracy. . . . . . . . . . . . . 1 to 99%

(Sensor) Failure Action. . . . . . . . . . . . . . . . . PostD(e)p(osit), Stop All, Stop Matl, TimeP(o)w(er)

CrystalTwo Tooling . . . . . . . . . . . . . . . . . . . . 1.0 to 999.9%

CrystalSix (XtalSix) and Crystal12 (Xtal12) sensor selections to specify a subset of available crystal positions:

    Xtal Position First . . . . . . . . . . . . . . . . . . 0 to 6 (XtalSix) or 12 (Xtal12)

    Xtal Position Last . . . . . . . . . . . . . . . . . . 0 to 6 (XtalSix) or 12 (Xtal12)

(Crystal) Quality Percent . . . . . . . . . . . . . . . 0 to 99%

(Crystal) Quality Counts . . . . . . . . . . . . . . . . 0 to 99

(Crystal) Stability Single . . . . . . . . . . . . . . . . 0 to 9999 Hz

(Crystal) Stability Total . . . . . . . . . . . . . . . . . 0 to 9999 Hz

Recorder Output. . . . . . . . . . . . . . . . . . . . . . 0 to 12

Recorder Function . . . . . . . . . . . . . . . . . . . . Rate, Thick(ness), RateDev(iation), Power

Recorder Range. . . . . . . . . . . . . . . . . . . . . . 0 to 99999

Final Thick(ness) . . . . . . . . . . . . . . . . . . . . . 0.000 to 999.99 kÅ

Thick(ness) Limit . . . . . . . . . . . . . . . . . . . . . 0.000 to 999.99 kÅ

Cruc(ible) . . . . . . . . . . . . . . . . . . . . . . . . . . 1 to 64

### 1.4.3.5 General Global Parameters

| | |
|---|---|
| Date Format . . . . . . . . . . . . . . . . . . . . . . . | DDMMYYYY or MMDDYYYY |
| LCD Dimmer Time . . . . . . . . . . . . . . . . . . . | 0 for Always On or # of Minutes till Off 0 to 99 minutes |
| Graph Scale . . . . . . . . . . . . . . . . . . . . . . . | Power, ±0.1 Å/s, ±0.5 Å/s, ±1 Å/s, ±2 Å/s,±3 Å/s, ±5 Å/s, ±10 Å/s, ±20 Å/s, ±50 Å/s |
| Graph Scan Rate . . . . . . . . . . . . . . . . . . . . | Auto, Slow, Medium, Fast |
| Test  . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | On / Off |
| Advanced Test . . . . . . . . . . . . . . . . . . . . . . | On / Off |
| Time Compressed  . . . . . . . . . . . . . . . . . . . | Yes / No |
| Audio Feedback . . . . . . . . . . . . . . . . . . . . . | Yes / No |
| RS232 Baud Rate  . . . . . . . . . . . . . . . . . . . | 9600, 19200, 38400, 57600, 115200 |
| RS232 Protocol  . . . . . . . . . . . . . . . . . . . . . | Standard, D(ata)log Page, D(ata)log Comma |
| DataLog XTAL History  . . . . . . . . . . . . . . . . | Yes / No |
| USB Datalog Format . . . . . . . . . . . . . . . . . . | Log Off (No datalogging), Page, Comma |
| Thickness Eq(uation) 1. . . . . . . . . . . . . . . . | Up to 6 Source numbers can be specified, each Source number can be used only once in the equation. |
| Thickness Eq(uation) 2. . . . . . . . . . . . . . . . | Up to 6 Source numbers can be specified, each Source number can be used only once in the equation. |
| Thickness Eq(uation) 3. . . . . . . . . . . . . . . . | Up to 6 Source numbers can be specified, each Source number can be used only once in the equation. |
| DAC 1 to 12 Scale . . . . . . . . . . . . . . . . . . . | 0.1 to 10.0 |
| DAC 1 to 12 Polarity. . . . . . . . . . . . . . . . . . | Positive / Negative |

## 1.4.4  Display

Type/Color/Size . . . . . . . . . . . . . . . . . . . . . . LCD/Color/TFT/7 inch diagonal

Dimming Feature . . . . . . . . . . . . . . . . . . . . . Always Full on or Full on when in use. Full off when no process running and no key interaction for dimming time

Format . . . . . . . . . . . . . . . . . . . . . . . . . . . . WVGA

Resolution . . . . . . . . . . . . . . . . . . . . . . . . . 800 W x 480 H

Backlighting . . . . . . . . . . . . . . . . . . . . . . . . LED

Thickness Display Range. . . . . . . . . . . . . . . 0.000 to ±9999 kÅ

Thickness Display Resolution . . . . . . . . . . . 1 Å for 0.000 to ±9.999 kÅ, 10 Å for ±10.00 to ±99.99 kÅ 100Å for ±100.0 to ±999.9 kÅ

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1 kÅ for ±1000 to ±9999 kÅ

Rate Display Range . . . . . . . . . . . . . . . . . . . 0.000 to ±999.9 Å/s

Rate Display Resolution. . . . . . . . . . . . . . . . 0.001 Å/s for 0.000 to ±9.999 Å/s,

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 0.01 Å/s for ±10.00 to ±99.99 Å/s 0.1 Å/s for ±100.0 to ±999.9 Å/s

Power Display Range. . . . . . . . . . . . . . . . . . 0.00 to 99.99%

Graphic Display Functions . . . . . . . . . . . . . Rate Deviation at ±0.1 Å/s, ±0.5 Å/s, ±1 Å/s, ±2 Å/s, ±3 Å/s, ±5 Å/s, ±10 Å/s, ±20 Å/s, or ±50 Å/s or Power at 0 to 100%

Display Data Update Rate . . . . . . . . . . . . . . 1 Hz

## 1.4.5  DAC Outputs

Quantity and Type . . . . . . . . . . . . . . . . . . . . . 6 with BNC, 6 optional with 15 pin miniature D-sub providing analog outputs for Rate and Thickness.

Configuration . . . . . . . . . . . . . . . . . . . . . . . . User programmable for recorder or Source control.

Function and Ranges . . . . . . . . . . . . . . . . . Power, Rate, Rate Deviation, Thickness    Full scale voltage value fully selectable up to + or - 10 V relative to 0 V at 0 output

Current rating . . . . . . . . . . . . . . . . . . . . . . . . 20 mA per channel

Resolution  . . . . . . . . . . . . . . . . . . . . . . . . . . 15 bits over full range (10 V)

Update Rate . . . . . . . . . . . . . . . . . . . . . . . . . 10 Hz, maximum, (dependent on source characteristics).

Recorder Output Functions  . . . . . . . . . . . . Rate, Thickness, Rate Deviation, or Source Power.

Recorder Output Ranges

Rate . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 0 to up to 99999 Å/s programmable

Thickness . . . . . . . . . . . . . . . . . . . . . . . . 0 to up to 99999 Å programmable, [Function modulo (Thickness Range, Thickness)output is "saw-tooth" like with increasing thickness.]

Rate Deviation . . . . . . . . . . . . . . . . . . . . Desired rate ±50 Å/s

Accuracy. . . . . . . . . . . . . . . . . . . . . . . . . . . . ±1%

## 1.4.6  Logic Processing

Type . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . If/Then statements

Logical Functions . . . . . . . . . . . . . . . . . . . . . And; Or; Not; Parentheses; ON

Depth . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 5 "If" conditions and 5 "Then" results/actions per statement

# of Statements . . . . . . . . . . . . . . . . . . . . . . . 100 If/Then

Selectable events. . . . . . . . . . . . . . . . . . . . . . Deposition monitor events, states, external inputs, relays, timers, and counters.

Hierarchy . . . . . . . . . . . . . . . . . . . . . . . . . . . . Statements evaluated in numerical order at 10 Hz any time Cygnus 2 is on.

Partitioning . . . . . . . . . . . . . . . . . . . . . . . . . . . None

Initialization  . . . . . . . . . . . . . . . . . . . . . . . . . . All outputs transition to their normal states as early as possible during power-on initialization sequence.

## 1.4.7  Relays / Inputs

Relays  . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . SPST 2.5 A relays rated @ 30 V (dc) or
30 V (ac) RMS or 42 V (peak) maximum;
(8 standard, up to 16 optional with 2 additional I/O cards); D sub connector; relays are normally open in the power off state, but may be programmed to normally open or normally closed during operation.

Relay Ratings. . . . . . . . . . . . . . . . . . . . . . . . . 100 VA inductive; 2.5 A maximum.

# of TTL Compatible Outputs . . . . . . . . . . . . 14 with optional I/O card. Internally pulled up to 5 V (dc). May be pulled up externally to
24 V (dc) through 2.4 k resistor.
minimum high level 0.5 mA load @3.75 V
maximum low level 10 mA load @1.1 V

Inputs (TTL Compatible). . . . . . . . . . . . . . . . (14 standard, 14 additional optional)

Input Levels

    maximum high . . . . . . . . . . . . . . . . . . . . 24 V

    minimum high . . . . . . . . . . . . . . . . . . . . 2.5 V

    maximum low . . . . . . . . . . . . . . . . . . . . 1.1 V

Scan/Update Rate . . . . . . . . . . . . . . . . . . . . 10 Hz

Input/Output Name . . . . . . . . . . . . . . . . . . . Those that are Non-Hardware reserved may be named. (15 character max.)

## 1.4.8  Remote Communications

RS232C Serial Port . . . . . . . . . . . . . . . . . . Standard; INFICON binary protocol

Baud Rates. . . . . . . . . . . . . . . . . . . . . . . . . 115,200, 57,600, 38,400, 19,200, 9,600

Ethernet . . . . . . . . . . . . . . . . . . . . . . . . . . . Optional,  Programmable IP Address and Net Mask

USB port. . . . . . . . . . . . . . . . . . . . . . . . . . . Print screen bitmap (.bmp) files, Datalogging file, Configuration file store/retrieve

## 1.4.9  Accessories

Connector Kit . . . . . . . . . . . . . . . . . . . . . . . Connectors for inputs and relays

Operating Manual. . . . . . . . . . . . . . . . . . . . 074-5000-G1 CD-ROM

## 1.4.10  Power

Power . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 100-230 V (ac) +15% / -10% V (ac); 50/60 Hz ±3 Hz

Maximum apparent power . . . . . . . . . . . . . .  150 VA

Fuse . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . use 250 V 4 Amp,  5 x 20, Slow Blow

Temporary Overvoltages . . . . . . . . . . . . . . Short Term: 1430 V, <5 s
Long Term: 480 V, >5 s

### 1.4.11 Operating Environment

Usage . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Indoor only

Temperature . . . . . . . . . . . . . . . . . . . . . . . . . 0 to 50°C (32-122°F)

Humidity . . . . . . . . . . . . . . . . . . . . . . . . . . . Up to 85% RH, non-condensing

Altitude . . . . . . . . . . . . . . . . . . . . . . . . . . . . Up to 2000 meters

Installation (Overvoltage) . . . . . . . . . . . . . . Category II per IEC 60664

Pollution Degree . . . . . . . . . . . . . . . . . . . . . 2 per EN 61010

### 1.4.12 Storage Temperature

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

### 1.4.13 Warm Up Period

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

### 1.4.14 Size

Not including mounts or user connectors

5.25 in. H x 17.625 in. W x 13 in. D
(133.4 mm H x 447.7 mm W x 330 mm D)

Including mounts, but no user connectors

5.25 in. H x 19 in. W x 13 in. D
(133.4 mm H x 482.6 mm W x 330 mm D)

### 1.4.15 Installation Clearance Requirements
#### 1.4.15.1 Connector Clearances:

Front . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1.0 in. (25 mm) minimum without USB, 2.5 in (64 mm) minimum dependent on size of USB storage device

Rear . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4.0 in. (100 mm) minimum

#### 1.4.15.2 Cooling Clearances:

Rear . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 4.0 in. (100 mm) minimum

Sides . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1/4 in. (7 mm) minimum

### 1.4.16 Weight

With all options . . . . . . . . . . . . . . . . . . . . . . . 13 lb. (5.9 kg)

### 1.4.17 Cleaning

Use a mild, nonabrasive cleaner or detergent taking care to prevent cleaner from entering Cygnus 2.

## 1.5 Unpacking and Inspection

**1**  If Cygnus 2 has not been removed from its shipping container, do so now.

**2**  Carefully examine Cygnus 2 for damage that may have occurred during shipping. This is especially important if you notice obvious rough handling on the outside of the container. *Immediately report any damage to the carrier and to INFICON.*

**3**  Do not discard the packing materials until you have taken inventory and have at least performed a power on verification.

**4**  Take an inventory of your order by referring to your order invoice and the information contained in .

**5**  To perform a power-on verification, see .

**6**  For additional information or technical assistance, contact INFICON, refer to .

## 1.6 Parts and Options Overview
### 1.6.1 Base Configurations

Cygnus 2 Control Unit . . . . . . . . . . . . . . . . . 781-500-G11 North America, 781-500-G12 Europe

Ship Kit . . . . . . . . . . . . . . . . . . . . . . . . . . . . 781-020-G1 North America, 781-020-G2 Europe

Operating Manual on CD ROM . . . . . . . . . . 074-545 on 074-5000-G1 CD ROM included in Ship Kit

I/O Relay . . . . . . . . . . . . . . . . . . . . . . . . . . . Contains Input/Relay Interface Connectors (8 relay outputs, 14 TTL inputs). Included in Ship Kit.

### 1.6.2  Pre-installed Options or Spares

Additional Sensor Module . . . . . . . . . . . . . . 781-132-G1 (up to 2 extra)

**The following contain board and interface connector**

I/O Relay Card . . . . . . . . . . . . . . . . . . . . . . . 781-502-G1
(8 relay outputs, 14 TTL inputs)
781-503-G1
(8 relay outputs, 14 TTL outputs)

DAC Option Board and Kit . . . . . . . . . . . . . . 781-504-G1

Ethernet . . . . . . . . . . . . . . . . . . . . . . . . . . . 781-102-G2

### 1.6.3  Optional Accessories

Pneumatic Shutter
Actuator Control Valve . . . . . . . . . . . . . . . . . 750-420-G1

Sensor Emulator Kit . . . . . . . . . . . . . . . . . . . . . . . . . 760-601-G2

Handheld Controller  . . . . . . . . . . . . . . . . . . . . . . . . 755-262-G1

　　Function:Power Increase/Decrease/Stop/Switch Crystal

### 1.6.4  Oscillator Packages

Cygnus 2 Oscillator, 15 ft. and 6 in. cable . . pkg. . . 781-611-G15
Cygnus 2 Oscillator, 30 ft. and 6 in. cable pkg. . . . . 781-611-G30
Cygnus 2 Oscillator, 50 ft. and 6 in. cable pkg. . . . . 781-611-G50
Cygnus 2 Oscillator, 100 ft. and 6 in. cable pkg. . . . 781-611-G100
4 Meter Oscillator, 15 ft. and 6 in. cable pkg.  . . . . . 781-612-G15
4 Meter Oscillator, 30 ft. and 6 in. cable pkg.  . . . . . 781-612-G30
4 Meter Oscillator, 50 ft. and 6 in. cable pkg.  . . . . . 781-612-G50
4 Meter Oscillator, 100 ft. and 6 in. cable pkg.  . . . . 781-612-G100
4 Meter Oscillator, 15 ft. and 20 in. cable pkg.  . . . . 781-613-G15
4 Meter Oscillator, 20 ft. and 20 in. cable pkg.  . . . . 781-613-G20
4 Meter Oscillator, 50 ft. and 20 in. cable pkg.  . . . . 781-613-G50
4 Meter Oscillator, 100 ft. and 20 in. cable pkg.  . . . 781-613-G100

### 1.6.5  Sensors

Contact INFICON for a complete listing of sensors.

### 1.6.6 Replacement Cables

Oscillator to vacuum. . . . . . . . . . . . . . . . . . . . . . . . .755-257-G6
feedthrough cable, 6 in

Cygnus 2 Unit to Oscillator Cable 15 ft . . . . . . . . . .600-1261-P15

Cygnus 2 Unit to Oscillator Cable, 30 ft . . . . . . . . . .600-1261-P30

Cygnus 2 Unit to Oscillator Cable, 50 ft . . . . . . . . . .600-1261-P50

Cygnus 2 Unit to Oscillator Cable, 100 ft. . . . . . . . .600-1261-P100

## 1.7 Initial Power-On Verification

A preliminary functional check of Cygnus 2 can be made before formal installation. It is not necessary to have sensors, source controls, inputs or relays connected to do this. For more complete installation information, see Chapter 2, Installation and Interfaces and Chapter 10, Maintenance and Calibration Procedures.

⚠ **WARNING - Risk Of Electric Shock**

**There are no user-serviceable components within the Cygnus 2 case.**

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

**Refer all maintenance to qualified personnel.**

⚠ **WARNING - Risk Of Electric Shock**

**Never interrupt the protective earth circuit.**

**Any interruption of the protective earth circuit inside or outside Cygnus 2, or disconnection of the protective earth terminal is likely to make Cygnus 2 dangerous.**
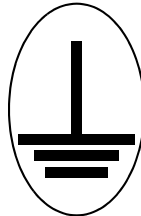
**This symbol indicates where the protective earth ground is connected inside Cygnus 2. Never unscrew or loosen this connection.**

**1** Confirm that AC line voltage is supplied and proper for Cygnus 2.

**2** Confirm that the back panel (main) AC switch is in the ON position.

**3** Press the ON/STBY button on the front panel. A green pilot light should be illuminated next to the power switch.

**4** The fan at the back of Cygnus 2 should be exhausting air.

**5** After the initial temporary boot-up screen which can be viewed in Maintenance Sys Status, the LCD monitor will display an image similar to the one shown in Figure 1-1 or Figure 1-2.

*Figure 1-1  Operate screen show graph*
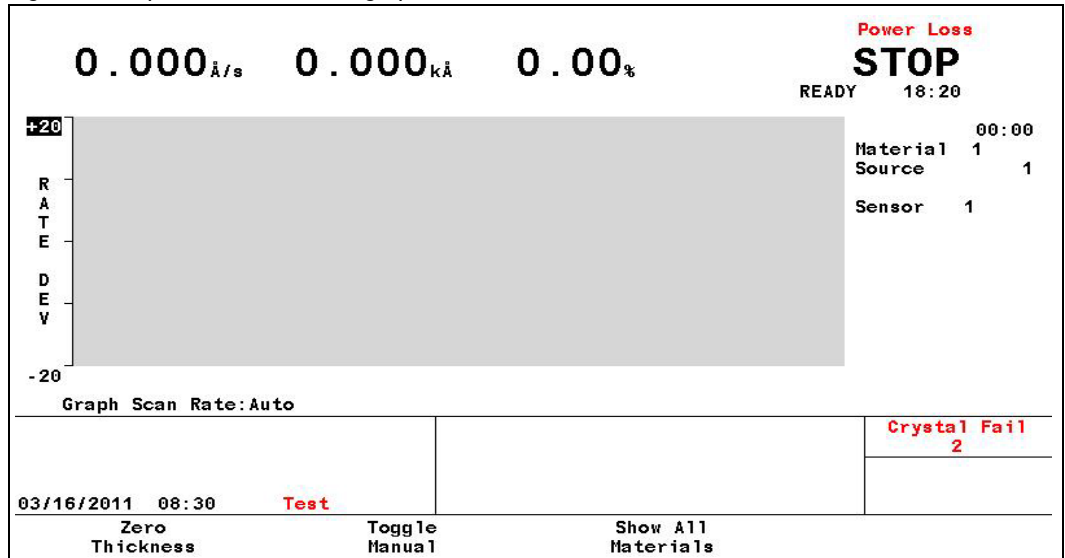


*Figure 1-2  Operate screen show all materials*
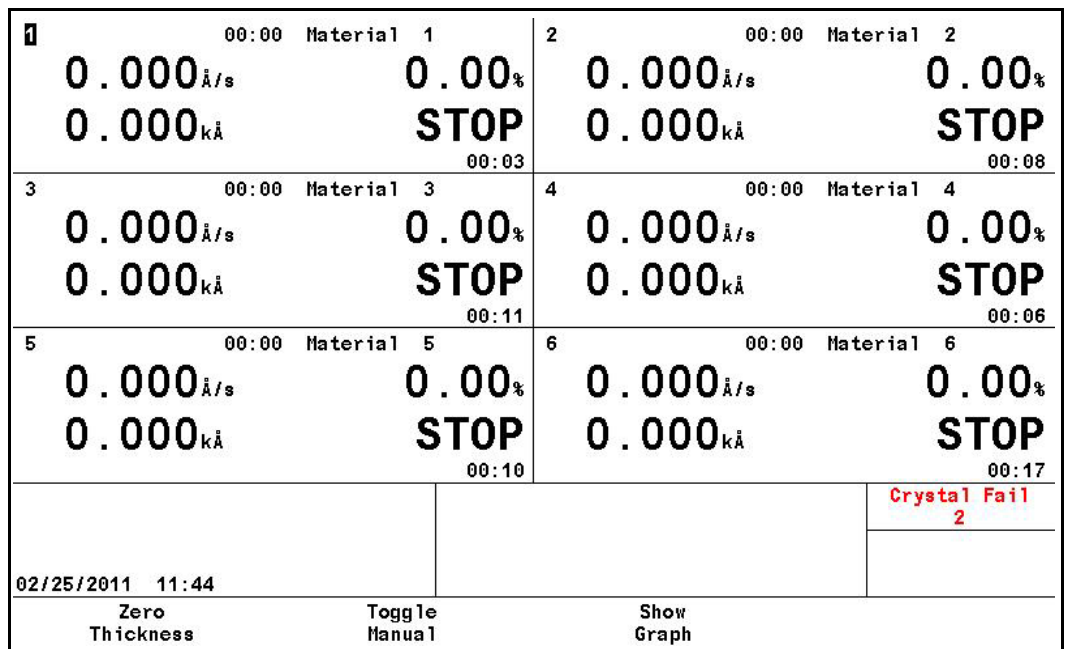
# *Chapter 2*
# *Installation and Interfaces*

## *2.1 Location Guidelines*

Before permanently installing Cygnus 2, read this entire chapter on installation and interfaces and follow its recommendations as closely as possible. INFICON has taken numerous steps to ensure its equipment will operate in a variety of harsh situations. Failure to adhere to these simple practices may adversely affect the performance and longevity of Cygnus 2.

### *2.1.1 Sensor Types*

The choice of sensor type must be dictated by the process, the deposition material and the physical characteristics of the process chamber. General guidelines for each sensor type produced by INFICON are outlined in the Sensor Data Sheets on the www.inficon.com website. For specific recommendations, consult your INFICON representative.

⚠️ **CAUTION**

**The performance of this Cygnus 2 depends on the careful installation of the chosen transducer. Improper installation will cause problems with deposition repeatability, crystal life and rate stability.**

### *2.1.2 Sensor Installation*

Figure 2-1 shows a typical installation of an INFICON water cooled crystal sensor in the vacuum process chamber. Use the illustration and the following guidelines to install your sensors for optimum performance and convenience.

*Figure 2-1  Typical installation*
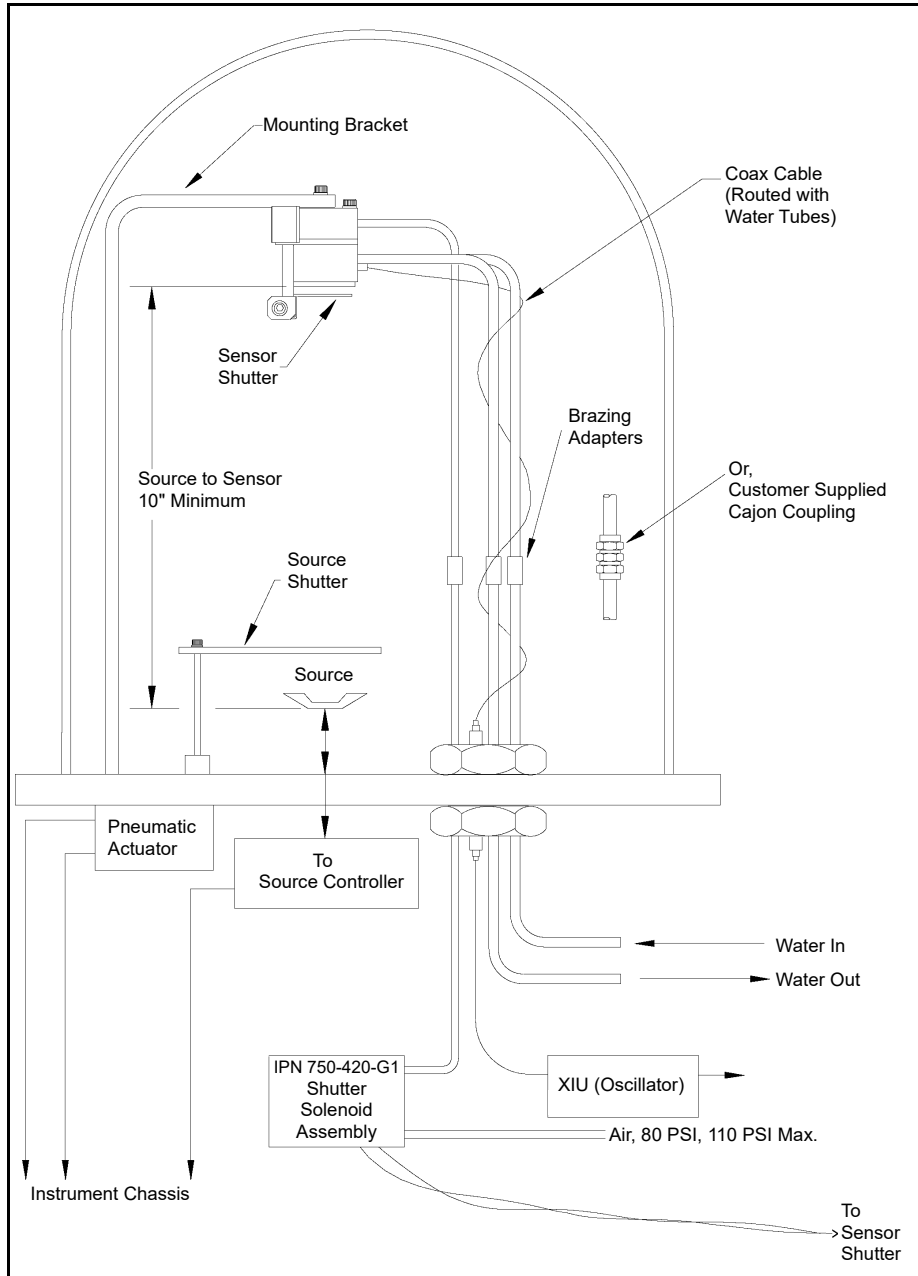
Generally, install the sensor as far as possible from the evaporation source (a minimum of 10 in. (25.4 cm) is recommended) while still being in a position to accumulate thickness at a rate proportional to accumulation on the substrate. Figure 2-2 shows proper and improper methods of installing sensors.

*Figure 2-2  Sensor installation guidelines*
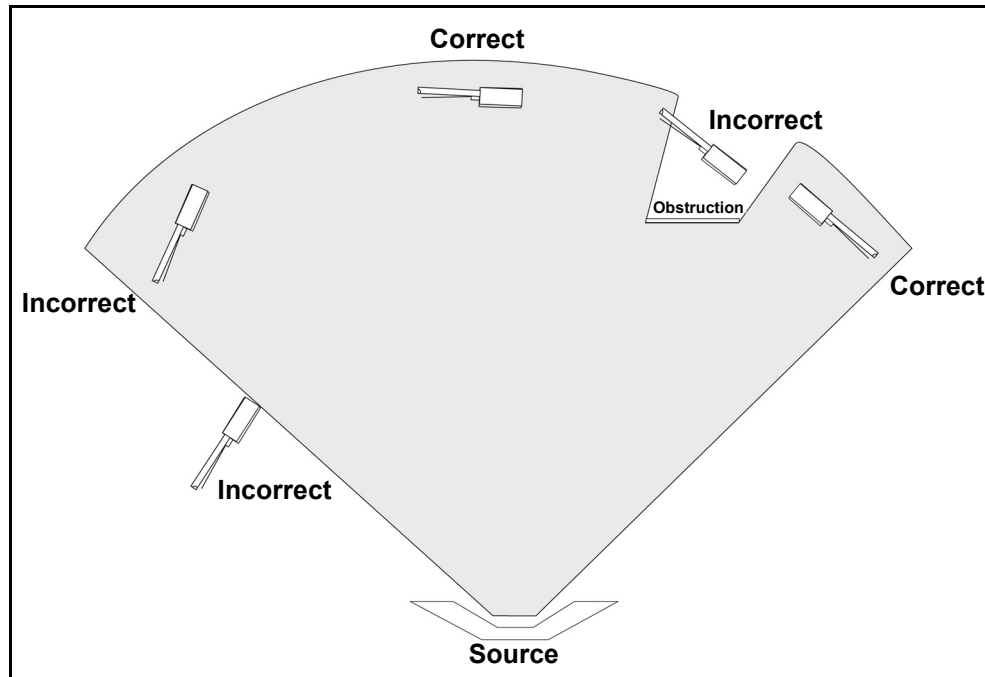


To guard against spattering, use a source shutter or crystal shutter to shield the crystal during the initial soak periods. If the crystal is hit with even a minute particle of molten material, it may be damaged and stop oscillating. Even in cases when it does not completely stop oscillating, it may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

◆ Mount the sensor to something rigid and fixed in the chamber. Do not rely on the water tubes to provide support.

◆ Plan the installation to insure there are no obstructions blocking the path between the sensor and the source. Be certain to consider rotating or moving fixtures.

◆ Install sensors so their central axis (an imaginary line drawn normal to the center of the crystal face) is aimed directly at the virtual source being monitored.

◆ Be sure there is easy access for the exchange of crystals.

◆ For systems employing simultaneous source evaporation (co-deposition), try to locate the sensors so the evaporant from each source is flowing to only one sensor. It is not generally possible to do this without special shielding or optional "material directors."

### 2.1.3 Cygnus 2 Installation

Cygnus 2 is designed to be rack mounted. It may be also used on a table. Cygnus 2 is forced-air cooled, with the air flow exiting the rear of Cygnus 2 for clean room convenience.

It is generally advisable to centrally locate Cygnus 2, minimizing the length of external cabling. The cable from the instrument to the XIU is typically fifteen feet. Thirty, fifty and one hundred foot cables are available.

## 2.2 Avoiding Electrical Interference

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

To maintain the required shielding and internal grounding and ensure safe and proper operation, Cygnus 2 must be operated with all enclosure covers, sub-panels and braces in place and fully secured with the screws and fasteners provided.

⚠️ **CAUTION**

**When using Cygnus 2 with an RF sputtering system, the cable between Cygnus 2 and oscillator should be kept as far away from the RF transmission cable as possible. Interference from the RF transmission cable may cause an erroneous crystal fail.**

### 2.2.1 Verifying/Establishing Earth Ground

If a ground must be established, the following procedure is recommended:

◆ Where soil conditions allow, drive two ten foot copper clad steel rods into the ground six feet apart. Pour a copper sulfate or a salt solution around each rod to improve the ground's conduction. A near zero resistance measurement indicates earth ground is achieved.

◆ Keep connections to this grounding network as short as possible.

## *2.2.2 Connections to Earth Ground*

There are two required earth ground connections:

◆ The earth ground connection on Cygnus 2 is a threaded stud with a hex nut. Connect a ring terminal to the ground strap, thus allowing a good connection and easy removal and installation. This connection must be made at installation. For best protection against high frequency noise, the length-to-width ratio of the earth conductor should not exceed 5:1. See Figure 2-3 for the suggested method of grounding.

◆ This Cygnus 2 is also connected to earth ground via a sealed three-core power cable, which must be plugged into a socket outlet with a protective earth ground terminal. Extension cables must always have three conductors including a protective earth ground conductor.

⚠ **WARNING - Risk Of Electric Shock**

**Never interrupt the protective earth ground intentionally. Any interruption of the protective earth ground connection inside or outside Cygnus 2 or disconnection of the protective earth ground terminal is likely to make Cygnus 2 dangerous.**
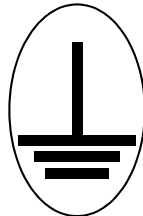
**This symbol indicates where the protective earth ground is connected inside Cygnus 2. Never unscrew or loosen this connection.**

⚠ **CAUTION**

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

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

In many cases, a braided ground strap is sufficient. However, there are cases when a solid copper strap (0.030 in. thick x 1 in. wide) is required because of its lower RF impedance.

*Figure 2-3  System grounding diagram*
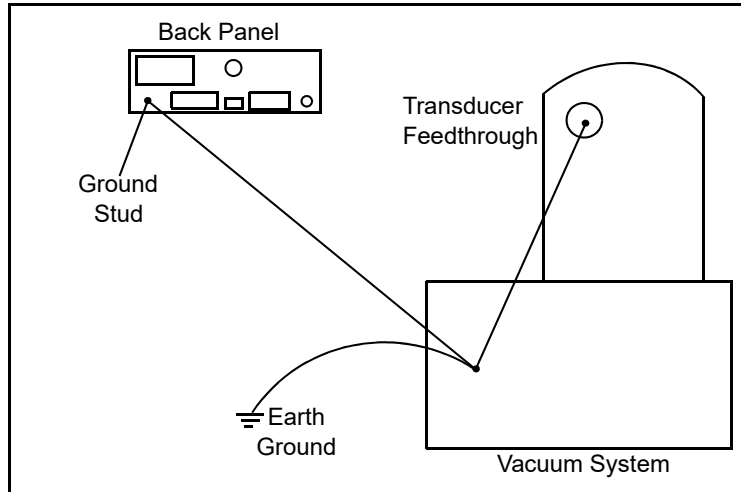


2.2.3  **Minimizing Noise Pickup from External Cabling**

When a Cygnus 2 is fully integrated into a deposition system, there can be many wire connections, each a potential path for electrical noise to reach the inside of Cygnus 2. The likelihood of these wires causing a problem can be greatly diminished by adhering to the following guidelines.

◆   Use shielded coax cable or twisted pairs for all connections.

◆   Minimize cable lengths.

◆   Avoid routing cables near areas that have the potential to generate high levels of interference. For example, large power supplies such as those used for electron beam guns or sputtering sources can be a source of large, rapidly changing electromagnetic fields. Placing cables as little as one foot away from these problem areas can significantly reduce noise pickup.

◆   Be sure that a good ground system and straps are in place per the recommendations in section 2.2.2 on page 2-5.

◆   Ensure that all Cygnus 2 covers and option panels are in place and tightly secured with the provided fasteners.

**NOTE:**  Always use shielded cables when making connections to Cygnus 2 rear panel to minimize electrical noise pickup.

## 2.3 Connecting the Controller

The operation of Cygnus 2 depends on the proper connection of power and signal interfaces to owner equipment and sources.

⚠️ **WARNING - Risk Of Electric Shock**

**This Cygnus 2 has line voltage present on the primary circuits whenever it is plugged into a mains power source.**

**Never remove the cover from Cygnus 2 during normal operation.**

**There are no operator serviceable items within Cygnus 2.**

**Removal of the cover must be done only by a technically qualified person.**

**In order to comply with accepted safety standards, Cygnus 2 must be installed into a rack or system which contains a mains switch. This switch must break both sides of the line when it is open and it must not interfere with the safety earth ground.**

Cygnus 2 is initially powered by AC line current. The line voltage provided in your facility must be within the voltage range shown in section 1.4.10, Power, on page 1-14.

### 2.3.1 Routing XIU Cables

The signals traveling on this cable are both analog and digital. It is suggested that it not be routed near areas with high levels of electromagnetic interference, even if its length must be somewhat increased.

### 2.3.2 Interface Cable Fabrication and Pin-Out

It is necessary to fabricate several cables in order to interface Cygnus 2 to the deposition system. Refer to section 2.2.3, Minimizing Noise Pickup from External Cabling, on page 2-6.

### 2.3.2.1  Source Control Connection

Six Digital-to-Analog (DAC) outputs are provided as standard equipment with Cygnus 2. These standard 6 DAC channels with BNC connectors and six optional DAC outputs on a 15 pin sub-D connector may be programmed for Source control or chart recorder functions as desired.

### 2.3.2.2  Crucible Indexer Connections

Example: 4 pocket crucible using outputs 6 and 7

Number of crucibles = 4

Crucible output = 6

For this example, wiring to the controller is based on Table 2-1. Only relays 6 and 7 are needed to encode the four possible positions.

*Table 2-1  Wiring to the controller*

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

### 2.3.2.3  DAC Option Kit

An optional Digital-to-Analog Converter (DAC) card can be installed into Cygnus 2. This card provides six additional DAC outputs, numbered 7 through 12, for Thickness and/or Rate as determined by the DAC Output Option parameters. The pin assignments for DAC outputs 7 through 12 are shown in Table 2-2.

*Table 2-2  Optional DAC pin assignments*

| Output Number | Pin |
|:---:|:---:|
| 7 | 1, 6 (GND) |
| 8 | 2, 7 (GND) |
| 9 | 3, 8 (GND) |
| 10 | 4, 9 (GND) |
| 11 | 5, 10 (GND) |
| 12 | 11, 12 (GND) |

A mating connector is included with the DAC option.

### 2.3.2.4 I/O Expansion Options

One I/O Relay module is included as standard equipment with Cygnus 2 and is used to interface with other machinery of the vacuum system. It can control components such as heaters, rotators or shutters through its 8 relays. It can respond to external instructions through its 14 isolated input lines. Standard equipment provides 8 relays and 14 input lines. Optionally, this can be expanded to 24 relays, 28 TTL inputs, and 14 open collector type outputs with the addition of another Relay I/O module and a TTL Relay module having 8 relays and 14 TTL open collector outputs.

The modules provide separate connectors for outputs and input lines. A 25-pin D-sub, male connector is used for the eight relays. A 15-pin D-sub, male connector is used for the input lines. Mating connectors are provided. Refer to Figure 3-2 on page 3-3 for connector locations and Table 2-3 on page 2-10 for connector pin assignment. Relay connections are rated at 30 V (dc) or 30 V (ac) RMS or 42 V (peak) maximum; 2.5 A maximum.

Inputs are activated by pulling the specific input terminal to ground (<0.8 V) through a contact closure to common (GND) or with TTL/CMOS Logic having current sink capability of 2 mA (1 low power TTL load).

⚠️ **WARNING - Risk Of Electric Shock**

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

*Table 2-3  Input/Relay pin connections*

| I/O Board #1 | | | | |
|---|---|---|---|---|
| **Relay #** | **Pins** | | **TTL Input #** | **Pin** |
| 1 | 7, 6 | | 1 | 15 |
| 2 | 9, 8 | | 2 | 14 |
| 3 | 11, 10 | | 3 | 13 |
| 4 | 13, 12 | | 4 | 12 |
| 5 | 5, 4 | | 5 | 11 |
| 6 | 3, 2 | | 6 | 10 |
| 7 | 1, 14 | | 7 | 9 |
| 8 | 15, 16 | | 8 | 8 |
| | | | 9 | 7 |
| | | | 10 | 6 |
| | | | 11 | 5 |
| | | | 12 | 4 |
| | | | 13 | 3 |
| | | | 14 | 2 |
| | | | GND | 1 |

| I/O Board #2 | | | | |
|---|---|---|---|---|
| **Relay #** | **Pins** | | **TTL Input #** | **Pin** |
| 9 | 7, 6 | | 15 | 15 |
| 10 | 9, 8 | | 16 | 14 |
| 11 | 11, 10 | | 17 | 13 |
| 12 | 13, 12 | | 18 | 12 |
| 13 | 5, 4 | | 19 | 11 |
| 14 | 3, 2 | | 20 | 10 |
| 15 | 1, 14 | | 21 | 9 |
| 16 | 15, 16 | | 22 | 8 |
| | | | 23 | 7 |
| | | | 24 | 6 |
| | | | 25 | 5 |
| | | | 26 | 4 |
| | | | 27 | 3 |
| | | | 28 | 2 |
| | | | GND | 1 |

| I/O Board #3 | | | | |
|---|---|---|---|---|
| **Relay #** | **Pins** | | **TTL Output #** | **Pin** |
| 17 | 7, 6 | | 25 | 9 |
| 18 | 9, 8 | | 26 | 10 |
| 19 | 11, 10 | | 27 | 11 |
| 20 | 13, 12 | | 28 | 12 |
| 21 | 5, 4 | | 29 | 13 |
| 22 | 3, 2 | | 30 | 14 |
| 23 | 1, 14 | | 31 | 15 |
| 24 | 15, 16 | | 32 | 1 |
| | | | 33 | 2 |
| | | | 34 | 3 |
| | | | 35 | 4 |
| | | | 36 | 5 |
| | | | 37 | 6 |
| | | | 38 | 7 |
| | | | GND | 8 |

### *2.3.2.5 RS-232C Communications*

RS-232C serial communications is included in Cygnus 2 as standard equipment. It can be used to remotely control or monitor Cygnus 2. An industry standard 9-pin D-Sub connector is required for the host computer side connection. Depending on the computer source, all connections may not be necessary. The length of the cable is limited to fifty feet according to published standards. Cygnus 2 interface operates as DCE (Data Communication Equipment). Pin assignments are for Cygnus 2 connector.

*Table 2-4  RS-232C pin connections*

| Signal Name | | Pin | EIA Name |
|---|---|---|---|
| TX | Transmit Data | 2 | BA |
| RX | Receive Data | 3 | BB |
| SG | Signal Ground | 5 | AB |
| GND | Shield Ground | 1 | |

### 2.3.2.6 Isolated +24 V (dc) Supply

An isolated +24 V (dc) power supply is available on a 9-pin D-Sub connector on the Cygnus 2 back panel. This supply is rated for 1.75 Amps maximum.

The pin assignments for this connector are shown in Table 2-5.

*Table 2-5  +24 V (dc) pin connections*

| Pin | Function |
|-----|----------|
| 1 | Return |
| 2 | Return |
| 3 | Return |
| 4 | Not Connected |
| 5 | Not Connected |
| 6 | +24 Volts |
| 7 | +24 Volts |
| 8 | +24 Volts |
| 9 | Not Connected |

⚠️ **CAUTION**

**Both the isolated 24 V (dc) supply and the RS-232C remote communications port use a 9-pin D-sub connector. Care must be taken not to inadvertently connect the RS-232C remote communications cable to the 24 V (dc) supply connector. Also, care must be taken not to inadvertently connect the 24 V (dc) supply cable to the RS-232C remote communications connector.**

# Chapter 3
# Operation

## 3.1  Front Panel Controls

Operational controls for Cygnus 2 are located on the front panel, see Figure 3-1.

*Figure 3-1  Cygnus 2 front panel*
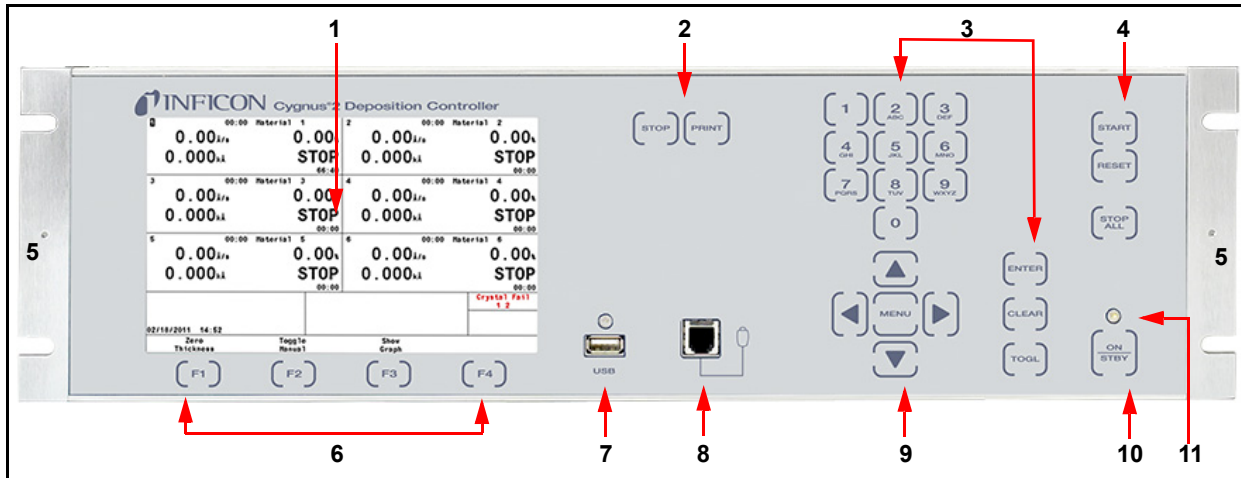


**1   LCD Screen**

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

**2   STOP and PRINT Function Keys**

The STOP key places an individual Material into the Stop state. The Material stopped is designated by the screen cursor position. The PRINT key sends the LCD screen content to the USB storage device.

**3   Data Entry Keys**

A keypad array with numerics 0 through 9 with telephone-style assigned letters for parameter entry. All numeric entries need to be followed by ENTER.

CLEAR is used to erase data entry errors. If an illegal value has been entered, CLEAR will erase the error message and re-display the last valid data. Pressing CLEAR on power-up clears any Lock codes. If no Lock codes are present, all user parameters will be cleared to their default values.

Pressing TOGL moves through selection options such as Yes or No or others such as Sensor types. Pressing ENTER continues with the selected choice.

**4    System Switches**

An array of three keys that provide START, STOP ALL and RESET for process control.

**START**: Starts the cursored Material if in Ready, Idle or Stop and Start Interlock is not in effect.

**RESET**: Places the cursored Material in Stop into the Ready mode.

**STOP AL**L: Places all Materials into the Stop mode.

**5    Handheld Controller Mount**

Tapped hole for attaching support bracket.

**6    F1, F2, F3, F4 Function Keys**

The function keys. They are used to select displays or menu items. Their function is indicated on the display and is described in subsequent sections.

**7    USB**

Receptacle for a storage device.

**8    Remote Control Jack**

Receptacle for the optional wired Handheld Controller (IPN 750-262-G1). For more information on the Handheld Controller, see section 3.5.5 on page 3-31.

**9    Cursor Keys**

An array of five keys used to move the display cursor either up, down, left or right. The MENU key is used to navigate through the Cygnus 2 displays. The keys auto-repeat; the cursor will continue to move as long as the key is held down.

**10   Power**

This switch controls secondary power to Cygnus 2 between ON and STANDBY.

**11   Pilot Light**

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

## 3.2 Rear Panel Interfaces

Interfaces for Cygnus 2 are located on the rear panel, see Figure 3-2.

*Figure 3-2 Cygnus 2 rear panel*
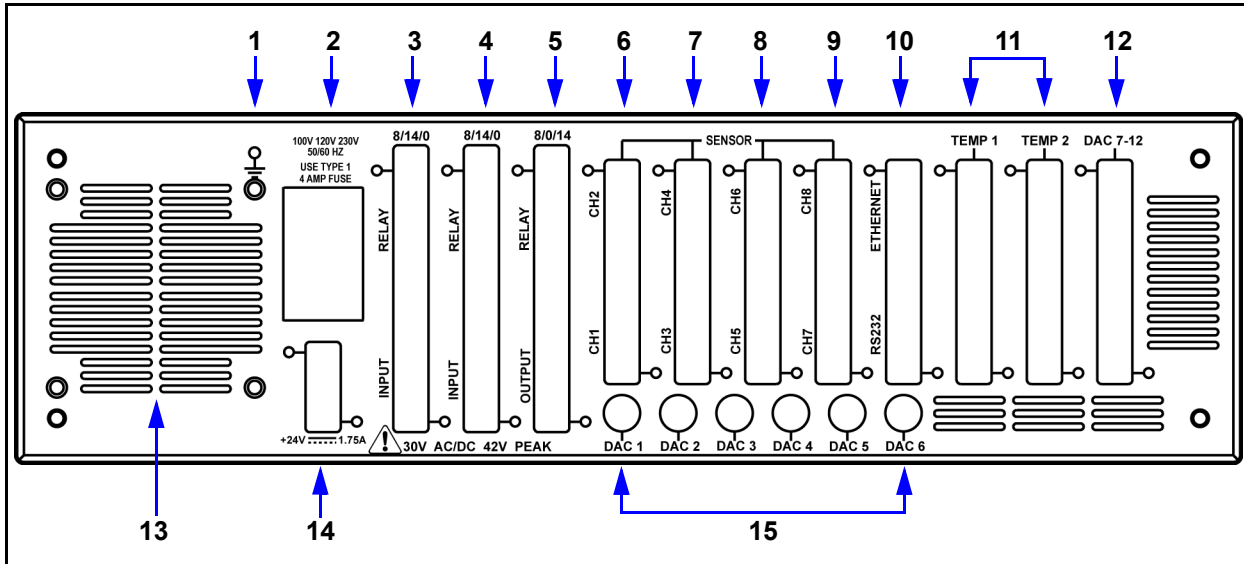


**1 Ground Stud**

Refer to section 2.2.2, Connections to Earth Ground, on page 2-5.

**2 AC Power Inlet, Fuse and Mains Switch**

Provides main power switch, fuse and common connector for international plug sets.

**3 8 Relay x 14 Input I/O Card (standard)**

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

**4 8 Relay x 14 Input I/O Card (optional)**

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

**5 8 Relay x 14 Output I/O Card (optional)**

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

**6 Sensor Connectors - Channels 1 and 2 (standard)**

Provides connection for two Sensor channels.

**7 Sensor Connectors - Channels 3 and 4 (optional)**

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

**8    Sensor Connectors - Channels 5 and 6 (optional)**

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

**9    Not used**

**10   TCP/IP Connector (Optional)**

Provides connections for TCP/IP interface.

**RS-232C Remote Communication Connector (standard)**

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

**11   For future expansion options**

**12   6-Channel DAC (optional)**

Provides recorder output for six channels (15 pin miniature D-sub connector). Outputs are programmable for recorder function.

**13    Fan Outlet**

Exhaust opening for the Cygnus 2's miniature fan; **Do not block!**

**14   24-Volt Supply (standard)**

Provides three 24 V (dc) supplies rated at 1.75 Amps. See Table 2-5 on page 2-12.

**15   6-Channel DAC (standard)**

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

## 3.3 Displays

Cygnus 2 has many display screens for monitoring and programming processes. The five main types of displays are: Operate, Sensor, Source, Material, and General.

To move from one display to another, use the cursor and MENU keys. Figure 3-3 provides an overview of the Main Menu display hierarchy. Figure 3-4 provides an overview of the Operate display hierarchy.

To maximize the life of the display, it can be set to turn off after a period of 1 to 99 minutes without a key press. See section 6.9, AUDIO / VISUAL Page Set Up, on page 6-9. Pressing a key before the dimmer time elapses resets the dimmer interval to start over. The default setting of 0 disables the dimmer function. When the display is dimmed, the START, RESET and STOP keys remain active. To restore the display to full brightness without stopping or starting the instrument, do not press the STOP or START key.

### 3.3.1 Main Menu Display

From the Main Menu screen, see Figure 3-3, move to any Cygnus 2 display by positioning the cursor to highlight the desired display and press the MENU key. A second pressing of the MENU key returns to the Main Menu display.

*Figure 3-3   Main menu*

### *3.3.2 Operate*

The default Operate display shows all six Materials, see Operate screen show all materials on page 1-20. To display an individual Material, cursor to it an d press F3, Show Graph. The Graph Operate display, Figure 3-4, provides information about the current Material in process. This includes the Material, Source #, and Sensor # currently in process. The rate, thickness, power level, state, state time, Material time, and process time are updated once a second.

The graph gives an analog display of the Power% level or the rate deviation from the desired rate while depositing. With the cursor on the upper Y-axis value, use the TOGL key to choose Rate Deviation or Power% graphing. Similarly, with the cursor on the X-axis label, use the TOGL key to choose the desired Graph Scan Rate. These selections will apply to all six Material graphs.

Below the graph is a message area consisting of five lines. The Status Messages area, see section 13.1, occupies the first four lines. Transient Messages, see section 13.4 and Input Error Messages, see section 13.5, share the fifth line. This area displays error messages, custom user messages and system status information, such as indicating Cygnus 2 is in Test mode. Status messages are displayed as long as a status is true. They are put up and taken down as the condition that set them changes. Since there is limited space for the status messages, if too many status messages are displayed at the same time (greater than 4), newer messages will be displayed. If they are cleared, the old messages will appear again assuming the condition is still applicable.

*Figure 3-4  Show graph operate screen*
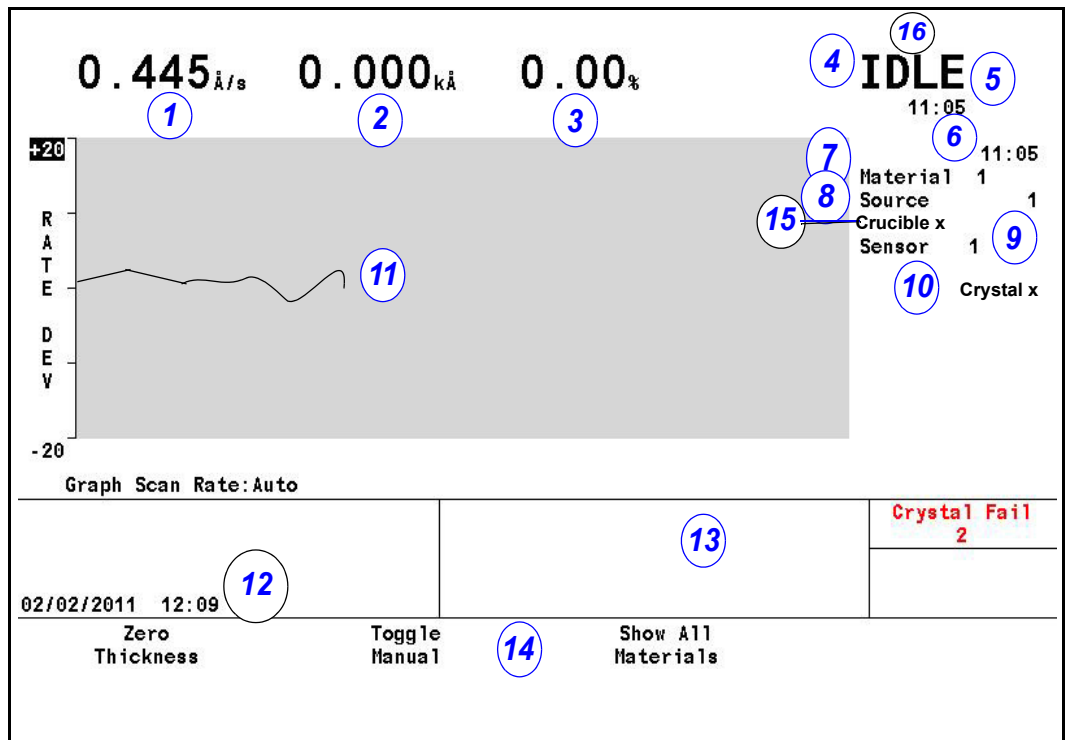
### Operate Display Description

1 **Rate**

2 **Thickness**

3 **Power Level**

4 **State of Material**

5 **State Timer**

6 **Material Timer**

7 **Material Being Deposited**

8 **Source Number In Use**

9 **Sensor Number In Use**

10 **Crystal Position In Use**

11 **Graphical Display of Rate Deviation or Power**

12 **Date and Time**

13 **Message Area**

14 **Function Key Definitions**

15 **Crucible Position**

16 **State preceding Stop**

During the OPERATE display, the function keys below the screen function as explained in Table 3-1.

*Table 3-1  Operate display function keys*

| Key | Function | Description |
|-----|----------|-------------|
| F1 | **ZERO THICKNESS** | Pressing F1 resets the displayed thickness of the current Material to zero. |
| F2 | **TOGGLE MANUAL** | Press F2 to put the Material in manual control so that the power level is controlled by the Handheld Controller (section 3.5.5). When in Manual, press F2 again to remove the Material from the Manual state and place it into the DEPOSIT state. |
| F3 | **SHOW ALL MATERIALS/ SHOW GRAPH** | Press F3 to toggle between showing all Materials (if more are running) or showing only one Material. |

*Figure 3-5  6 Material display*
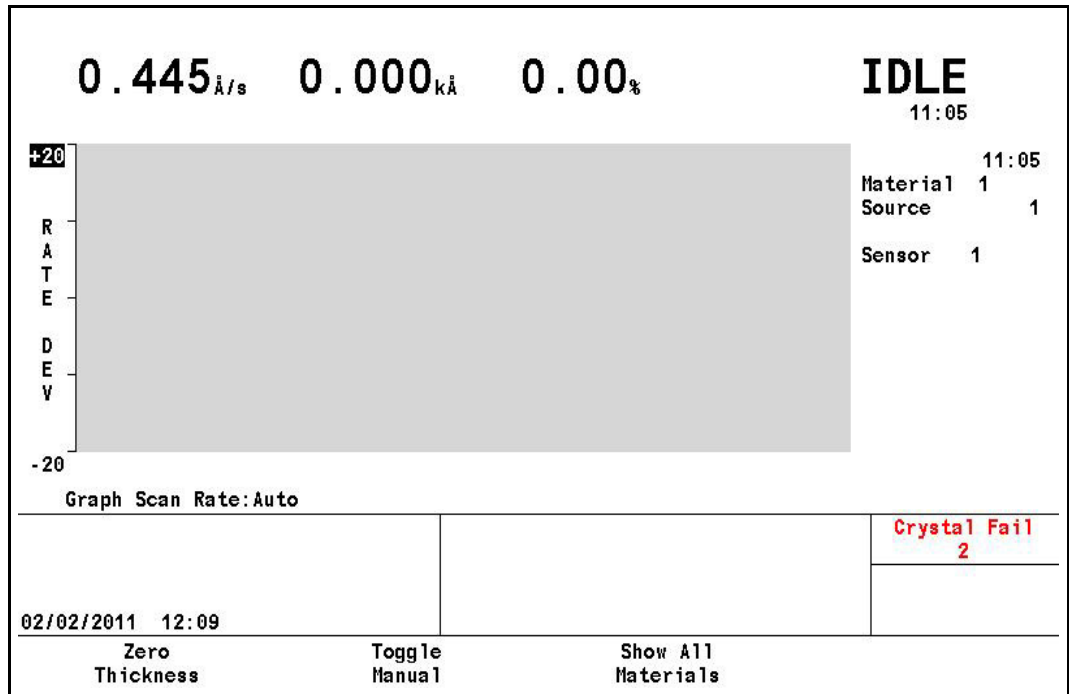


### 3.3.3  Sensor Information

#### 3.3.3.1  Sensor Information Rate/Xtal Display Description

**NOTE:**  N/A (not available) will be displayed in these fields for disabled features or for Sensors not in use.

*Figure 3-6  Rate/Xtal display*
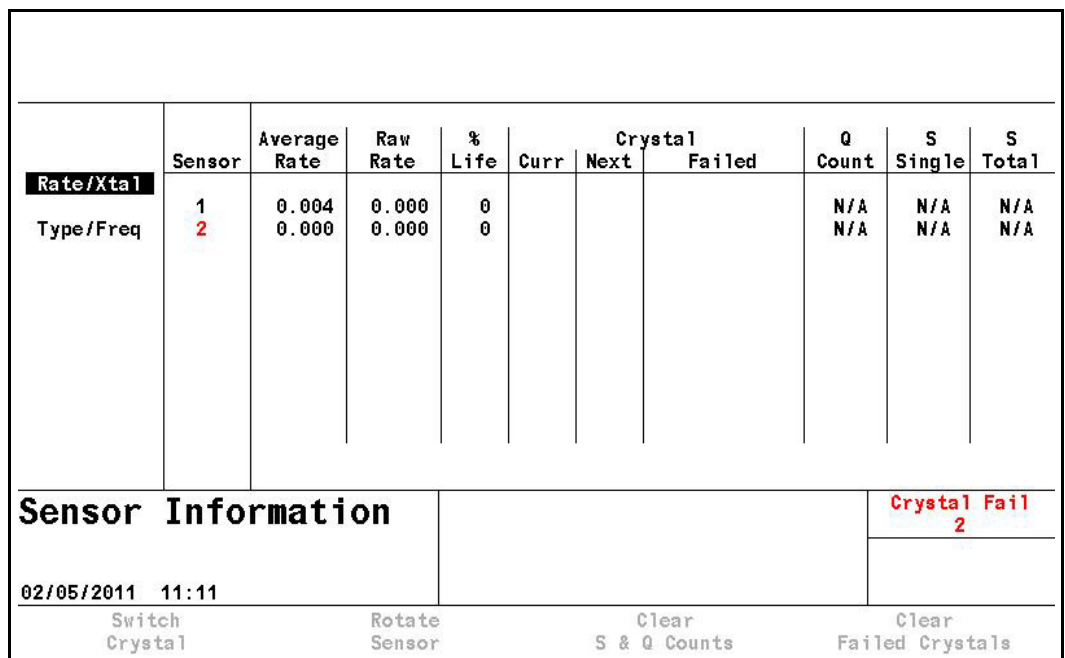
**Sensor (Number field)**

These numbers correspond to the Sensor connector channel numbers on the rear panel of Cygnus 2. Use the cursor keys to position the box cursor over the desired Sensor number. When either Switch Crystal, Rotate Sensor, Clear S & Q Counts, or Clear Failed Crystals is pressed, that function will be performed on the Sensor indicated by the box cursor if Cygnus 2 is in Ready, Stop or all active Materials are in Idle. Text will only be shown for installed cards, unless you are in TEST.

**Average Rate**

This average is calculated based on a 2.5 second average of the Filtered Rate.

**Raw Rate**

Shows the instantaneous rate measurement. The rate fields are useful in identifying if a Sensor's rate measurements are becoming erratic.

**% Life**

Cygnus 2 allows a 1.5 MHz frequency shift from 6.0 to 4.5 MHz on the monitor crystal corresponding to 100% crystal life. The value shown represents the amount of crystal life consumed; 0% corresponds to 6.0 MHz, 100% corresponds to 4.5MHz. The amount of useful crystal life is highly dependent on the nature of the material being deposited as well as deposition conditions.

**Crystal**

This field is subdivided into three categories; current position (**Curr**), next position (**Next**), and **Failed**. Information is displayed in these fields only if the Sensor has more than one position.

**Curr**: For a XtalTwo sensor, the Curr field will show either 1 or 2. 1 indicates the active crystal of the dual sensor head. 2 indicates the inactive (shuttered) crystal of the dual sensor head. For a multi-position sensor, the Curr field indicates the current position of the sensor head.

**Next:**  The Next field indicates the position to which the sensor head will rotate upon pressing the CrystalSwitch function key.

**Failed**: The Failed field indicates the sensor head positions containing failed crystals.

**Q Count (Crystal Quality value field)**

This field displays the value currently accumulated in the Crystal Quality counter when active. Delay indicates the Crystal Quality counter is not active. The Crystal Quality counter will become active five seconds after entering DEPOSIT and if the Crystal Quality parameter is non-zero, .

**S Single (Crystal Stability value field)**

This field displays the positive single frequency shift currently in the Crystal Stability counter, .

**S Total (Crystal Stability value field)**

This field displays the positive total frequency shift currently accumulated in the Crystal Stability counter.

### 3.3.3.2 Crystal Life and Starting Frequency

On the Sensor Information RATE/XTAL display, crystal life is shown as a percentage of the monitor crystal's frequency shift, relative to the 1.50 MHz frequency shift allowed by Cygnus 2. This quantity is useful as an indicator of when to change the monitor crystal to safeguard against crystal failures during deposition. It is normal to change a crystal after a specific amount of crystal life (% change) is consumed.

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

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

### 3.3.3.3 Function Key Selection Choices

To enable the function keys for the Sensor Information Rate/Xtal Display, move the cursor key to a Sensor number.

**F1 Switch Crystal**

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

**F2 Rotate Sensor**

If the Sensor number chosen is a XtalSix, Xtal12 or Generic sensor type, press F2 to sequentially rotate the sensor head through all positions. This is useful to initialize a multi-position sensor after replacing failed crystals. The action is

taken on the Sensor indicated by the box cursor if Cygnus 2 is in Ready, Stop or all active Materials are in Idle. Failed crystal numbers are shown in the Failed column under Crystal.

Generic Sensor Status showing which crystals are good and which are failed relative to the current position is displayed in the bottom region of the table. This information is not retained upon leaving the Sensor Information display. To re-gain this information, press F2 again.

**F3   Clear S and Q Counts**

Press F3 to clear the Quality and Stability counters for the Sensor chosen by the box cursor.

**F4   Clear Failed Crystals**

Pressing F4 resets the status of the Sensor that the box cursor is on for failed Sensors and crystal positions.

### 3.3.3.4  Sensor Information Type/Freq Display Description

*Figure 3-7  Type/Freq display*



**Sensor**

Sensor identifies the Sensor channel. Failed Sensor numbers appear in red.

**Sensor Type**

Shows the Sensor type configured for the Sensor channel.

**Z-Ratio**

This two-column field displays the type and value of the Z-Ratio being used for the given Sensor.

**Matl** indicates the Z-Ratio being used for thickness calculation is the value found in the Material parameter Z-Ratio.

**Auto** indicates Cygnus 2 Auto-Z feature is used for thickness calculations. Auto-Z continually calculates the Z-Ratio for the "as deposited" film. If Cygnus 2 suddenly lost the ability to calculate Auto-Z, Auto would change to either Matl or Sens. Matl has the same meaning as described above, Sens indicates the last calculated Auto-Z value (prior to failure) is used for thickness calculations for this Sensor.

Cygnus 2 determines to use Matl or Sens depending on the frequency of the fundamental resonance. If the fundamental frequency closely matches the last valid fundamental frequency prior to Auto-Z failure, Cygnus 2 will use the Sens value. Otherwise Cygnus 2 will use the Matl value.

**Act(ivity)**

Activity is a measure of the Sensor circuit health or ability to conduct current. The values range from a maximum of 800 (healthiest) to a minimum of 0 (least healthy).

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

Activity also can be used to gauge the health of the sensor head electrical contacts. For example, if a new monitor crystal is placed into the sensor head and has a crystal life of near 0%, but the Activity value for this crystal is lower than 550, this indicates the sensor head or in-vacuum cable is in need of repair.

**Frequency**

This field is subdivided into two categories: **Fundamental** and **Anharmonic**.The Fundamental frequency will be shown for all working Sensors. If Auto-Z is in effect for the Sensor, the Anharmonic frequency will also be shown. Frequency value will be displayed.

### 3.3.3.4.1 TEST XIU

To test any XIU (Crystal Interface Unit), move the cursor onto the respective Sensor number. Pressing F1 then initiates the XIU self test. The XIU self test determines whether the crystal interface unit (XIU) and measurement card pair is operating properly. "XIU Test Passed" message will appear to indicate this. "XIU Test Failed" message will appear when there is a defect in the XIU itself, the XIU interface cable or the measurement card.

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

### 3.3.4 Sensor Screen

From the main MENU display, placing the cursor on Sensor and pressing MENU brings up the Sensor display.

The Sensor Overview display, see Figure 3-8, shows the current configuration for all six Sensors.

*Figure 3-8  Sensor overview display*



Moving the cursor onto one of the Sensor numbers and pressing F1. Select Sensor brings up the Sensor display.

See section 4.1.2, Sensor Parameters, on page 4-2 for programming details.

### 3.3.5 Source

The Source Overview display, see Figure 3-9, shows the current configuration for all six Sources.

*Figure 3-9  Source overview display*



Once the right cursor key has been used to move to one of the six Sources, the Select Source function key will appear. Pressing F1 will then display the Source's parameter screen.

The Source display allows configuring the selected Source.

See section 4.2.2, Source Parameters, on page 4-5 for programming details.

### *3.3.6 Material*

This display is organized into eight sub pages accessible thru the Select Menu described below.

See Chapter 5, Material Set-Up for programming details and screen displays.

#### *3.3.6.1 Overview Page*

The Material Overview display, see Figure 3-10, shows all 6 available Materials. Materials are initially shown as Material 1 to Material 6. Once a chemical formula or other name has been assigned, that name will be shown. See section 5.1.2, Material Definition, on page 5-2

*Figure 3-10  Material overview page*



#### *3.3.6.2 Source Page*

The Material Source page allows entering or editing Density, Z-Ratio, Crucible to use, Control Loop type and associated control loop parameters. The operating limits for Min. and Max Power are also defined here. If desired, a Recorder Output (one of the unused standard six or optional additional six analog outputs) can be selected for Filtered Rate, Thickness, Rate Deviation or Power and the full scale Range value selected. See section 5.1.3, Material Source Page Parameters, on page 5-3.

### 3.3.6.3 Sensor Page

The Material Sensor page, see Figure 3-11, allows selecting the Tooling factor. Other choices will be shown according to the Sensor Type. If the Sensor is a CrystalTwo, the Tooling factor for the secondary crystal can be specified. In the case of a multi-position rotary sensor head, the range of crystal positions to use can be specified.

In addition, Quality and Stability settings are available to force a crystal switch to a backup crystal when the primary crystal starts to become unstable.

*Figure 3-11  Material sensor page*



### 3.3.6.4 Pre/Post Page

Up to three pre-deposition phases with rise times, power levels and soak times can be specified. Also, Auto Soak 2 can be enabled as well as Shutter or Control Delay. See section 5.1.5, Pre/Post Screen Deposit Page Parameters, on page 5-10.

### 3.3.6.5 Deposit Page

Set the desired deposition rate, Final Thickness, Thickness Limit, Time Limit, Rate Filter Time, Time Power Avg Time, Ion Assist Deposit, and the state to enter after reaching Final Thickness.

Two new rates can be specified while in Deposit and RateWatcher can be enabled.

See section 5.1.7, Deposit Page Parameters, on page 5-14.

#### 3.3.6.6 Lib A-Hf, Lib Hf-Sc, Lib Sc-Z Sub-Displays

These three libraries allow convenient selection of a Material by its chemical formula along with the correct density and Z-Ratio values. Cursor to a Material formula, then press F1 Define Material to select that Material. The Material/Source display will be shown where the remaining parameters can be entered. See section 5.1.2, Material Definition, on page 5-2.

### 3.3.7 General

The General screen is organized into eight sub screens described below.

See Chapter 6, General Parameters for programming details and screen displays.

#### 3.3.7.1 Process Page

The Process page shows global parameters and allows editing them.

*Figure 3-12  Process page*



| | | |
|---|---|---|
| **Process** | Thickness Eq 1 | 0 |
| | Thickness Eq 2 | 0 |
| DACs | Thickness Eq 3 | 0 |
| Comm | | |
| Message | | |
| Date/Time | | |
| Test | | |
| Lock | | |
| Audio/Visual | | |

General      Carousel Open 4      Crystal Fail 2

02/05/2011  12:03

**Thickness Eq 1, 2 and 3** . . . . . . . . . allows summing of thicknesses from up to 6 Sources for use in conjunction with a logic statement Thick Sum event.

See section 6.2, General Process Page, on page 6-1

#### 3.3.7.2 DACs Page

Polarity and full scale voltage for all DAC outputs are configured here. 0 output corresponds to 0 Volts. See section 6.3, DACs Page Parameters, on page 6-2.

### 3.3.7.3  Comm Page

Datalogging of crystal data is enabled here and RS232 and optional Ethernet parameters are entered.

◆ Datalog Xtal Info

◆ RS232 / Baud Rate/ Protocol

◆ Ethernet / IP Address/ Net Mask

See section 6.4, COMM Page Parameters, on page 6-3.

### 3.3.7.4  Message Page

Ten messages of up to 19 characters each can be entered. Display of messages can be turned on and off using Logic statements.

See section 6.5, MESSAGE Page Set-up, on page 6-5.

### 3.3.7.5  Date/Time Page

Toggle between date formats and enter the current date and time.

Date Format . . . . . . . . . . . . . . . . . . . Calendar/ Day/ Month/ Year

System Time. . . . . . . . . . . . . . . . . . . See section 6.6, DATE / TIME Set Up, on page 6-6.

### 3.3.7.6  Test Page

Allows executing the programmed Material with a dummy rate signal.

Test . . . . . . . . . . . . . . . . . . . . . . . . . On/Off

Time Compressed . . . . . . . . . . . . . . No/Yes to speed up all times by factor of 10

Advanced Test . . . . . . . . . . . . . . . . . On/Off. Responds to crystal failures in "On" mode.

See section 6.7, TEST Page Set Up, on page 6-7.

### 3.3.7.7  Lock Page

Allows setting lock codes to prevent parameter changes or file access.

Program Lock Code/ File Access Code

See section 6.8, LOCK Page Code Set-up, on page 6-8.

### 3.3.7.8  Audio/Visual Page

Audio Feedback: turns key beep on or off.

LCD Dimmer Time: 0 disables, sets time in minutes for screen to be turned off after no keys pressed and no Materials are running7.

See section 6.9, AUDIO / VISUAL Page Set Up, on page 6-9.

### 3.3.8 Digital I/O

The Digital I/O displays show configuration of all inputs, see Figure 3-13, and outputs, see Figure 3-14, and allows configuring inputs and outputs on the three possible I/O boards. See Chapter 7, Digital I/O for programming details.

*Figure 3-13  All inputs display*



**NOTE:** On All Input and All Output pages, active inputs and outputs are displayed in a standard font. Inactive inputs and outputs are displayed in a shadow font.

*Figure 3-14  All outputs display*

### 3.3.9  Logic

100 logic statements can be set up. Logic statements are evaluated sequentially, 10 times per second, while Cygnus 2 is powered up.

See Chapter 8, Logic Statement Set-Up for programming details.

### 3.3.10  Maintenance

The Maintenance display is organized into two subscreens: Source Maint(enance) and Sys(tem) Status.

See Chapter 10, Maintenance and Calibration Procedures for programming details.

### 3.3.11  Counter / Timer

See Chapter 11, Counters and Timers.

### 3.3.12  USB Storage

Config . . . . . . . . . . . . . . . . . . . . . . . allows saving and retrieving configuration files to and from the USB storage device.

Datalog . . . . . . . . . . . . . . . . . . . . . . shows datalog files on USB storage device.

Screen Shot . . . . . . . . . . . . . . . . . . shows Print files on USB storage device.

See Chapter 12, USB Storage.

### 3.3.13  Programming Guidelines

**1**  Define Materials.

To define Materials, the MATERIAL pages of the MATERIAL screen are used. Each of up to 6 distinct Materials used must be defined. The Material definition includes rate, density, Z-ratio, tooling, soak power settings, thickness, RateWatcher, rate ramps, time limits and whether to STOP on max power. Control loop characteristics also relate to the Material. Also, one Source and one Sensor are automatically associated with each Material, for example Source 1 and Sensor 1 are fixed to Material 1, etc. up to Source 6 and Sensor 6 for Material 6. See Chapter 5 for a detailed description for programming these parameters.

**2**  Configure General parameter information.

The final step in defining a process is to program the parameters on the GENERAL display. This includes the Process Thickness Equations, DAC voltage and polarity, Communication parameters, User Messages, Date/Time, Test mode, Lock Codes and Audio Feedback as well as LCD Dimmer time. See Chapter 6 for a detailed description of General parameters.

*Figure 3-15  Process state diagram*
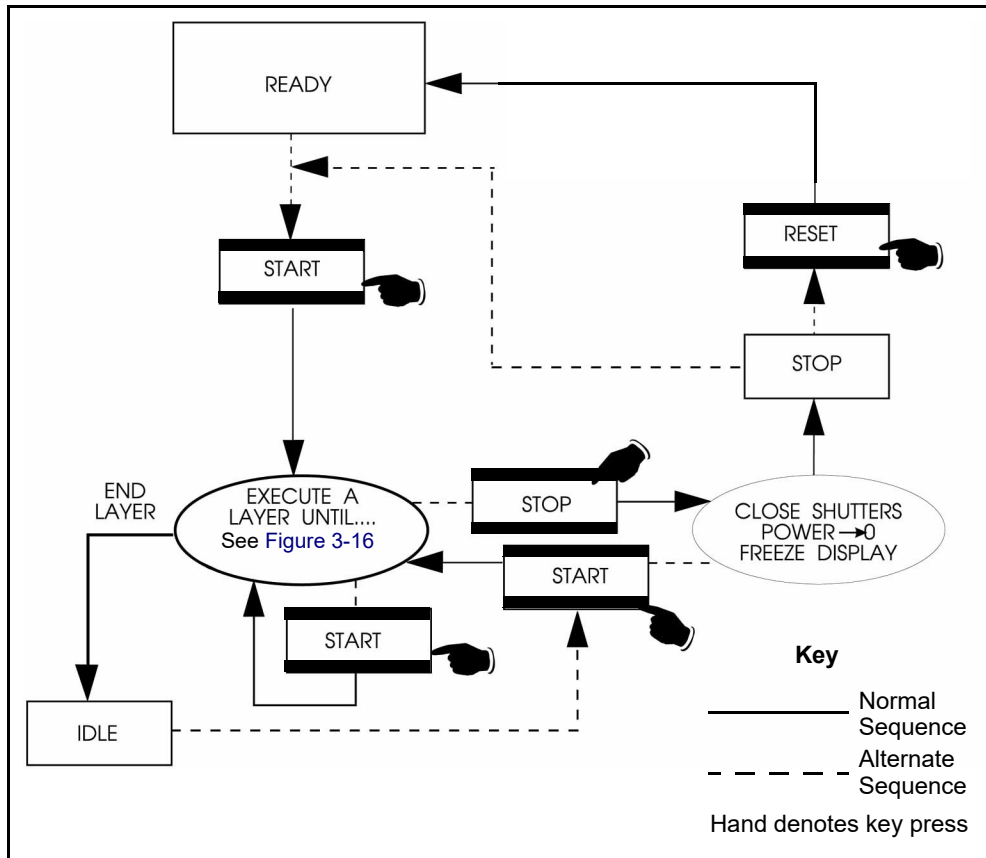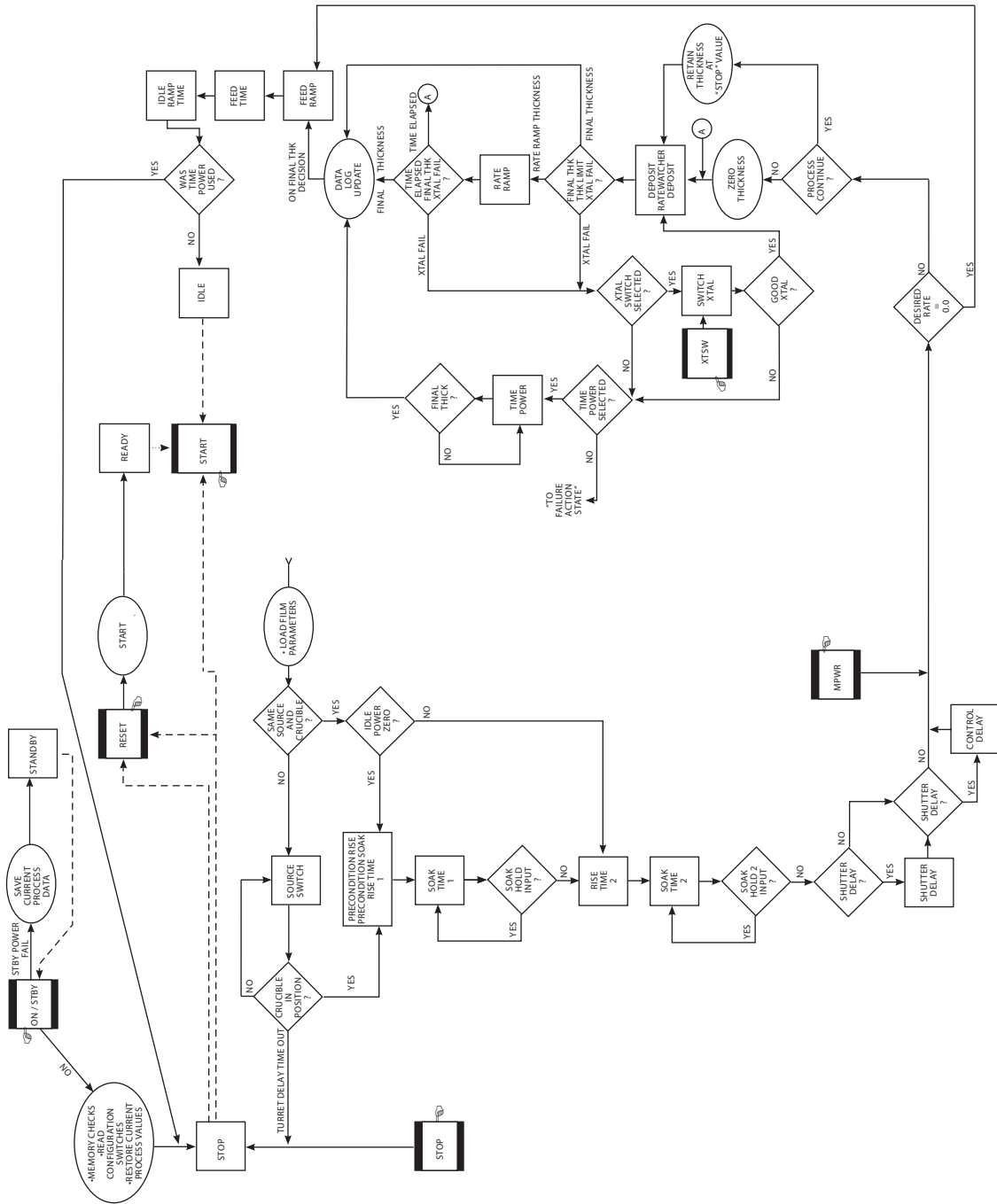
*Figure 3-16  Simplified Cygnus 2 state sequence diagram*

## 3.4  State Descriptions

*Table 3-2  State descriptions*

| STATE | CONDITION | RELAY CONTACT STATUS | | REMOTE COMM ENCODES |
| --- | --- | --- | --- | --- |
| | | **Source Shutter** | **Sensor Shutter** | |
| | | | | |
| 1.  **READY** | Cygnus 2 will accept a START command. | Inactive | Inactive | 0 |
| 2.  **CRUCIBLE SWITCH (Crucible Sw)** | During this state, the crucible turret is being moved from its current position to the one called out for the given Material. If the idle power of the Source in use is not zero the power is set to zero before the crucible position changes. Cygnus 2 advances to next state when turret input goes low for the programmed position or turret delay has elapsed (depending on parameter settings). | Inactive | Inactive | 1 |
| 3.  **PRECON RISE** | Source power rises to Precondition power level over the precondition rise time. [PreCon Rise Time] | Inactive | Inactive | 2 |
| 4.  **PRECON SOAK** | Source is maintained at precondition power level for the precondition soak time. [PreCon Soak Time, PreCon Soak Power] | Inactive | Inactive | 3 |
| 5.  **RISE  1** | Source is rising to Soak Power 1 level. [Rise Time 1] | Inactive | Inactive | 4 |
| 6.  **SOAK 1** | Source is being maintained at Soak Power 1 level. [Soak Time 1, Soak Power 1] | Inactive | Inactive | 5 |
| 7.  **RISE  2** | Source is rising to Soak Power 2 level. [Rise Time 2] | Inactive | Inactive | 6 |
| 8.  **SOAK  2** | Source is being maintained at Soak Power 2 level. [Soak Time 2, Soak Power 2] | Inactive | Inactive | 7 |
| 9.  **SHUTTER DLY** | Rate is being controlled. Advances to Deposit State once the Source is in Rate Control within Shutter Delay Accuracy for 5 seconds. | Inactive | Active | 8 |
| 10. **DEPOSIT** | Rate control. [Rate, Final Thickness, PID Control, Process Gain, Primary Time Constant, System Dead Time] | Active | Active | 9 |
| 11. **RATE RAMP 1** | Rate control, desired rate changing. [New Rate 1, Start Ramp 1, Ramp Time 1] | Active | Active | 10 |
| 12. **RATE RAMP 2** | Rate control, desired rate changing. [New Rate 2, Start Ramp 2, Ramp Time 2] | Active | Active | 11 |

*Table 3-2  State descriptions (continued)*

| STATE | CONDITION | RELAY CONTACT STATUS | | REMOTE COMM ENCODES |
|---|---|---|---|---|
| | | Source Shutter | Sensor Shutter | |
| **13. TIME POWER** | Crystal failed; Source maintained at average control power and average rate prior to crystal failure. [Failure Actions] | Active | Inactive | 12 |
| **14. Manual** | Manual is entered via front panel key or remote communications command.<br><br>Thickness is incrementing if Source shutter is open. The Source power is controlled by the hand-held controller or remote communications | Active or Inactive<br>depending on the state when manual is entered. Shutter can be opened or closed by the operator via remote communications during manual. | Active<br>Shutter can be opened or closed by operator via remote communications during manual. | 13 |
| **15. (Non Deposit Control) NonDep CNTL** | The state is entered after the pre-deposit (if "Dep after Pre-dep" parameter set to no) or via external stimulus (remote command, digital input) or after deposit if "On Final Thickness" set to Non-Deposit Control. Thickness is not incrementing. The Source power is controlled to the desired rate by the control loop. The state is ended via external stimulus. | Inactive | Active | 14 |
| **16. NonDep Hold** | Non-deposit hold is entered when in non-deposit control and there are no available crystals to continue the control if the time power option had been chosen. Non-deposit hold can also be entered from time power using the RL3 Remote command. Thickness is not incrementing. The Source power is maintained at the average control power prior to the crystal failure. Both aggregate rate and power can be adjusted via. remote communications. The state is ended via external stimulus. | Inactive | Inactive | 15 |
| | | | | |
| **17. FEED RAMP** | Source changing to Feed Power level. [Feed Power, Feed Ramp Time] | Inactive | Inactive | 16 |
| **18. FEED** | Source maintained at Feed Power level. [Feed Time] | Inactive | Inactive | 17 |
| **19. IDLE RAMP** | Source changing to Idle Power level. [Idle Ramp Time, Idle Power] | Inactive | Inactive | 18 |

*Table 3-2  State descriptions (continued)*

| STATE | CONDITION | RELAY CONTACT STATUS | | REMOTE COMM ENCODES |
|-------|-----------|:---:|:---:|:---:|
| | | Source Shutter | Sensor Shutter | |
| **20. IDLE** | Source resting at Idle Power; will accept a START command. | Inactive | Inactive | 19 |
| **21. STOP** | The respective Material's Source output is set to zero power. The Material's display is frozen at the last thickness value. | Inactive | Inactive | 20 |
| **NOTE:** In STOP Cygnus 2 will accept a START provided a valid crystal is available for the Material being started. | | | | |

# 3.5  Special Features

Cygnus 2 has several special features to enhance the performance of the instrument.

## 3.5.1  Crystal Switching

Cygnus 2 offers a choice of Single, XtalTwo (CrystalTwo®), XtalSix (CrystalSix®), Xtal12 (Crystal12®), or Generic sensors. The CrystalTwo, CrystalSix, Crystal12, and Generic sensors provide one or more backup crystals in case a crystal fails during deposition. Sensor types are specified on the Sensors screen.

The XtalTwo option requires the 779-220-G1 or 779-220-G2 XTAL2 Switch. The XTAL2 Switch is connected to any Sensor input through an XIU package.

All multi-position and shuttered sensors require the Pneumatic Actuator Control Valve, part number 750-420-G1, and a feedthrough with an air tube.

A crystal switch will automatically occur when:

- Cygnus 2 is configured for a XtalTwo (CrystalTwo) sensor type, a Material is STARTed or running and there is another good crystal available when the active crystal fails.

- Cygnus 2 is configured for a XtalSix, Xtal12 or Generic, a Material is STARTed or running, and there is at least one good crystal left in the carousel when the active crystal fails.

- Using a XtalSix or Xtal12 and pressing START if the current position is not within the First/Last Xtal position range listed on the Sensor page of the Material screen.

- S and Q levels are exceeded while in deposit.

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

◆ During a state of STOP, READY or IDLE.

◆ When the designated Sensor fails during pre-deposit. (A Stop Material will occur if the failure action is configured for Time Power.)

◆ During deposition if the secondary crystal of a XtalTwo switch fails, or the last good crystal of a XtalSix, Xtal12 or Generic fails. (In either case a TIME-POWER, STOP Material, POST DEPOSIT, or STOP ALL will occur, depending on the failure option chosen.)

A crystal switch can be manually executed via the front panel, handheld controller, remote communications, or logic statements when the system is configured for a multi-position sensor.

**NOTE:** When crystal switching with the handheld controller, Cygnus 2 must be on the Sensor Information screen and the cursor on the appropriate Sensor number.

### 3.5.1.1 XtalTwo (CrystalTwo)

In the case of the XtalTwo (a Dual Sensor head with a 779-220-G1 or 779-220-G2 XTAL 2 Switch), the CrystalSwitch output must be wired so that it simultaneously energizes the Pneumatic Shutter Actuator Control Valve which applies the air pressure to actuate the dual sensor shutter mechanism and the RF relay in the XTAL 2 Switch, exposing crystal #2 while covering crystal #1 and rerouting the RF signal. This allows the dual sensor to be operated with only one oscillator kit and requires only one Sensor connection at Cygnus 2.

Power-up initialization is performed on a dual sensor to verify that the secondary crystal is good.

If a crystal fail occurs while in Deposit, Cygnus 2 will switch to the second crystal and continue. The Failed Crystal list can be cleared while in Deposit by pressing the F4 function key on the Sensor Information screen with the cursor positioned on the appropriate Sensor number. While in Ready, the Failed Crystal list can also be cleared by executing a crystal switch with the Hand held controller or by pressing the Switch Crystal function key in the Sensor Information screen or via communications command RG23 (Switch Sensor) see section 9.4.31, Remote General Action, on page 9-43. A good crystal must be available to switch to in the case of using the crystal switch method.

### 3.5.1.2  XtalSix (CrystalSix)

On power-up, all crystals are read to determine how many good and bad crystals are present. Cygnus 2 uniquely identifies and tracks all six positions in the CrystalSix.

During deposition, Cygnus 2 will automatically switch to the next position with a good crystal when there is a crystal failure. When the last good crystal fails the Xtal Fail message is displayed, the Xtal Fail state becomes true and Cygnus 2 will go directly to Time Power, POST DEP, STOP Material or STOP ALL, as appropriate.

When the Sensor selected is a XtalSix, the relay contacts are pulsed closed for one second, opened for one second, closed for one second, then opened for each position. The first one second closure will advance the CrystalSix carousel into an intermediate position between two crystals. Opening the closure for one second allows the ratchet mechanism to relax whereupon the second contact closure advances the next crystal into the proper position.

### 3.5.1.3  Xtal12 (Crystal12)

On power-up, Cygnus 2 will rotate the Sensor until position 1 is detected. It will continue to rotate through the other 11 positions to determine the state of all crystals. At the conclusion of the sequence, the Sensor Information screen shows the Sensor in position 1 and the position number of any failed crystals. The Crystal12 has resistors electrically in parallel for each of the 12 positions. Cygnus 2 verifies that the resistance value is correct at each position. If the value is not as expected, Cygnus 2 pulses again and rechecks the position. If position 1 is not detected or after 13 pulses of the wrong value, Cygnus 2 reports a Crystal Sw Fail message. In that case, all crystals are also marked as failed, except for current position status.

When the carousel is removed from the Sensor for crystal replacements, Cygnus 2 displays Carousel Open. This message also appears if the connection between the XIU (oscillator) and the sensor is absent. After the carousel is replaced, Cygnus 2 assumes the current position is 12 and all crystals are failed. A Crystal Switch or Rotate Sensor function must be initiated in the Sensor Information screen or via Remote Communication to enable Cygnus 2 to catalog the state of all crystals and to return to position 1. This must also be done after the Sensor type has been changed to Xtal12. The Rotate Head function is permitted only if the Material is in Ready, Stop or Idle.

During deposition, Cygnus 2 will automatically switch to the next position with a good crystal when there is a crystal failure. When the last good crystal fails, the CrystalFail message is displayed, the Xtal Fail state becomes true and Cygnus 2 will go directly to Time Power or STOP ALL, POST DEP, STOP Material, as appropriate.

When configured for a Xtal12, the relay contacts are only pulsed closed for one second then opened again once for each position. There is no intermediate position.

### 3.5.1.4 Generic Sensor Crystal Switching

Selecting Generic as the Sensor type enables sequential crystal switching for the # Positions selected (maximum of 12). Upon a crystal switch, the Switch Output will first close for the Pulse On time and then open for the Pulse Off time. The setting # Pulses determines how many On/Off pulse sequences will occur for each movement to the next crystal position. Cygnus 2 will not keep track of which position the Generic Sensor is on nor will it keep track of which crystals are good and which are failed. The Position Selection feature is not available for the Generic sensor.

After a crystal switch sequence, Cygnus 2 will attempt to find the resonant frequency for the crystal in this position. If Cygnus 2 does not find a good resonant frequency for this crystal, it will again pulse the Crystal Switch Output and attempt to find a resonant frequency at the next position. The maximum number of attempts to find a good resonant frequency is one less than the # Positions value. If a good resonant frequency is not found after all attempts, Cygnus 2 will enter the Time Power, POST DEP, STOP Material or STOP ALL state depending on the Sensor / Option Action chosen in the Material/Sensor display.

Start resets all crystal fail flags to good.

## 3.5.2 Source/Crucible Selection

Cygnus 2 can control a Source with up to 64 crucibles through up to six binary encoded relays. This is configured by setting the Number Of Crucibles, Crucible Outputs, Turret Feedback, Turret Input, and Turret Delay parameters on the SOURCE page of the SOURCE screen. (See section 4.2.2, Source Parameters, on page 4-5 for details on programming the parameters associated with Source/crucible selection.)

To define which crucible to use for a Material, set the Cruc(ible) parameter on the MATERIAL/Source screen. When the Material is started, if the current crucible position is different from the one requested, the system's turret controller will move the crucible into position. This will be signified on the OPERATE screen by the state indicator CRUCIBLE SW(ITCH). The Material sequencing will continue on to Pre-condition Rise Time after either the turret delay time expires or an input indicates the turret is in position, depending on which option is chosen. The specific method used is determined by the parameter Turret Feedback on the SOURCE screen.

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

### 3.5.2.1 Example: Programming Turret Source Crucible Selection

Interfacing a turret source controller to Cygnus 2 requires both hardware connections to the turret controller and properly defining certain Cygnus 2 parameters.

Proceed to the SOURCE screen and choose the Source that is going to be defined as the turret source. This is accomplished by Editing the chosen Source as follows:

**1** Designate the Number of Crucibles; for example, four.

**2** Select the Crucible Output. This defines the number of the first relay that encodes the crucible number selected by the active Material. Relays are defined sequentially with the first relay containing the least significant bit (LSB). The greater the number of crucibles selected, the greater the number of relays required. The number required is based on binary encoding (actual coding is binary -1, with 00 representing position 1 and 11 representing position 4). Any unused sequence of relays may be used if it is long enough to provide sufficient selections. Outputs are NO (Normally Open).

**3** Determine whether Turret Feedback is desired. This allows the turret position controller to stop further Cygnus 2 processing until the requested turret position is satisfied. If chosen, a turret input must be connected to the turret position controller's feedback signal.

Enter a Turret Delay Time which allows an adequate time for positioning to take place. Once the delay time has expired, Cygnus 2 state processing continues.

**4** The selection of a particular crucible for a Material is defined in the Material page.

### 3.5.3 Auto-Z

The Auto-Z feature of Cygnus 2 automatically determines the Z-Ratio of a crystal. This feature is enabled on the SENSOR page of the SENSOR screen. For the theory behind Auto-Z, see section 14.1.6, Auto-Z Theory, on page 14-9.

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

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

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

**1** New Crystal

The first category is for a "new" crystal, one that does not have any material deposited onto it. If both frequencies fall within the allowed range for new crystals, Cygnus 2 will allow an Auto-Z calculation with this crystal.

**2** Known, Used Crystal

The second category is for a "known, used" crystal, to account for the possibility that a person would remove a good monitor crystal and then reinsert the same crystal. Whenever a crystal fail occurs, the last valid crystal frequencies are stored in Cygnus 2. Upon inserting a coated monitor crystal, the measured frequencies for this crystal will fall outside of the allowed range for "new" crystals. These frequencies are then compared with the stored values to determine if this crystal is the same one as was in use prior to the crystal fail. If the crystal is the same as used previously, and Auto-Z was being calculated previously, Cygnus 2 will allow an Auto-Z calculation with this crystal.

**3** Unknown, Used Crystal

The third category is for an "unknown, used" crystal. This category is for a used crystal that, upon insertion, shows measured frequencies that are outside of the allowed "new" crystal range and also do not match the frequencies stored within Cygnus 2. This results in an "unable to Auto-Z" condition because the initial frequencies of the uncoated monitor crystal are not known.

**4** Unable to detect anharmonic frequency.

As mass is deposited onto the crystal, the oscillation is damped. This damping may be severe enough that the resonance can no longer be determined. If Cygnus 2 loses the ability to measure the first anharmonic frequency, but is still able to determine the fundamental frequency, the "unable to Auto-Z" message is displayed. Cygnus 2 will then continue to use the fundamental frequency to monitor the deposition.

If Cygnus 2 loses the ability to measure the fundamental frequency and all available crystals in a multi-position sensor head are flagged as failed, the Crystal Fail message is displayed and the Xtal Fail logic state becomes true.

**5** Unable to Auto-Z

An "unable to Auto-Z" condition occurs whenever:

◆ The anharmonic frequency cannot be measured.

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

### 3.5.4  Rate Watcher

Cygnus 2 includes a sample and hold function which enables periodic sampling of the deposition rate by opening and closing the Sensor shutter. If you are controlling inherently stable deposition sources, this function is useful in maximizing crystal life. When RateWatcher is enabled, during deposit, rate control will be established. The Sensor shutter will close for a designated amount of time. The shutter will once again be opened to validate and adjust the power level. This procedure is repeated throughout the deposition. Three Material/Deposit parameters—RateWatcher Option, RateWatcher Time and RateWatcher Accuracy—control this function. See section 5.1.7, Deposit Page Parameters, on page 5-14.

### 3.5.5  Handheld Controller

A Handheld Controller, see Figure 3-17, is available as an accessory with Cygnus 2. The Handheld Controller serves as a wired remote to manually control power, switch crystals and produce a STOP.

The Handheld Controller is attached to Cygnus 2 with a modular plug to the front panel.

Power is affected only when in Manual mode by moving the POWER/STOP switch laterally. Pressing to the left as indicated by the INCR arrow, increases the power. Pressing to the right as indicated by the DECR arrow, decreases the power.

A STOP is produced by moving the POWER/STOP switch down.

When on the Sensor Information screen, a crystal switch is activated by pressing the red button on the body of the controller.

The Handheld Controller kit includes a convenience hook for the Handheld Controller that can be attached to Cygnus 2's mounting ears or some other accessible location.

*Figure 3-17  Handheld controller*
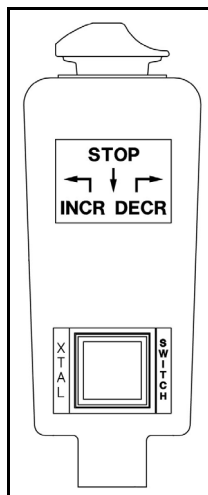
#### 3.5.5.1 Determining Soak Power with the Handheld Controller

The Handheld Controller is a useful tool that can be used to determine the appropriate Soak Power levels. Below is an example of how a typical process Soak 1 and Soak 2 can be determined using the Handheld Controller.

**Determining Soak 1**

Use the Handheld Controller to slowly increase power, a few percent-per-minute. Watch the rate until some rate increase is detected. Depending on the type of source used, this may take several minutes. Once a non-zero rate is achieved, note the current percent power. Use a percent or more lower than this for the Soak Power 1 parameter.

**Determining Soak 2**

After ~30 - 60 seconds of Soak 1, using the Handheld Controller, again slowly increase the power a percent at a time until the desired Deposition Rate is reached. Use a percent or two less than this number for the Soak Power 2 parameter.

### 3.5.6 Test Mode

Test can be turned on or off in the General/Test display page. "Test" will be shown in red while Test mode is active.

#### 3.5.6.1 Standard or Time Compressed

This Cygnus 2 contains a software-controlled test mode which simulates actual operation. In Time Compressed mode, all Material times are sped up so that a long process can be simulated in one tenth of the time. The purpose of the test mode is to verify basic operation and to demonstrate typical operation. The rate display during test mode operation is:

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

Crystal fails are ignored in these test modes. Auto crystal switching is disabled. All other relays and inputs operate normally.

#### 3.5.6.2 Advanced Test

In Advanced Test mode, crystal fails are recognized and auto crystal switching is enabled.

### 3.5.7  USB Storage Device

The USB port allows storage of all parameter information, screen shots as well as automatic datalogging information to a storage device. The maximum number of files which may be stored depends on the storage device memory size. Cygnus 2 is limited to displaying 120 files as 8 pages of 15. The directories are Config, Datalog and Screen Shot.

The parameter set may be stored under a new or existing filename and retrieved from an existing file. A file containing the Cygnus 2 parameter set is referred to as a configuration file. Datalog information will be saved only if the USB Datalog Format setting in the Datalog page of the USB Storage screen is set to Comma or Page.

Multiple files may be contained on one storage device. Filenames may be eight characters long; extensions are used to differentiate between configuration files, screen shots and datalogging files. All files must be contained in the appropriate directory. Storage/retrieval from sub-directories is not allowed for screen shots and datalog files

Cygnus 2 supports the writing of filenames using alphanumeric characters selected using the cursor keys. Characters A through Z and numbers 0 through 9 inclusive are available. Cygnus 2 has the ability to display the files contained on the memory stick. A scrolling feature is enabled to view those filenames which cannot fit as indicated by +++ on the screen. Error messages include: Disk Full; File Not Found; Disk Write Protected; Media Error; Disk not Found; File is Read Only.

Datalog files are automatically named using the Date and Material number. See section 3.5.9, Datalog, on page 3-35 for the Datalog string details.

Screen shots are named as DDMMYYXX or MMDDYYXX depending on the date format setting. XX is a number that increments 0-99, resetting to 0 every day.

**NOTE:** A File Access Code parameter is enabled when Cygnus 2 has a Program lock code set. By entering a File Access Code, the Cygnus 2 parameters can be saved to, or retrieved from, the USB storage device only without entering the Program Lock Code. (See Chapter 6, General Parameters.)

⚠️ **CAUTION**

**Do not remove the USB storage device from the Cygnus 2 while a Save or Retrieve operation is taking place.**

### 3.5.8  Lock and Access Codes

Cygnus 2 has several forms of protection to prevent unauthorized changing of parameters. Refer to the General setup section for a description of parameter and Program lock codes and the File Access Code. In addition, a method of locking the entire display is available through the remote communications. Lock codes are entered on the General display. See Chapter 6, General Parameters.

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

## *3.5.9  Datalog*

When a Source Shutter closes, an end of deposit occurs, or following a Stop, a set of data will be collected. The data gives the user a snap shot of the layer data as the layer completed.

There are three ways this data can be managed:

***1***  **USB Storage USB Datalog Format set to Page or Comma**

The data can be sent to a user supplied USB memory device in a data log file. The file is saved as "MMDDYYC#.IDL" or "DDMMYYC#.IDL" depending on the Date Format chosen in the General screen Date/Time page, see section 6.6, where "C#" is Material Number.The data is formatted depending on the setting of the "USB Data log format". Page format, see section 3.5.9.2, will insert a carriage return and a line feed at the end of each line of data. In Comma format, see section 3.5.9.3, a comma separates each piece of data.

Datalogging the crystal frequency data is an optional subset of the datalog string and is enabled by selecting Yes for Datalog Xtal Info on the Comm page of the General screen.

The information will be saved under a filename on the USB storage device. Datalog files saved to the USB storage device will be automatically named using the date and Material number. The format of the filename is MMDDYYC#.IDL or DDMMYYC#.IDL depending on the Date Format chosen where C# is the Material number. If the USB storage device already contains a file with the same filename as the new datalog information, the new datalog information will be appended to the old file.

At each Source shutter close, the datalog information will be appended to the file (when saved to USB).

***2***  **General Comm RS-232 Protocol set to Dlog Comma or Dlog Page**

The data can also be sent to the RS-232 port if the General parameter "RS-232 Protocol" is set to "Dlog Page" or "Dlog Comma". See section 3.5.9.2 and section 3.5.9.3 for format descriptions. The RS-232 port then becomes a "send only" port. The port will supply the data log data and will not accept any commands from a remote computer.

Datalogging the crystal frequency data is an optional subset of the datalog string and is enabled by selecting Yes for Datalog Xtal Info on the Comm page of the General screen.

***3***  **SL16 # and SL17 # commands**

The data log information is always available via Status command SL16 # (no crystal history) or SL17 # (with crystal history) in the remote communications. The data is returned in the standard remote communications packet as binary words. For more information, see section 9.4.29, Status Material, on page 9-39.

### 3.5.9.1 Datalog contents:

The following values make up the data in the datalog. The data is sent in ASCII strings when the RS-232 port is set for data logging. The data is also saved as ASCII strings in the datalog files. The ASCII strings are made up of the labels and values in the following list. ASCII strings are CRLF (Carriage Return Line Feed) terminated. When the data log is requested via the remote status Material command SL16 # (no Crystal History) or SL17 # (with Crystal History), the values are sent in the binary format only.

- Year (Integer)
- Month (Integer)
- Day (Integer)
- Hour (Integer)
- Minute (Integer)
- Material x (Integer)
- Material x (x is the Material number or, in data log files, the name if the name is programmed)
- Material Time seconds (Integer)
- Deposit Time seconds (Integer)
- Ending Thickness kÅ (Float)
- Average Rate A/s (Float)
- Average Rate Deviation A/s (Float)
- Ending Power % (Float)
- Average Power % (Float)
- Where it goes next (Byte):
    - 0 = NonDeposit Control or NonDeposit Hold
    - 1 = Post Deposit
    - 2 = Stop
- Termination Reason (Byte) (Matches the "Cause of Stop" Remote encoding comm, see :
    - 128 = Normal termination,
    - 127 = Manual Source shutter closing,
- Time Power Flag (Byte) (0 = No, 1 = Yes)
- Power Fail Flag (Byte) (0 = No, 1 = Yes)
- Power Fail Thickness kÅ (Float) (0 if not a power fail, otherwise the thickness when the power was lost.)

**NOTE:** If Data Log Xtal Info Parameter is set to Yes, the following Crystal History will be sent for each Sensor, see Table 3-3. The Crystal history contains the history of every crystal in every Sensor used in the Material. In the Remote status command SL17 #, the crystal history for all twelve crystals in all six Sensors is returned. If there is a minus sign in front of the Freq value, it indicates that this crystal failed during the layer. The frequency value shown in that case is the last valid reading obtained before the crystal failed. If the General Comm Datalog Xtal Info parameter is set to No, all zeros are sent in the remote status command SL17 #.

*Table 3-3  Sensor 1 to 6*

| Crystal | Begin Freq | End Freq | BegLife | EndLife | Beg Activity | End Activity | Stability Value | Quality Value |
|---------|-----------|----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1 | <Float> | <Float> | <Integer> | <Integer> | <Integer> | <Integer> | <Integer> | <Integer> |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |

Table 3-3 is extended as necessary to show all crystals in a sensor.

### 3.5.9.2 Page Format ASCII Example:

To USB Storage Device and/or RS-232 Protocol Dlog Page for Material #1.

| | |
|---|---|
| DATE: | 09/16/2010 |
| TIME: | 09:13 |
| LAYER #: | 1 |
| MATERIAL NAME: | ONE |
| LAYER TIME: | 01:02 |
| DEPOSITION TIME: | 01:02 |
| THICKNESS: | 2.504 kAng |
| AVE. AGG. RATE: | 40.0 Ang/S |
| AVE. RATE DEV.: | 0.0 Ang/S |
| ENDING POWER: | 0.0 % |
| AVE. POWER: | 0.0 % |
| WHERE NEXT: | Post Deposit |
| COMPLETION MODE: | NORMAL |

If Datalog Xtal Info was set to Yes, Crystal History is also sent as shown:

Sensor number of the sensor used, Crystal number of crystal(s) used, labels and values are sent in the order displayed below.

SENSOR 1

| XTAL | BEG. FREQ. | END FREQ. | BEG. LIFE | END LIFE | BEG. ACT. | END ACT. | STAB. | QUAL. |
|---|---|---|---|---|---|---|---|---|
| 1 | 5976244 | 5976243 | 0% | 0% | 187 | 189 | 0 | 0 |
| 3 | 5966388 | 5966388 | 0% | 0% | 331 | 328 | 0 | 0 |
| 5 | 5971051 | 5971051 | 0% | 0% | 669 | 674 | 00 | |

If there is a minus sign in front of the Freq value, it indicates that this crystal failed during the layer. The frequency value shown in that case is the last valid reading obtained before the crystal failed.

### 3.5.9.3 Comma Format ASCII Example to USB Storage Device:

"09/15/2010","14:04", 1,"ONE ","00:15","00:15",   0.600,    40.0,    0.0, 0.0, 0.0,"Post Deposit        ","TIME POWER"

If Datalog Xtal Info was set to Yes, Crystal History consisting of Sensor #, Crystal#, with the crystal data for twelve crystals is sent as displayed below.

"SENSOR 1",1,      0,      0, 0, 0,  0,  0,      0,  0,2,      0,      0, 0, 0,  0,  0,      0, 0,3,       …

The Dlog Comma protocol format is actually comma-and-quote delimited intended for file importation into a spreadsheet program. When a spreadsheet program imports a file having the comma delimited format, data groups that are strictly numbers become value entries, data groups surrounded by quotes are stored as labels.

For the comma delimited format, all the data fields are returned for all the crystals in a multi-position sensor. If a crystal is not used during the deposition, the data fields will contain zeros.

### 3.5.10  DAC Monitoring

Cygnus 2 continually compares the actual output voltages at the DAC BNC connectors with the internally generated values to detect external or internal equipment malfunction. If the values do not agree, Cygnus 2 takes the following action:

If the DAC output is assigned for Source control:

- ◆ Stop the Material.
- ◆ Display Source Fault message.
- ◆ Set this Source Output to zero.

If the DAC output is assigned for Recorder use:

- ◆ Set this output to zero.
- ◆ Display Recorder Fault message.

Both types of faults remain active until a RESET is performed.

### 3.5.11  Trend Analysis

Along with control of the deposition process, Cygnus 2 allows rate and thickness information from individual quartz crystal sensors to be output to the Digital-to-Analog (DAC) outputs. This enables mapping of an individual sensor's information, which is useful in monitoring the change in source flux distribution during the deposition process.

#### 3.5.11.1  Cygnus 2 Parameters Associated with the Trend Analysis Feature

**RECORDER OUTPUT** . . . . . . . . . . . 0 to 12

This parameter designates which of the DAC outputs is to be used as a recorder output. 0 indicates there is not a DAC identified with this particular Material. Values 1 through 6 correspond to the six DAC BNC outputs on the back of the Cygnus 2 labeled DAC 1 to DAC 6. DAC outputs 7 to 12 require the optional DAC outputs card.

**SENSOR RECORDER FUNCTION** . Rate/Thick/RateDev

This parameter determines the function of the Sensor's recorder output. Default is (Unfiltered) Rate, not affected by the Rate Filter Time.

**RECORDER RANGE** . . . . . . . . . . . . 0 to 99999

The full scale range value selected corresponds to the value selected in the General/DACs page for the DAC output. Default value is 100.

A recorder output cannot be associated with a DAC that is configured as a Source output. An error message will be displayed if this is attempted.

# *Chapter 4*
# *Sensor and Source Set-Up*

## *4.1 Sensor Set-Up Introduction*

The basic Cygnus 2 has one sensor measurement board with two Sensor channels, identified as CH1 and CH2 on the Cygnus 2 back panel and as Sensor # 1 and Sensor # 2 on the display screens. Two more sensor measurement boards can be added to support up to six sensors. The second sensor measurement board will be installed in the next slot labeled CH3 and CH4 and the associated sensors will be Sensor# 3 and Sensor# 4 etc. Each Sensor connection requires an external oscillator (XIU) package.

Sensor Set-Up is initiated by moving the cursor to the Sensor heading on the Main Menu and pressing MENU. To return to the Main Menu display, press MENU again.

### *4.1.1 Sensor Display Navigation*

The Sensor Overview display, see Figure 4-1, shows the current configuration of all six possible Sensors even if only one measurement board is installed.

To make changes, use the left/right cursor to move to the appropriate Sensor, then press F1 Select Sensor to bring up that Sensor's screen. See Figure 4-2.

*Figure 4-1  Sensor overview*

| | Sensor # | 1 | 2 | 3 | 4 | 5 | 6 | | |
|---|---|---|---|---|---|---|---|---|---|
| **Overview** | Sensor Type | Single | XtalTwo | XtalSix | Xtal12 | Generic | Single | | |
| Sensor | Switch Out | 0 | 1 | 2 | 3 | 4 | 0 | | |
| | Shutter Out | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | Auto-Z | No | No | No | No | No | No | | |
| | Recorder | | | | | | | | |
| | Output | 7 | 8 | 9 | 10 | 11 | 0 | | |
| | Function | Thick | Rate | Thick | Rate | Rate | Rate | | |
| | Range | 100 | 100 | 100 | 100 | 100 | 100 | | |
| | # Positions | 1 | 1 | 1 | 1 | 10 | 1 | | |
| | # Pulses | 1 | 1 | 1 | 1 | 1 | 1 | | |
| | Pulse On  s | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | | |
| | Pulse Off  s | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | | |

Sensor

Carousel Open 4

Crystal Fail 2

02/05/2011  11:33

Select Sensor

*Figure 4-2  Sensor parameter editing*



## 4.1.2  Sensor Parameters

**SENSOR TYPE** . . . . . . . . . . . . . . . . Single (0), XtalTwo (1), XtalSix (2), Xtal12 (3), Generic (4). Press the TOGL key to move through the choices. Default is "Single".

Values in brackets are used with the remote communication commands. This parameter enables the Crystal Switch feature for the multi-position heads and enables the crystal indexing feature on the handheld controller. If a multi-position sensor is selected, the Switch Out parameter appears. Additional parameters appear for a Generic type, see section 1.4.3.2, Sensor Parameters, on page 1-7. This parameter cannot be changed while executing a process.

**SWITCH OUT**. . . . . . . . . . . . . . . . . . 0 to 38

This parameter appears when the Sensor type is not Single. It designates which of the 38 outputs is to be used as the Crystal Switch output for this Sensor. Values 1 through 38 correspond to the appropriate output. Value 0 indicates that the Crystal Switch Output is not used. The default value is 0. If a value other than 0 is entered, the output chosen as the Crystal Switch output is designated as such on the Digital I/O display. The default setting for the contact closure on this output is Normally Open.

**SHUTTER OUT** . . . . . . . . . . . . . . . . 0 to 38

This parameter designates which of the 38 outputs is to be used to activate the Crystal Shutter for this Sensor. Values range from 0 to 38. Values 1 through 38 correspond to the appropriate output. Value 0 indicates that a shutter is not used. The default value is 0. If a value other than 0 is entered, the output chosen as the Crystal Shutter output is designated as such on the Digital I/O display. The output is set to be true as long as the Material containing the Sensor is in SHUTTER DELAY, DEPOSIT, NON DEPOSIT CONTROL, MANUAL, or in the Sample period of the RateWatcher function. The condition remains true until the end of POST DEPOSIT, TIME POWER, and HOLD, or until a STOP command is received, or during the Hold period of the RateWatcher function.

**Auto-Z** . . . . . . . . . . . . . . . . . . . . . . . No (0), Yes (1)

This parameter designates the method in which the Z-Ratio value will be obtained for use in computing thickness with this Sensor. No indicates that the Z-Ratio established in Material Definition is used. Yes indicates that the Auto-Z calculation feature of the system is used. Auto-Z cannot be enabled on a crystal which is "unable to Auto-Z". Refer to section 3.5.3 on page 3-29 for details on why a crystal is unable to Auto-Z. The default value is No for the Material Z-Ratio.

**Recorder Settings**

**OUTPUT** . . . . . . . . . . . . . . . . . . . . . . 0 to 12

This parameter designates which of the DAC outputs is to be used as this Sensor's recorder output. Values range from 0 to 12. 0 indicates there is no DAC used with this Sensor. Values 1 through 6 correspond to the six DAC BNC outputs on the back of the Cygnus 2 labeled DAC 1 to DAC 6. DAC outputs 7 to 12 require the optional DAC output card.

**FUNCTION**. . . . . . . . . . . . . . . . . . . (Unfiltered) Rate (0), Thick (1), RateDev (2)

This parameter determines the function of the Sensor's recorder output. Default is 0 for the unfiltered Rate, not affected by the Rate Filter Time.

**RANGE** . . . . . . . . . . . . . . . . . . . . . . 0 to 99999 (for Rate and Thick)

The full scale range value selected corresponds to General Parameter DAC Scale and Polarity. Default is 100. Grayed out if RateDev is selected.

## 4.2  Source Set-Up Introduction

Cygnus 2 provides the capability to configure the six Source control channels. Each Source control channel is treated as an individual device.

Source Set-Up is initiated by moving the cursor to the Source heading on the Main Menu and pressing MENU. You may return to the Main Menu display by pressing MENU again.

### 4.2.1  Source Navigation

The Source Overview page shows the current configuration of all six Sources.

*Figure 4-3  Source overview page*



To make changes, use the left/right cursor to move to the appropriate Source, then press F1 Select Source to display that Source's screen

## 4.2.2  Source Parameters

*Figure 4-4  Source parameter page*



The following parameters can be edited for each of the 6 Source control channels.

**SOURCE NUMBER** . . . . . . . . . . . . . 1 to 6

Enter the number of the Source to be edited.

**DAC OUTPUT** . . . . . . . . . . . . . . . . . 0 to 12

This parameter designates which of the DAC outputs is to be used as a Source output. Values range from 0 to 12, with 0 indicating there is no DAC identified with this particular Source. Values 1 through 6 correspond to the six DAC BNC outputs on the back of the Cygnus 2 labeled DAC 1 to DAC 6. DAC outputs 7 to 12 require the optional DAC outputs card.

**SHUTTER OUTPUT** . . . . . . . . . . . . 0 to 38

This parameter designates which of the 38 outputs is to be used as the Source Shutter relay. Values range from 0 through 38. 0 indicates that a shutter is not used and values 1 through 38 correspond to the appropriate relay or open collector type output. The default value is 0. If a value other than 0 is entered the relay chosen as the Source Shutter relay is designated as such in the Digital I/O Display. When running a Material containing the Source for which the Shutter Output parameter is programmed, the logic condition is set to be true when the Material is in DEPOSIT, TIME POWER, RATE RAMPS or MANUAL. The condition remains true until the end of DEPOSIT or until a STOP command is received.

**NUMBER OF CRUCIBLES** . . . . . . . One(0), Four(1), Eight(2), 16(3), 32(4), 64(5)

Values in brackets are for use with remote communication commands. Refer to section 3.5.2, Source/Crucible Selection, on page 3-28 for an example of programming Turret source crucible selection. This parameter can be used to automatically index the turret position when using a multiple pocket turret source. The value is selected using the TOGL and ENTER keys. The default value is 0 and indicates a single pocket source. If a 0 is chosen, the parameters Crucible Output, Turret Feedback and Turret Delay or Turret Input are grayed out on the Display. The number of crucibles determines the number of relays needed for the crucible output. As the relays are binary encoded (actual coding is binary - 1, with 000 representing position 1 and 111 representing position 8), 2 relays are needed for 4 crucibles, 3 for 8, 4 for 16, 5 for 32 and 6 for 64.

**CRUCIBLE OUTPUT** . . . . . . . . . . . . 0 to 37

This parameter designates which of the outputs are to be used as Crucible Outputs. Values range from 0 to 37. The default is 0 and indicates the Crucible Output is inactive. The value entered into this parameter indicates which of the outputs begins the sequence of outputs used as crucible control outputs. For example, a Four(1) entered into the Number of Crucibles parameter and a 1 entered into the Crucible Output parameter will designate output relays 1 and 2 as crucible control outputs with the least significant bit of the binary coding in relay output 1. An Eight(2) entered into the Number of Crucibles parameter and a 1 entered into the Crucible Output parameter will designate output relays 1, 2, and 3 as crucible control outputs with the least significant bit of the binary coding in relay output 1.

**TURRET FEEDBACK** . . . . . . . . . . . Yes (1), No (0)

Some turret source indexers provide feedback to signify when the turret is in the proper position. This parameter allows Cygnus 2 to accept this input and respond accordingly. Parameter entry may be either Yes or No. Yes indicates that Turret Feedback is expected and the Turret Input parameter is displayed on the screen. No indicates there is no Turret Feedback. The default value is No. See the Turret Input and Turret Delay descriptions below.

**NOTE:** If the turret feedback is set to Yes and the Material is STARTed, Cygnus 2 will proceed to the CRUCIBLE SW state. If the turret input is not received within the Turret Delay time, the Material will STOP.

**TURRET INPUT** . . . . . . . . . . . . . . . . 0 to 28

This parameter designates which of the 28 inputs is to be the Turret Feedback input. Values range from 0 to 28. Values 1 through 14 correspond to the appropriate input on I/O Relay Module 1, values 15 to 28 require the I/O Relay Module 2. Value 0 indicates that an input for turret feedback is not used. The default value is 0. However, an input must be assigned or the state sequence

will never proceed past the Source switching state. If a value other than 0 is entered, the input chosen as the Turret Input is designated as such on the Digital I/O display. Input lines are activated with a contact closure to ground.

**TURRET DELAY** . . . . . . . . . . . . . . . 2 to 180 s

The Turret Delay time sets the maximum amount of time the Process will remain in CRUCIBLE SW(itch), waiting for rotation to complete without turret feedback before proceeding to the pre-condition state. If a Turret Input signal is expected (Turret Feedback = Yes) this is the time Cygnus 2 will wait to receive the input signal. If the signal is not received within this time, Cygnus 2 will stop. If the Turret Input becomes active during the delay time, processing continues immediately. Permissible values are 2 to 180 seconds. The default value is 5 seconds.

> ⚠️ **CAUTION**
>
> **Cygnus 2 will proceed to the Pre-Condition state after the Turret Delay time expires. This could result in damage to your equipment if the crucible is not in position after expiration of the Turret Delay time.**

## 4.3 DAC Output Selection Rules

The six standard DAC outputs, DAC 1 to DAC 6, located on the back of the Cygnus 2 and the six optional DAC outputs, DAC 7 to DAC 12, may be used for rate control or to record rate, thickness and rate deviation. Since these outputs can be set up for different functions, certain rules apply.

◆ No DAC output can be set up as both a recorder output and a Source output. If this is attempted, an error message will be displayed.

◆ A DAC output cannot be set up for more than one Source. If this is attempted the error message DAC Used Source # will be displayed.

◆ A DAC output can be set up for more than one recorder output including any combination of Material or Sensor recorders Rate/Thickness or Sensor Rate/Thickness.

◆ If a DAC output is set up for multiple recorder outputs that are required to be operative at the same time, the error message Recorder Conflict will appear. This is a non-fatal error (that is, it will not cause Cygnus 2 to STOP) and the message will remain until the conflict is resolved or a STOP takes place.

The priority of a recorder output that is in conflict is:

a. Filtered Rate/Thickness on the Material

b. Sensor Unfiltered Rate/Thickness from Sensor.

# *Chapter 5*
# *Material Set-Up*

## *5.1 Introduction*

Cygnus 2 can store definition parameters for up to 6 Materials. Any Material that is to be used must be defined. Materials can be defined by referencing the internal Material Library containing more than two hundred cataloged materials and by completing a series of parameter entries at the front panel.

Material Set-Up is initiated by moving the cursor to the Material heading on the Main Menu and pressing MENU. To return to the Main Menu screen, press MENU again.

### *5.1.1 Material Overview Page*

The Material Overview display, see Figure 5-1, shows all 6 available Materials. Materials are initially shown as Material 1 to Material 6. Use the right arrow cursor to move into the Material table.

*Figure 5-1 Material overview display*



With the cursor on one of the 6 Materials, press F1 Select Material. See Figure 5-3 on page 5-3. The screen changes to show the Material screen. To assign one of the chemical formulas with its correct density and Z-Ratio values to this Material #, move the cursor to the appropriate library display: Lib A-Hf, Lib Hf-Sc or Lib Sc-Z.

### 5.1.2 Material Definition

*Figure 5-2 Material library A - Hf display*

```
-0.015Å/s    2.365kÅ    0.00%           READY

           Material  1
Overview   Density  10.500    Silver
           Z-Ratio   0.529    (*) Indicates Default Value
  Source
           Ag        B2O3      Bi2O3     CaTiO3    Cr        CuS       GaAs
  Sensor   AgBr      B4C       Bi2S3     CaWO4     Cr2O3     Dy        GaN
           AgCl      BN        Bi2Se3    Cd        Cr3C2     Dy2O3     GaP
 Pre/Post  Al        Ba        Bi2Te3    CdF2      CrB       Er        GaSb
           Al2O3     BaF2      BiF3      CdO       Cs        Er2O3     Gd
  Deposit  Al4C3     BaN2O6    C         CdS       Cs2SO4    Eu        Gd2O3
           AlF3      BaO       C         CdSe      CsBr      EuF2      Ge
 Lib A-Hf  AlN       BaTiO3    C8H8      CdTe      CsCl      Fe        Ge3N2
           AlSb      BaTiO3    Ca        Ce        CsI       Fe2O3     GeO2
 Lib Hf-Sc As        Be        CaF2      CeF3      Cu        FeO       GeTe
           As2Se3    BeF2      CaO       CeO2      Cu2O      FeS       Hf
 Lib Sc-Z  Au        BeO       CaOSiO2   Co        Cu2S      Ga        HfB2
           B         Bi        CaSO4     CoO       Cu2S      Ga2O3     HfC

Material   1                    Carousel Open 4            Crystal Fail
                                                                2

02/05/2011  13:54
       Define
       Material
```

The three Material Libraries—Lib A - Hf, Lib Hf - Sc and Lib Sc - Z—provide an alphabetic list of materials by chemical name along with their density and Z-Ratio. Once a Material is selected from the library listing by moving the cursor to it, press F1 Define Material. The correct chemical formula and library name, density and Z-Ratio values will now be imported to this Material # and the Material/Source page will appear. To rename this Material, cursor to the name and use the keys in cell-phone format to enter up to 15 characters.

To move among and through the Materials, use the four cursor keys.

## 5.1.3  Material Source Page Parameters

*Figure 5-3  Material source screen*



**MATERIAL NUMBER** . . . . . . . . . . . 1 to 6

Change the number to edit or create a different Material.

**NAME**. . . . . . . . . . . . . . . . . . . . . . . 15 characters max.

The default will be Material #. The default name is returned as a blank entry when queried via communications. Materials selected from the library will be shown by their chemical formula. The Name can be edited using the keys in cell-phone fashion.

**DENSITY** . . . . . . . . . . . . . . . . . . . . . 0.100 to 99.999 g/cc

This parameter is specific to the material being deposited onto the Crystal. It is one of two parameters that relate the mass loading on the crystal to a thickness. If a material is chosen from the Material Library, the density is automatically entered. The default value is 1.000.

**Z-Ratio** . . . . . . . . . . . . . . . . . . . . . . . 0.100 to 15.000

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

**CONTROL LOOP** . . . . . . . . . . . . . . . NonPID (0), PI (1), PID (2)

The bracketed value is used for changing the setting via the remote communications commands. This parameter establishes the control loop algorithms pertaining to either a slow responding source or a fast responding source. The default value is NonPID (0).

**NonPID** is best for fast and medium speed responding systems with **high noise** levels (for example, an electron beam gun with or without a liner, having a large sweep amplitude of low frequency, 10 Hz or less).

**PI** is best for fast, medium, or slow systems with **medium noise** levels (for example, an electron beam gun with medium sweep amplitude frequency, 20 to 100 Hz; also, sputtering and resistive sources).

**PID** is best for fast, medium or slow systems with **low noise** levels (for example, an electron beam gun with sweep off or at a high frequency, 100+ Hz, and sputtering and resistive sources).

**PROCESS GAIN** . . . . . . . . . . . . . . . 0.010 to 999.990 Å/s/% pwr

This parameter determines the change in % Power for a given rate deviation (dRate/dPower). The larger the Process Gain value, the smaller the change in power for a given rate error. Process Gain is calculated by dividing the change in rate caused by the corresponding change in power. The default value is 10.00.

**TIME CONSTANT** . . . . . . . . . . . . . . . 0.010 to 9999.99 s

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

*Figure 5-4  Time constant*
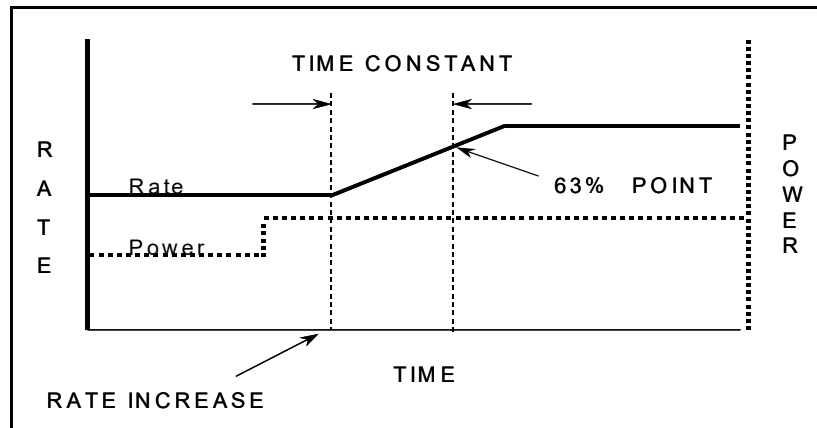
**DEAD TIME** . . . . . . . . . . . . . . . . . . . 0.010 to 9999.99 s

This value is defined as the time difference between a change in % power and the start of an actual change in rate. The default value is 1.0. This parameter is disabled if the CONTROL LOOP option parameter is set to 0 (NonPID).

*Figure 5-5  Control delay time DT*
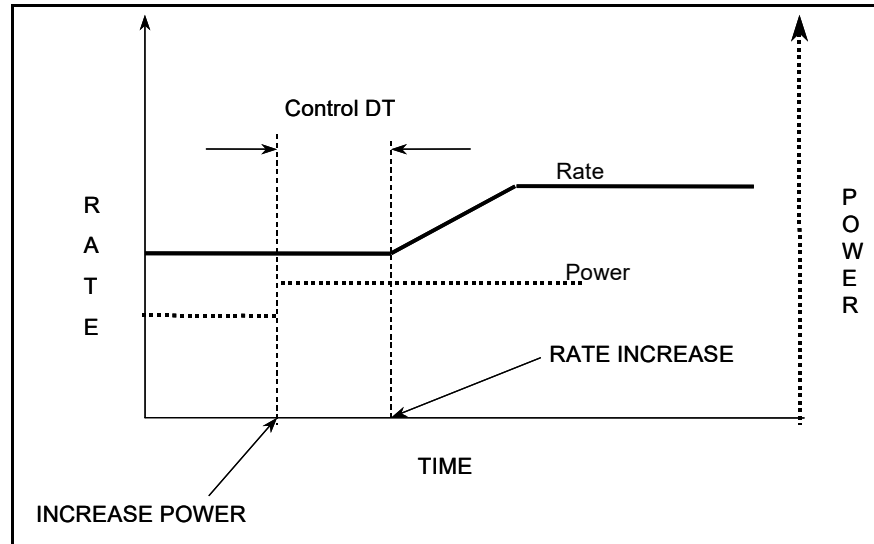


**CRUC(IBLE)** . . . . . . . . . . . . . . . . . . 1 to 64

The Crucible parameter is used in conjunction with the Number of Crucibles selected in Source Set-Up. The value entered sets the state of the Crucible relays. Values range from 1 to the number of Crucibles chosen, up to a maximum of 64. This parameter is set to 1 if the Crucible function is not chosen in configuring the Sources. The default value is 1.

**MAXIMUM POWER** . . . . . . . . . . . . . . 0.01 to 99.99%

This parameter is used to set the maximum permissible % power level. The control voltage output will not exceed this limit. The default value is 90.00%.

**MAX POWER OPTION** . . . . . . . . . . Continue (0),  Post-Dep (1), Stop All (2), Stop Matl (3)

This parameter provides a safety feature.

0 = Continue. Allows the Material to continue in its current state.

1 = PostDeposit. The Material will proceed to the programmed post deposit state(s).

2 = Stop All. Source control voltages for all Materials are set to zero.

3 = Stop Material. Source control voltage for the designated Material is set to zero.

The default setting is Stop Matl (3).

**MINIMUM POWER** . . . . . . . . . . . . . 0.00 to 99.98%

This parameter is used to set the minimum permissible % power level. It must be less than the Maximum Power value. The control voltage output will not exceed this limit. The default value is 0.00%.

**RECORDER OUTPUT**. . . . . . . . . . . 0 to 12

There are twelve (six standard, six optional) DAC outputs available which may be divided among Source control voltage outputs, individual Sensor rate/thickness recorder outputs, aggregate rate/thickness or power level recorder outputs. A value of zero indicates there is not a recorder output chosen for that function. Values 1 through 6 correspond to the six DAC BNC outputs on the back of the Cygnus 2 labeled DAC 1 to DAC 6. DAC outputs 7 to 12 require the optional DAC outputs card. The default value is zero for Filtered Rate, see Rate Filter Time in section 5.1.7.

**RECORDER FUNCTION** . . . . . . Filtered Rate (0), Thick(ness) (1), RateDev(iation)(2), Power (3)

Default is Zero.

**RECORDER RANGE**. . . . . . . . . 0 to 99999 (for Rate and Thick)

Selects the full scale value in the appropriate units, Parameter is grayed out for RateDev and Power. Units are Å/s for Rate and Å for Thickness. Default value is 100. Full scale values are fixed at ± 10 or 20 Å/s for Rate Deviation, depending on what was selected on the Operate screen and 100% for Power.

### 5.1.4  Material Sensor Parameters Page

*Figure 5-6  Material sensor page*



**MATERIAL NUMBER** . . . . . . . . . . . 1 to 6

Change the number to edit or create a different Material.

**MASTER TOOLING** . . . . . . . . . . . . . 1.0 to 999.9%

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

The MASTER TOOLING factor is calculated using equation [1].

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

where $\text{TF}_i$ = Initial Tooling Factor, $T_m$ = Actual Thickness at the Substrate, and $T_x$ = Thickness on the Crystal.

The default value is 100%.

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

**If the Sensor type is XtalSix (CrystalSix)  or Xtal12 (Crystal12)**

**XTAL POSITION FIRST** . . .0 to 6 (12 for Xtal12)

**XTAL POSITION LAST**. . . .0 to 6 (12 for Xtal12)

If all available positions are to be used for this Material, set both values to 0. Otherwise, enter values to select the set of positions to use for this Material. Permissible values for a CrystalSix are 0 to 6, 0 to 12 for a Crystal12. Default is 0.

If an out-of-range position condition results when a Sensor type is changed, the position values will be defaulted to 0.

**(SENSOR) FAILURE ACTION**. . . . .   PostDp (1), Stop All (2),
                                          Stop Matl (3), TimePw (4)

Desired process change when the Sensor fails. PostDp (1) continues into post-deposit states. In Stop All (2), all Source control voltages will be set to zero. In Stop Material (3), only the associated Material will enter the stop state. Its Source control voltage will be set to zero. TimePw (4) continues to Final Thickness using stored average power and rate. The default setting is Stop Material (3).

**CRYSTALTWO TOOLING** . . . . . . . . 1.0 to 999.9%

This parameter applies only if the Sensor type is XtalTwo (CrystalTwo). Sets the Tooling factor when a dual sensor or two single sensors are connected to the same Sensor channel using a CrystalTwo switch. Default value is 100%.

**QUALITY PERCENT** . . . . . . . . . . . . 0 to 99% and >0.5 Å/s

Quality Percent selects the permissible rate deviation in percent of the measured rate relative to the desired rate. The default value is 0% which disables the function.

**QUALITY COUNTS** . . . . . . . . . . . . . . 0 to 99

This sets the number of measurements that must be outside the allowed Quality Percent before the crystal is declared failed. If the rate deviation relative to the 2.5 sec average rate is greater than the programmed Quality Percent limit, the Counts value is incremented. If the rate deviation is less than the programmed Quality Percent, the Counts value is decremented. Counts are not allowed to have negative values. If Counts exceeds the value programmed, Cygnus 2 will automatically crystal switch, complete the process on TIME-POWER, POST DEP, or STOP the process. The rate deviation is computed on each individual rate measurement during the deposit phase, that is, every 100 ms. Upon entering Deposit, the Quality Count is delayed by five seconds. The Q Count on the Sensor Information screen will show DLY (delay) when in pre-deposit, and during the delay period at the beginning of Deposit.

The default value is 0, which disables the function.

**NOTE:** After a crystal fails due to exceeding the Counts value, the Crystal Fail can be cleared by installing a new crystal or pressing the F3 key to Clear S and Q counts on the Sensor Information screen. This action must be repeated for each Sensor used by cursoring to the appropriate Sensor number.

**STABILITY SINGLE** . . . . . . . . . . . . . . 0 Hz and 25 to 9999 Hz (Values 1 to 24 are not allowed)

This sets the maximum permissible increase in frequency from one measurement to the next that will cause a crystal fail. The default value is 0 Hz which disables the function.

**STABILITY TOTAL** . . . . . . . . . . . . . . 0 Hz and 25 to 9999 Hz (Values 1 to 24 are not allowed)

This sets the maximum total permissible increase in frequency accumulated during the active Material that will cause a crystal fail. The default value is 0 Hz which disables the function.

**NOTE:** After a crystal fails due to exceeding the allowable Hz value, the Crystal Fail can be cleared by installing a new crystal or pressing the F3 key to Clear S and Q counts on the Sensor Information screen. This action must be repeated for each Sensor used by cursoring to the appropriate Sensor number.

### 5.1.5 Pre/Post Screen Deposit Page Parameters

*Figure 5-7  Material pre/post page*

**MATERIAL NUMBER** . . . . . . . . . . . 1 to 6

Change the number to edit or create a different Material

**NOTE:** The first power ramp consisting of Pre-Cond Rise and Pre-Cond Soak is skipped if the Idle power is nonzero.

**PRECON RISE TIME**. . . . . . . . . . . . 00:00 to 99:59 min:s

This parameter provides the time period over which the Source power is ramped from 0 to Pre-Cond Soak Power. The default values is 00:00.

**PRECON SOAK POWER** . . . . . . . . 0.00 to 99.99%

This parameter is usually set to the power level at which the source material just begins to glow. Cygnus 2 ramps the power level from zero to Pre-Cond Soak Power linearly over the time period Pre-Cond Rise Time. The default value is 0. If set to a value greater than Maximum Power, Maximum Power has priority.

**PRECON SOAK TIME**. . . . . . . . . . . 00:00 to 99:59 min:s

This parameter provides the time period for which Cygnus 2 holds at Precon Soak Power. The default value is 00:00.

**RISE TIME 1** . . . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

This parameter provides the time period over which the power is ramped from 0 or from Precon Soak Power if programmed to Soak Power 1. The default values is 00:00.

**SOAK POWER 1** . . . . . . . . . . . . . . . 0.00 to 99.99%

This parameter is usually set to the power level at which the material just begins to melt. Cygnus 2 ramps the power level from zero or Precon Soak level if programmed to Soak Power 1 linearly over the time period Rise Time 1. The default value is 0. If set to a value greater than Maximum Power, Maximum Power has priority. See section 3.5.5.1for information on determining appropriate Soak Power using the optional Handheld Controller (IPN 755-262-G1).

**SOAK TIME 1** . . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

This parameter provides the time period for which Cygnus 2 holds at Soak Power 1. The default value is 00:00.

**RISE TIME 2** . . . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

This parameter sets the time period in which Cygnus 2 linearly ramps the power level from Soak Power 1 to Soak Power 2. The default value is 00:00.

**SOAK POWER 2** . . . . . . . . . . . . . . . 0.00 to 99.99%

This parameter sets the power level at which the rate from the Material very nearly matches the desired deposition Rate. Cygnus 2 can ramp the power level if programmed from zero, from idle power, from Soak Power 1 linearly to the Soak Power 2 level over the time period RISE TIME 2. The default value is 0%. If set to a value greater than Maximum Power, Maximum Power has priority.

**SOAK TIME 2** . . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

This parameter sets the time period for which Cygnus 2 holds the power level at Soak Power 2. The default value is 00:00.

**AUTO SOAK 2** . . . . . . . . . . . . . . . . . Yes (1), No (0)

The Auto Soak 2 option, when enabled by selecting Yes (1), calculates an average power setting during the DEPOSIT state. This average power replaces the value programmed in Soak Power 2 so the next time this Material is executed, the Soak Power 2 level is the Auto Soak 2 value. In this manner the Soak Power 2 value closely matches the power level required to achieve the desired deposition rate. The power is the average over the interval defined under the Time Power Averaging Time parameter, see section 5.1.7. The default value is No (0).

**DEP AFTER PRE-DEP** . . . . . . . . . . Yes (1), No (0)

Selects the state to follow the last Soak. Standard processing will continue with Deposit. In special cases, No (0) or Non-deposit control may be appropriate. In this state, the rate is controlled but thickness is not incremented and the Source shutter relay is not active. Default is Yes(1) for Deposit.

> ⚠️ **CAUTION**
>
> **The Sensor must be positioned so the rate can be monitored with the Source shutter closed when going to the non-deposit control state.**

*Figure 5-8  Source power level profile*
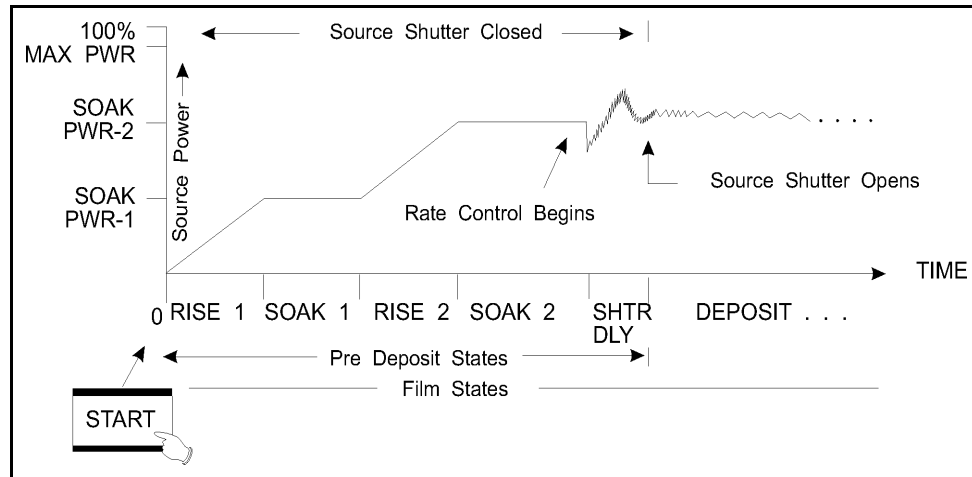


**DELAY OPTION**. . . . . . . . . . . . . . . . None (0), Shutter (1), Control (2), Both (3)

The default value is None (0).

**Shutter (1)**: The Source shutter relay remains in its normal state and the crystal shutter relay is active. The Sensor, which must be positioned to sample the source flux with the Source shutter closed, provides closed loop rate control. The rate control must be within the specified Shutter Delay Accuracy or 0.5 Å/s of the desired deposition rate for 5 seconds before Cygnus 2 will enter the DEPOSIT state, opening the Source shutter and thus exposing the substrate to a well controlled rate of evaporant flux. If the required rate control accuracy cannot be achieved within 60 seconds, the Material will STOP.

**Control (2):** Control delay suspends DEPOSIT control loop action on the Source control power for the time interval programmed in Control Delay Time. During Control Delay, the Source and Sensor shutters are activated.

**Both (3):** Cygnus 2 will first enter a shutter delay state followed by the control delay interval.

**CONTROL DELAY TIME** . . . . . . . . . 00:00 to 99:59

> This is the time interval for Cygnus 2 to be held in the Control Delay state. The parameter is displayed only if the Delay Option chosen is Control or Both. The default value is 00:00.

**SHUTTER DELAY ACCURACY** . . . 1 to 99%

> Specifies how close the rate value must be to the setpoint value for 5 seconds before opening the Source shutter.The parameter is displayed only if the Delay Option chosen is Shutter or Both. The default value is 5.

## 5.1.6 Post Deposit Parameters

### Feed Ramp State

The next three parameters define a feed ramp provided to maintain power levels during a wire feed. After reaching Final Thickness, Cygnus 2 will enter the Feed Ramp state for the specified time. Control voltage is ramped from the power level at the end of the DEPOSIT state to the Feed Power level. Feed Power is held constant until the end of Feed Time. At the end of Feed Time, Cygnus 2 will proceed to the Idle ramp state. Source and Sensor shutter are inactive.

**FEED POWER** . . . . . . . . . . . . . . . . 0.0 to 99.99%

> This is one of three parameters used to affect a Feed Ramp. This value establishes the control voltage power level at which the Source is maintained during wire feed. The default value is 0. If set to a value greater than Maximum Power, Maximum Power has priority.

**FEED RAMP TIME**. . . . . . . . . . . . . . 00:00 to 99:59 min:s

> This is the time interval for the Source power to ramp linearly from the power level at the end of Deposit to Feed Power level. The Feed state is active during Feed Ramp Time. The default value is 00:00.

**FEED TIME** . . . . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

> This is the time interval for which the Source power is maintained at Feed Power. The Feed state is active during Feed Time. The default value is 00:00.

### Idle Ramp State

The next two parameters define an idle ramp provided to establish the Source power level after the Deposit or Feed state. Control voltage is ramped from the power level at the end of the Deposit state (or Feed Power, if one is set) to the Idle Power level. The control voltage is maintained at the Idle Power level until Cygnus 2 enters the STOP state or until the next Material, using the specified Source, is started, or the turret source is rotated.

**IDLE POWER** . . . . . . . . . . . . . . . . . . 0.0 to 99.99%

This value is the power level at which the Source is maintained after the DEPOSIT state (or after Feed state if one is set up). Idle Power is usually the same as Soak Power 1. The default value is 0%. If set to a value greater than Maximum Power, Maximum Power has priority. The power level will be set to zero before a crucible switch is done.

**IDLE RAMP TIME** . . . . . . . . . . . . . . 00:00 to 99:59 min:s

This is the time interval over which the Source power is ramped linearly from the power level at the end of Deposit (or Feed state if one is set) to Idle Power. The default value is 00:00.

## 5.1.7  Deposit Page Parameters

*Figure 5-9  Material deposit page*



**MATERIAL NUMBER** . . . . . . . . . . . 1 to 6

Change the number to edit or create a different Material

**RATE** . . . . . . . . . . . . . . . . . . . . . . . . 0.000 to 999.9 Å/s (default = 0.000)

**NOTE:**  Rate = 0.000 will take a Material in control to post-Deposit state.

This specifies the rate at which the deposition is to be controlled during the DEPOSIT and NON-DEPOSIT CONTROL states. The Rate is calculated based on:

- ◆ The rate information acquired by the Sensor in use, based on the density and Z-Ratio values entered for this Material.
- ◆ The tooling factors that correct for any relative difference in flux distribution reaching the Sensor used for this Material.

**TIME LIMIT** . . . . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

> This is the deposition time at which the Time Limit is triggered. This time begins to accumulate at the start of the Deposit state. The Time Limit, once triggered, remains active until the start of the IDLE state. The default value is 00:00.

**RATE FILTER TIME** . . . . . . . . . . . . . One Tenth (0), Four Tenths (1), One (2), Four (3), Ten (4), Twenty (5), Thirty (6) seconds

> This parameter is used to apply a boxcar filter to the measured raw rate which is used to produce the Rate DAC output voltage.

> The Rate Filter Time may be used for enhanced resolution. If a source has a long time constant, rate may be taken as constant over longer intervals. Averaging provides an opportunity to reduce rate noise. Depending on the source of the noise, averaging can improve rate resolution:

> - If the noise is crystal frequency resolution limited—the thickness change over one second provides ten times the thickness change vs. the thickness change measured over a tenth of a second. A one second averaging interval will improve rate resolution by 10 times.

> - If the sensor noise is random, then RMS reduction of rate noise is provided by the square root of the number of point's averaged (example a 10 point average provides a factor of 3.1 noise reduction).

> The selection of the appropriate Rate Filter Time value will be dependent on the characteristics of the source. The default value is One Tenth.

**TIME POWER AV(ERA)G(ING) TIME** 0 to 30 min. (default = 0)

> This parameter value determines the amount of time used in calculating the average rate and average power for use in Time Power and for Auto Soak 2.

> The Averaging Time parameter is the time interval used to calculate both the average rate and average power applied, if a crystal fails, for Time-Power and Non-Deposit Hold states. When the Averaging Time parameter value is 0, then a 2.5 second average, ignoring the most recent 0.5 second, is the averaging interval.

> The status message ABBR(EVIATED) AVERAGE is generated if the averaging interval has not been reached, but there was at least a complete whole minute of data to average.

> The status message NO or NEG AVERAGE is generated and Stop is entered if a crystal fail occurred within the first minute of control with Averaging Time set >0. This error also occurs if there is a crystal fail during the first 2.5 seconds of control with the Averaging Time = 0. (There are also remote communication commands to get and set the average rate and average power values.)

**ION ASSIST DEPOSIT** . . . . . . . . . . No (0), Yes (1).

Sets the logic condition to True if Yes (1) is selected and the Deposit state is entered. Default is No (0).

**ON FINAL THICKNESS**. . . . . . . . . . Continue (0), Post-Dep (1), NonDepCntl (2).

Selects the state to enter after reaching Final Thickness. Standard processing will continue with Post-Deposit (1), the default setting. In special cases, Non-Dep(osit)Cntl(Control) (2) may be appropriate. In this state, the rate is controlled but thickness is not incremented and the Source shutter relay is not active. Continue (0) ignores reaching Final Thickness but the logic condition is set to True.

⚠️ **CAUTION**

**The Sensor must be positioned so the rate can be monitored with the source shutter closed when going to the non-deposit control state.**

**FINAL THICKNESS**. . . . . . . . . . . . . 0 to 999.99 kÅ

This is the thickness setting that triggers the end of the DEPOSIT state. A value of 0.000 kÅ allows skipping the deposit state. The Source Shutter and Sensor Shutter relays return to their normal states and the Material enters the Idle Ramp or the Feed Ramp state. The default value is 0.000 kÅ, see Skip Deposit, section 5.2.1.

**THICKNESS LIMIT** . . . . . . . . . . . . . 0.0 to 999.99 kÅ

This sets the thickness at which the Thickness Limit logic state is set True. This thickness begins to accumulate after entering the Deposit state. The state remains active after reaching Thickness Limit until the beginning of the IDLE state. The default value is 0.000 kÅ.

**RAMP 1 RATE**. . . . . . . . . . . . . . . . 0.000 to 999.9 Å/s

Rate Ramp 1 is provided to effect a rate change while depositing a Material. The aggregate rate is ramped linearly from the original rate setpoint to the New Rate 1 value over the time interval Ramp 1 Time. It is allowed to ramp to a higher or a lower rate. The default value is 0.0.

**START RAMP 1**. . . . . . . . . . . . . . . . 0.000 to 999.9 kÅ

This value sets the thickness at which to start the Rate Ramp. This thickness value must be less than the Start Ramp 2 thickness value if the value of Start Ramp 2 is non-zero. A value of zero disables the feature. The default value is 0.

**RAMP 1 TIME** . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

This value determines the time period over which to ramp the rate from the original rate to New Rate 1. The default value is 00:00.

**RAMP 2 RATE** . . . . . . . . . . . . . . . . 0.000 to 999.9 Å/s

Ramp 2 Rate is provided to effect a rate change while depositing a Material. The aggregate rate is ramped linearly from the original Ramp 1 Rate setpoint to the New Rate 2 value over the time interval Ramp 2 Time. It is allowed to ramp to a higher or a lower rate. The default value is 0.0.

**START RAMP 2** . . . . . . . . . . . . . . . . 0.000 to 999.9 kÅ

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

**RAMP 2 TIME** . . . . . . . . . . . . . . . . 00:00 to 99:59 min:s

This value is the time interval over which the rate is ramped linearly from New Rate 1 to New Rate 2. The default value is 00:00.

## 5.2  Special Material Parameter Features
### 5.2.1  Skip Deposit

If the Final Thickness is set to 0.000 kÅ, Cygnus 2 will skip the DEPOSIT State. State processing will go directly to the post-Deposit parameter state from the last pre-Deposit state.

### 5.2.2  RateWatcher™ Sample and Hold Feature

Two parameters, Ratewatcher Time and Ratewatcher Accuracy, define the Sample and Hold feature. When enabled by selecting RateWatcher Option = Yes, this feature periodically samples the deposition rate by automatically opening the sensor shutter and exposing the sensor to the deposition source. The power is adjusted so the actual rate is set to the desired rate. The sensor shutter is then automatically closed and power is held constant at the adjusted level. A five second time delay for thermal stabilization occurs between opening the shutter and taking measurements. During this time, DELAY is displayed in Cygnus 2 message area.

The RateWatcher Sample phase uses the measured deposition rate to control the source power. When the deposition rate meets the requirements of the RateWatcher Accuracy parameter, the RateWatcher Acceptance Window Time is started. If the rate falls out of the RateWatcher Accuracy requirement, the RateWatcher Acceptance Time Interval is reset to zero.

If the deposition rate meets the RateWatcher Accuracy requirement for the duration of the Acceptance Window Time, the sensor shutter is closed and RateWatcher enters Hold phase for the RateWatcher Time duration.

Finally, after the Hold Time has elapsed, RateWatcher will enter a 5 second Delay phase. During the Delay phase, the crystal is exposed to the deposition, but the accumulated rate and sustained power are that from the previous Hold phase. This Delay phase allows the crystal to thermally stabilize to the deposition before re-entering the RateWatcher Sample phase.

The RateWatcher Sample Acceptance Window Time (that is, the length of time that the rate must be within the accuracy range before going into hold) will be calculated as follows:

| Time Power Avg Time | Rate Filter Time | RateWatcher Sample Acceptance Window Time | Rate and Power Averages Used |
|---|---|---|---|
| 0 min | <10 sec | 5 seconds | 2.5 minus 0.5 second averages |
| 0 min | 10 sec | 10 seconds | 2.5 minus 0.5 second averages |
| 1 min | anything | 60 seconds | 2.5 minus 0.5 second averages |
| >1 min | anything | Average Time * 60 seconds | Average of minute averages (as with Time Power) of Average Time - 1 minute |

**RateWatcher OPTION**. . . . . . . . . . . No (0), Yes (1)

> Default is No (0) which disables the function and grays out the Time and Accuracy parameters.

**RateWatcher TIME** . . . . . . . . . . . . . 00:00 to 99:59 min:s

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

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

**RateWatcher ACCURACY** . . . . . . . 1 to 99%

> During the rate sampling period, the deposition rate is measured by the crystal; source power control is active. When the rate is within the desired accuracy continuously for five seconds, the shutter is closed and the deposition state returns to HOLD. The minimum accuracy is 1% or 0.1 Å/s, whichever is greater. Values range from 1 to 99%. The default value is 5%

# Chapter 6
# General Parameters

## 6.1  General Set-Up Overview

Cygnus 2 provides the capability to modify a series of top level parameters that define the controller's method of handling system level activities. Some of the parameters are automatically incremented by Cygnus 2.

General Set-Up is initiated by moving the cursor to the General heading on the Main Menu and pressing MENU. This will invoke the General display (see Figure 6-1). You may return to the Main Menu display by pressing MENU again.

## 6.2  General Process Page

*Figure 6-1  General/Process display*



```
   ┌─────────────────────────────────────────────────────────────┐
   │                                                             │
   │                                                             │
   │  ┌─────────┬──────────────────────────────┬──────────────┐ │
   │  │ Process │ Thickness Eq 1        0       │              │ │
   │  │         │ Thickness Eq 2        0       │              │ │
   │  │  DACs   │ Thickness Eq 3        0       │              │ │
   │  │         │                              │              │ │
   │  │  Comm   │                              │              │ │
   │  │         │                              │              │ │
   │  │ Message │                              │              │ │
   │  │         │                              │              │ │
   │  │Date/Time│                              │              │ │
   │  │         │                              │              │ │
   │  │  Test   │                              │              │ │
   │  │         │                              │              │ │
   │  │  Lock   │                              │              │ │
   │  │         │                              │              │ │
   │  │Audio/Visual                          │              │ │
   │  ├──────────────────────┬───────────────┼──────────────┤ │
   │  │ General              │ Carousel Open 4│ Crystal Fail │ │
   │  │                      │                │      2       │ │
   │  │                      │                │              │ │
   │  │ 02/06/2011  07:37    │                │              │ │
   │  └──────────────────────┴───────────────┴──────────────┘ │
   │                                                             │
   └─────────────────────────────────────────────────────────────┘
```

Select a parameter for entry by positioning the box cursor at the desired value following the parameter description. New values are input from the front panel followed by pressing the Enter key input. Values are cleared by pressing the Clear key.

**THICKNESS EQUATION 1, 2, 3** . . . 0 to 654321

> Each of the three thickness equations can be set up to sum the thickness of the specified Sources. Each Source can only be used once in an equation and can be used in all three equations. For example, 12 means sum the thickness of Sources 1 and 2, 1234 sums the first four Sources. Thickness equations are designed to be used in logic statements. The default value is 0.

## 6.3 DACs Page Parameters

Polarity and full scale voltages can be set up for all DACs, see Figure 6-2. Move the cursor key to the DAC. Use the TOGL key to select + or - for the polarity. Use the numeric keys to enter the full scale voltage in the range of 0.1 to 10.0 volts. These parameters cannot be updated for a Material that is running. Default is -10.0.

*Figure 6-2  General DACs page*

## *6.4 COMM Page Parameters*

*Figure 6-3  General comm display*



**DATALOG XTAL INFO**. . . . . . . . . . . Yes (1), No (0)

> This parameter selects whether to output the crystal use history in addition to the standard set of datalog information. Default is No.

**RS-232**

**BAUD RATE**. . . . . . . . . . . . . . . . . . 9,600 (0), 19,200 (1) , 38,400 (2) , 57,600 (3), 115,200 (4)

> Default is 115,200. Use the TOGL key to select the desired rate.

**PROTOCOL** . . . . . . . . . . . . . . . . . . . Standard (0), Dlog Page (1), Dlog Comma (2)

> Standard enables receiving communication commands from an external host and sending the expected responses. Dlog Comma and Dlog Page allow only one-way transmission of information from Cygnus 2 to the external device. The Dlog Comma format allows importation of the Data Log string into a spreadsheet program. Dlog Page format is designed for use as text only. A carriage return (d13, h0D) and line feed (d10, h0A) are inserted at the end of each line of data. The Dlog information is transmitted when the Source shutter closes at the end of Deposit or following a Stop or a Suspend while in Deposit. The default is Standard (0).

**If the Ethernet option is installed, the following parameters will be shown**

**IP ADDRESS** . . . . . . . . . . . . . . . . . . nnn.nnn.nnn.nnn

Use the up and down cursor keys to scroll through the address and the numerics keys to enter the desired address. The default address is 10.211.72.203. This setting is not cleared on pressing CLEAR on power-up.

**NET MASK** . . . . . . . . . . . . . . . . . . . nnn.nnn.nnn.nnn

The net mask is some number of leading bits set to 1, followed by all 0. The default net mask value is 255.255.0.0: This setting is not cleared on pressing CLEAR on power-up.

| 255 | .255 | . 0 | .0 |
|-----|------|-----|-----|
| 11111111 | 1111111 | 00000000 | 00000000 |

**Test RS-232 Function Key**

Once the cursor is in the parameter area, the Test RS-232 function can be performed by pressing the F1 function key. Plug the loop-back connector 760-406-P1 supplied in Cygnus 2 ship kit into the RS-232 connector on the rear panel and press F1. Message RS-232 Test Failed or RS-232 Test Passed will appear. If the loop-back connector is not available, jumper pins 2 and 3 to perform the test. Contact INFICON Service if the RS-232 Test Failed message appears.

## 6.5  MESSAGE Page Set-up

Ten 19 character messages can be created by the user from the front panel or via communications. ASCII characters allowed include all the characters starting with the space character h20 through the character h7E. These Messages are turned on and off under control of logic statements. Up to four Messages can be displayed in the Message area. Newer Messages will displace older ones. Cygnus 2 status messages have priority and will also displace user Messages.

Move the cursor key to one of the 10 Message lines. Then use the alphanumeric keys in cell-phone fashion to enter characters. Use 0 for a space and the _ character, A second press on 0 enters numeric 0. #,& and * characters can be entered by pressing 1 multiple times. To edit a Message, move the cursor to the Message and press any numeric key.

*Figure 6-4  General message page*

## *6.6  DATE / TIME Set Up*

*Figure 6-5  General date/time page*

```
┌─────────────────────────────────────────────────────────────┐
│                                                             │
│                                                             │
│  ┌──────────────────────────────────────────────────────┐  │
│  │Process  │                                             │  │
│  │ DACs    │                                             │  │
│  │         │Date Format        MM/DD/YYYY                │  │
│  │ Comm    │                                             │  │
│  │         │Calendar                                     │  │
│  │Message  │ Day                    22                   │  │
│  │         │ Month                   2                   │  │
│  │Date/Time│ Year                 2011                   │  │
│  │         │                                             │  │
│  │ Test    │System Time          08:56                   │  │
│  │         │                                             │  │
│  │ Lock    │                                             │  │
│  │         │                                             │  │
│  │Audio/Visual                                           │  │
│  ├──────────────────────────┬──────────────┬────────────┤  │
│  │General                   │              │Crystal Fail│  │
│  │                          │              │     2      │  │
│  │                          │              │            │  │
│  │02/22/2011  08:56         │              │            │  │
│  └──────────────────────────┴──────────────┴────────────┘  │
│                                                             │
└─────────────────────────────────────────────────────────────┘
```

**DATE FORMAT** . . . . . . . . . . . . . . . MM/DD/YYYY, DD/MM/YYYY

> Default is MM/DD/YYYY. Use the TOGL key to select DD/MM/YYYY.

**CALENDAR**

> **DAY** . . . . . . . . . . . . . . . . . . . . . . 1 to 31
>
> **MONTH** . . . . . . . . . . . . . . . . . . . 1 to 12
>
> **YEAR** . . . . . . . . . . . . . . . . . . . . . 2001 TO 2099

**SYSTEM TIME** . . . . . . . . . . . . . . . . HH:MM

## 6.7 TEST Page Set Up

*Figure 6-6  General test page*



**TEST** . . . . . . . . . . . . . . . . . . . . . . . . . On (1), Off (0)

> Press the TOGL key to move through the choices. The default is Off. Cygnus 2 contains a software controlled Test Mode which simulates actual operation. The purpose of the Test Mode is to verify basic operation and for demonstrating typical operation to the technician. The word "TEST" will be displayed when TEST is on.

> The Rate displayed during Test Mode operation is determined as shown in equation [1].

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

> Relays, inputs, Source and recorder outputs operate normally during Test Mode but Crystal fails are ignored unless Advanced Test is set to On.

**TIME COMPRESSED** . . . . . . . . . . . Yes (1), No (0)

> When in TEST mode, TIME COMPRESSED allows a faster than real time execution of the Process. This is useful when testing a long Process. A value of Yes increases the speed of execution 10 to 1. The default value is No.

**ADVANCED TEST** . . . . . . . . . . . . . . On (1), Off (0)

> If set to On, Cygnus 2 will respond to crystal fails and switch to backup crystal positions. The text "A TEST" will be displayed when the Advanced Test is On. The default value is Off.

## *6.8  LOCK Page Code Set-up*

*Figure 6-7  General lock page*



**PROGRAM LOCK CODE** . . . . . . . . 1 to 9999

The lock code is set by moving to Program Lock Code and entering the desired code of up to 4 digits. If no lock code is desired, no entry needs to be made. The lock code will be in effect after turning the unit off and an again.The text "L LOCK" will be displayed when Program Lock is set. Default value is 0.

**NOTE:** If a lock code was previously programmed, that code must subsequently be entered on the Main Menu screen, with the cursor positioned on XXXX at the Lock Code XXXX at the lower right corner of the Main Menu options area. After entering the lock code on that screen, the lock code can be cleared if desired by entering 0 for the Program Lock Code on the General / Lock page.The lock code can also be cleared by pressing CLEAR on power-up, however, if no lock code has been programmed, this will reset all parameters to their default values.

**NOTE:** Program lock codes are not stored on and retrieved from the USB port.

**FILE ACCESS CODE** . . . . . . . . . . . 1 to 9999

> The File Access Code allows configuration file retrieval from the USB port when the Program Lock Code is locked. This allows a process recipe to be entered into Cygnus 2 from a USB storage device without unlocking the Program Lock Code. If the File Access Code has not been enabled, USB port retrieval is not allowed when a Program Lock Code is present. This parameter has no effect if there are no lock codes, or the access code is set to zero. Default value is 0.
>
> When pressing CLEAR on power-up, the File Access Code is cleared when the parameters are cleared, not when the lock codes are cleared. The File Access Code is not stored on nor retrieved from the USB port.

## 6.9  AUDIO / VISUAL Page Set Up

*Figure 6-8  General audio/visual page*



**AUDIO FEEDBACK** . . . . . . . . . . . . . Yes (1), No (0)

> Default is No. Yes Activates Audio Feedback, signifying keyboard interaction.

**LCD DIMMER TIME** . . . . . . . . . . . . . 0 to 99 min

> Determines the time before the backlight is turned off to conserve display life. Default is 0 minutes which disables the dimmer function.

> **NOTE:** The backlight is ON when a process is running. It is only OFF when time elapsed since last key press and in READY or IDLE and end-of-process exceeds the LCD Dimmer Time setting.

> **NOTE:** All keys previously active in the dimmed page remain active. Pressing any active key performs that key's function and restores the display.

# Chapter 7
# Digital I/O

## 7.1  Digital I/O Screen

The Digital I/O screen is selected by moving the cursor on the Main Menu screen to Digital I/O and pressing Menu. The I/O Map display for board 1 is shown in Figure 7-3 on page 7-3. Upon entry the cursor will be placed at the last referenced output or input number.

## 7.2  All Input Page

*Figure 7-1  All input page*



All input names assigned by Cygnus 2 or by the user are shown to facilitate system diagnosis. Darker font color designates inputs that are currently active.

## 7.3  All Output Page

*Figure 7-2  All output page*



All output names assigned by Cygnus 2 or by the user are shown to facilitate system diagnosis. Darker font color designates inputs that are currently active.

## *7.4  I/O Board Page*

*Figure 7-3  I/O map board 1 page*

```
                    Relay Output                    TTL Input
              Name              Type          Name

All Input    1 Xtal Switch 2      NO        1 _____
             2 Xtal Switch 3      NO        2 _____
All Output   3 _____      NO        3 _____
             4 Xtal Switch 5      NO        4 _____
I/O Bd 1     5 _____      NO        5 _____
             6 _____      NO        6 _____
I/O Bd 2     7 _____      NO        7 _____
             8 _____      NO        8 _____
I/O Bd 3                                    9 _____
                                           10 _____
                                           11 _____
                                           12 _____
                                           13 _____
                                           14 _____

I/O Board 1                                        Crystal Fail
                                                         2

02/22/2011  09:18
```

Names, up to 15 characters in length, can be entered by the user for any input or output unless Cygnus 2 has automatically assigned a name. Names created by Cygnus 2 cannot be edited. To enter or edit a user name, move the cursor onto the appropriate input or output and use the keyboard in cell phone fashion to create or edit the name.

### *7.4.1  Output Type*

Output Types may be defined as normally open (NO) or normally closed (NC). Relay and TTL output types are changed by positioning the cursor on an output type and pressing the TOGL key followed by the ENTER key.

# *Chapter 8*
# *Logic Statement Set-Up*

## *8.1 Logic Statement Overview*

Cygnus 2 programmable logic capabilities allow it to respond to digital external inputs to control the execution of a Material or series of Materials without operator intervention. You can tailor these capabilities by programming the logic statements.

A logic statement consists of an IF part and a THEN part. The IF part consists of one or more conditional events selected from a table. IF parts can be based on external inputs or internal system conditions or a combination of both. The THEN part similarly consists of one or more actions selected from another table. When the event string is determined to be true, the associated actions are executed in left to right order. The state of the Logic statement is indicated on the Logic Overview display and on logic statement group pages. The color of the logic statement number will turn green to indicate the IF part of the statement is true. Also, three stars (***) will be present. The expressions are evaluated in numerical sequence starting with logic statement 1.

◆ Programming is accessed by moving the cursor to the Logic heading of the main menu and pressing MENU.

◆ Single or multiple actions may be triggered by inputs or the fulfillment of a user specified logical condition.

◆ Inputs are only processed when they or the statement they are used in undergo a transition and on Cygnus 2 power-up.

◆ Single or multiple complex defined conditions are used to define an event.

◆ The Logical operators; AND, OR, and NOT (negate) as well as grouping operators (parentheses) are available to define very precise conditions. An additional operator, ON, specifically ties certain events together.

◆ It is possible to execute an action immediately or delay it for a definable period of time through use of a timer or a counter.

◆ Each Logic statement is evaluated every measurement cycle of 100 ms, but evaluation is suspended while a configuration file is being loaded.

◆ Material entries for each logic statement can be made exclusive or inclusive.

◆ The components of the Logic statements may be the transition between or entry of a specific state, specific programmable time limits, programmable thickness limits or various error conditions.

◆ There are user defined messages which may be displayed.

◆ Inputs and outputs may be named on an I/O map display. Additionally on this display, the outputs may be defined as normally open (NO) or normally closed (NC).

◆ Logic statements may be chained together using the Statement ### Event.

These features allow moderately complex vacuum processing plants to be controlled without the addition of any other intelligent machines.

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

Cygnus 2 has the capacity for 100 logic statements.

## 8.2  Editing the Logic Statements

All Materials must be in Ready, Idle or Stop to edit or create logic statements. Logic Set-Up is initiated by moving the cursor to the Logic heading on the Main Menu and pressing MENU. This will invoke the Logic display (see Figure 8-1). You may return to the Main Menu display by pressing MENU again. Upon entry to the Logic display, the cursor will be placed at the last referenced Logic statement.

There will be an indication for each statement programmed, (the > symbol next to the statement number) and an indication that the statement is True (green color change and three stars *** will be present).

*Figure 8-1  Logic overview page*



Logic statements that are "true" are indicated in green and with *** asterisk.

## 8.2.1 Logic Statement Groups

To view logic statements in groups of four, move the cursor in the left pane down to that group. Individual statements in that group can then be edited by moving the cursor to the statement number and pressing F1 Edit, see Figure 8-3.

*Figure 8-2  Logic 1 - 4 page*



From the Logic Overview display, a logic statement can also be selected for editing by positioning the cursor at the desired statement number and pressing F1 Select. See Figure 8-2.

## 8.2.2 Logic Statement Editing

*Figure 8-3  Logic event IF selection*

```
IF   External Input  1

THEN Start            1

---------------------------------- Events ----------------------------------
Pre-Deposit        Deposit                         Statement       External Input
In Deposit         Rate Ramp 1                     Computer Cntrl
Post-Deposit       Rate Ramp 2                     Test            Ion Assist Dep
Non-Deposit        Time Power       Material
                   Non-Dep Control
Ready              Non-Dep Hold                    Stop
Crucible Switch    Feed Ramp                       Xtal Fail
                   Feed                            Xtal Switching
Pre-Cond Rise      Idle Ramp        Material End
Pre-Cond Soak      Idle                            Max Power        Rate < 0.1
Rise 1                                             Min Power        Rate Dev Err
Soak 1             Thick Limit      Timer HH:MM    Manual           Xtal Life >
Rise 2             Final Thick      Timer Seconds  Auto-Z Fail      Xtal Activity <
Soak 2             Thick Sum        Count Limit    Cruc Swch Fail
Shutter Delay      Time Limit                      Shttr Dly Error  Parenthesis

Logic Statement     1                                          Crystal Fail
                                                                    2

02/22/2011  12:01
        Event/              Delete          Cancel          Save &
        Action              Element         Changes         Exit
```

*Figure 8-4  Logic action Then selection*

```
IF  External Input  1

THEN Start            1

---------------------------------- Actions----------------------------------
Extern Out On     Switch Xtal      Clear Counter   Message On     Xtl Fl Inhb On
Extern Out Off    Zero Thickness   Increment Count Message Off    Xtl Fl Inhb Off
                  Zero Dep Time
                  Trig Fnl Thick   Start Timer     PreCond S/H On RWS Inhibit On
                                   Cancel Timer    PreCond S/H Off RWS Inhibit Off
                                                   Soak 1 Hold On
Start             Start Deposit                    Soak 1 Hold Off RWS Initiate On
                  Continue Dep     Clock Hold On   Soak 2 Hold On  RWS Init Off
Stop                               Clock Hold Off  Soak 2 Hold Off
Reset             Go to Non-Dep
                  Go to Post-Dep   Start Inhbt On
                                   Start Inhbt Off

Logic Statement     1                                          Crystal Fail
                                                                    2

02/22/2011  12:07
        Event/              Delete          Cancel          Save &
        Action              Element         Changes         Exit
```

While in logic-edit, the select menu area will be cleared from the screen. This allows the whole screen to be used for statement editing. A single statement is displayed to edit. The lower portion of the screen will be used to display either the

event or the action list. Events are displayed if the cursor is on the IF portion of the statement and Actions are displayed if the cursor is on the THEN portion of the statement. Cursor begins on the first IF item.

The following function keys are active when the cursor is on the upper half of the page.

- ◆ **Event/Action** key will move the cursor to the event or action list on the lower half of the screen to select an event or an action. The cursor will jump to whichever event or action in the list that the cursor had been on in the upper half. The event or action in the statement will be highlighted to indicate which element is being worked in.

- ◆ **Delete Element** key will remove the element the cursor is on from the statement.

- ◆ **Cancel Changes** key returns the statement to the way it was before editing was started.

- ◆ **Save & Exit** key will save the statement and re-display the four-statement screen with the select menu.

When the cursor is on the lower half (event or action list) of the page the following function keys are active:

- ◆ **If/Then** (F1) key will return the cursor to the IF/THEN statement, with the cursor returning to the highlighted element in the logic statement.

- ◆ **Replace** (F2) key will write over the highlighted element with the selected Action/Event. The highlight moves to the next element in the statement.

- ◆ **Insert** (F3) key will insert the selected action or event into the highlighted element and moves the elements programmed to the right. The highlight remains on the inserted element in the statement. If the statement is full then a full statement error message will appear.

- ◆ **Negate** (F4) key will negate the highlighted event element in the statement. Actions cannot be negated.

To add or delete parenthesis use the cursor in the Event list to select the event Parenthesis. Pressing Insert or Replace, see Figure 8-5, will add a parenthesis before or after the highlighted event in the statement. If a parenthesis is already there, Insert will act as a toggle, removing the parenthesis.

*Figure 8-5 Function Keys IF/THEN, REPLACE, INSERT*



With the cursor in the lower half of the Event page, the F4 key will carry the Negate function in addition to the first three shown above.

When moving the cursor from an event or action, the next element is a numeric field, if required.

A connector field is required between events. The Toggle key is used to select the connector in the statement.

## 8.2.3 AND/OR and ON Logic Connectors

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

For those Events which are Material specific an additional operator can be selected. This is the ON operator and pressing the TOGL key will now toggle between AND, OR, and ON.

### 8.2.3.1 ON Operator

The ON operator is designed for use in multi-Material applications to link an event to a particular Material.

The only Event allowed following the ON connector is Material ###. Only the events that can be associated with Material can precede the ON operator. This includes all States, Pre-Deposit, Deposit, Post-Deposit, Non-Deposit, Final Thickness,

Thick Limit, Time Limit, Material, Material End, Crystal Fail, Crystal Switching, Max Power, Min Power, Backup Sensor In Use, Crucible Switch Fail, Rate < 0.1, Auto-Z Fail, Ion-Assist, and Rate Deviation Error.

There cannot be two consecutive ONs in a statement. A ON B ON C is not allowed. A ON B and C ON D is acceptable.

Neither the event preceding nor the event following the ON can have a NOT function or a parenthesis. For example ~A ON B or A ON ~B is not allowed. Neither is A ON (B and C) or (A and B) ON C.

The ON connector always takes precedence over the AND and OR operators no matter where it appears in the statement. For example, A AND B ON C will be evaluated as A AND (B ON C) not as (A AND B) ON C.

## 8.3  IF Event Definitions

If two or more Materials are active simultaneously, an Event condition is considered TRUE if it is true for any Material (for example, if the first Material is in DEPOSIT and the second Material is in PRE-DEPOSIT, both the DEPOSIT and the PRE-DEPOSIT Events would be TRUE).

The presence (or absence) of an input's leading edge detection on the transition from high to low (or low to high) is used to evaluate the event condition. Inputs are not re-evaluated if held level at either the high or low state.

IF events can be connected using logic connectors, refer to section 8.2.3, AND/OR and ON Logic Connectors, on page 8-6. IF events can be negated.

**AUTO-Z FAIL #**

Sets the logic condition to be true whenever an Auto-Z fail condition occurs on Sensor #. The condition remains true until the Auto-Z Fail condition is cleared. Numeric inputs for Sensor # range from 0 through 6 (0 for any Sensor).

**COMPUTER CNTRL**

Sets the logic condition to be true when a Set Logic Statement vvv (1 to 100) command is received from the remote communications port. The logic condition remains true until a Clear Logic Statement vvv command is received from the remote communications port. See Remote Commands RG5 and RG6 (see section 9.4.31, Remote General Action, on page 9-43).

**COUNT LIMIT  XX yyy**   (xx can be 1 to 20 and yyy can be 0 to 999)

Sets the logic condition to be true when the specified counter XX (1 to 20) has reached the count number set by yyy (1 to 999). The condition remains true until the specified counter is cleared using Clear Counter XX.

**CRUC SWCH FAIL**

Sets the logic condition to be true if a Turret Feedback input is specified and is not received within the allocated time span. The condition remains true until the input arrives or a Reset is done.

**CRUCIBLE SWITCH**

Sets the logic condition to be true while switching crucibles. The condition remains true until the turret delay time has expired or the turret input arrives or a Reset is done.

**DEPOSIT**

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

**EXTERNAL INPUT ##**   (## can be 1 to 28)

Designates a hardware input which, when it changes state, can be used to trigger an Action. Inputs can be given names up to 15 characters long.  Inputs are activated by pulling the specific input's terminal to ground (<0.8 V) through a contact closure to common (GND) or with TTL/CMOS logic having current sink capability of 2 mA (1 low power TTL load).

**FEED**

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

**FEED RAMP**

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

**FINAL THICK**

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

**IDLE**

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

**IN DEPOSIT**

Sets the logic condition to be true at the beginning of the Deposit state and **includes** Time-Power and Rate Ramps. It is also true while in Manual **and** the Source/Substrate shutter output is active. The condition is cleared when entering the post-deposit state, or when a STOP/RESET or a STOP/START sequence is executed.

**IDLE RAMP**

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

**ION ASSIST DEP**

Sets the logic condition to be true at the start of Deposit if Ion Assist Deposit has been enabled for this Material. The condition remains true until the end of Deposit. The condition is also cleared when entering the Manual state, and when a STOP/RESET or a STOP/START sequence is executed

**XTAL LIFE > # ##**

Sets the logic condition to be true whenever the Life value ## on Sensor # is greater than the value entered for ##, which can be 1 to 99, for at least 5 seconds. The condition remains true until the Life value is less than ## for at least 5 seconds. Numeric inputs for Sensor # range from 0 through 6 (0 for any Sensor).

**MANUAL**

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

**MATERIAL  ##**

Sets the logic condition to be true whenever a Material ## is in the READY state or when it is STARTed. The condition remains true until the Material is no longer active. Values for ## range from 1 to 6.

**MATERIAL END ##**

Sets the logic condition to be true when the specified Material ## enters the IDLE state. The condition remains true until a START or a STOP ALL/RESET command is received. Numeric inputs range from 0 to 6, with 0 indicating any Material.

**MAX POWER**

Sets the logic condition to be true as long as any Source is at Max(imum) Power. The condition remains true until every Source is less than Maximum Power.

**MIN POWER**

Sets the logic condition to be true as long as any Source is at Min(imum) Power. The condition remains true until every Source is greater than Minimum Power.

**NON-DEP CONTROL**

This Event is evaluated true if a Material is in the Non-Deposit Control state, that is, there is rate control with the Source/substrate shutter closed. The condition remains true until the end of the Non-Deposit Control state.

**NON-DEP HOLD**

This function is similar to Time Power except the Source/substrate shutter is closed and there is no determinant end point. The condition remains true until the state is exited, for example when a Stop command is given.

**POST-DEPOSIT**

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

**PRE-COND RISE**

Sets the logic condition to be true at the beginning of the Pre-Cond Rise state. The condition remains true until the Pre-Cond Soak or a subsequent non-zero state is entered, or until a STOP/RESET sequence is executed.

**PRE-COND SOAK**

Sets the logic condition to be true at the beginning of the Precond Soak state. The condition remains true until the Rise 1 or a subsequent non-zero state is entered, or until a STOP/RESET sequence is executed.

**NOTE:** This state, PRECOND RISE, RISE 1 and SOAK 1 are skipped if the same Material was used and has a non-zero Idle power.

**PRE-DEPOSIT**

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

**RATE <0.1**

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

**RATE DEV ERR**

This condition will evaluate true when the actual deposition rate differs from the rate setpoint by the larger of 5% or 0.1 Å/s for more than 60 seconds or 20 times the control loop time constant while in Deposit. The condition remains true until the Material leaves deposit.

**RATE RAMP 1**

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

**RATE RAMP 2**

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

**READY**

Sets the logic condition to be true as long as Cygnus 2 is in the READY state. The condition remains true until a START command is received or when entering Manual State.

**RISE  1**

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

**NOTE:** This state, PRECOND RISE, PRE-COND SOAK, and SOAK 1 are skipped if the same Material was used and has a non-zero Idle power.

### RISE  2

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

### SHUTTER DELAY

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

### SHTTR DLY ERROR

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

### SOAK  1

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

### SOAK  2

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

### STATEMENT ###

This Event can be used to test a logic statement transition and the appropriate Action is taken when the statement designated becomes true. A true statement is indicated by three small asterisks below the statement number. Numeric inputs range from 1 through 100.

### STOP

Sets the logic condition to be true as long as Cygnus 2 is in Stop. The condition remains true until a START or RESET command is received.

### TEST

Sets the condition to be true when Cygnus 2 is in TEST.

### THICK LIMIT

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

**THICK SUM # ###**

Sets the logic condition to be true when the sum of thickness indicated by the designated Thickness Equation #, 1 to 3, reaches the thickness value ### (0-999.9) kÅ.

**TIME LIMIT**

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

**TIME POWER**

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

**TIMER HH:MM #** HH:MM

Sets the logic condition to be true when the designated timer # (1 to 20) reaches the specified number of hours and minutes HH:MM, 00:00 to 99:59.

**TIMER SECONDS # ###**

Sets the logic condition to be true when the designated Timer # (1 to 20) reaches the specified time expressed in seconds, sss.s, 0 to 999.9.

**XTAL ACTIVITY < # ###**

Sets the logic condition to be true whenever the Activity value ### on Sensor # is less than the value entered for ### for at least 5 seconds. The condition remains true until the Activity value is greater than ### for at least 5 seconds. The Activity value ### can be 1 to 999. Numeric inputs for Sensor # range from 0 through 6 (0 for any Sensor).

**XTAL FAIL #**

Sets the logic condition to be true as long as there is a Crystal Fail on Sensor #. In the case of a multi-position sensor, a Crystal Fail occurs when the last available crystal fails. The logic condition remains false if the XTL FL INHB Action is active (ON). The condition remains true until a working crystal is input to the appropriate Sensor. Numeric inputs for Sensor # range from 0 through 6 (0 for any Sensor).

**XTAL SWITCHING #**

Sets the logic condition to be true while a crystal switch is taking place on Sensor #. The condition remains true until the crystal switch is completed. Numeric inputs for Sensor # range from 0 through 6 (0 for any Sensor).

## 8.4 THEN Action Definitions

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

| | |
|---|---|
| START INHBT (ON/OFF) | XTL FL INHB (ON/OFF) |
| RWS INHIBIT (ON/OFF) | RWS INITIATE (ON/OFF) |
| SOAK 1 HOLD (ON/OFF) ## | SOAK 2 HOLD (ON/OFF) ## |
| EXTERN OUT (ON/OFF) ## | MESSAGE (ON/OFF) ## |
| CLOCK HOLD (ON/OFF) | PRE COND S/H (ON/OFF) |

**CANCEL TIMER ##** . . . . . . . . . . . . . 1 to 20

Deactivates the designated timer ## and resets it to zero.

**CLEAR COUNTER ##** . . . . . . . . . . . 1 to 20

Clears the designated counter ##.

**CLOCK HOLD (ON/OFF) ##** . . . . . . 0 (any Material) to 6

This feature controls the state timer during any non-rate control state. These states include the pre-deposit states—Ready, Crucible Switch, PreCond Rise, PreCond Soak, Rise 1, Soak 1, Rise 2, Soak 2—and the post-deposit state Idle Ramp.

For the feature to be activated the state's timer must be non-zero. If the Cygnus 2 is in the Ready state and a Start command is executed while CLOCK HOLD is active, Cygnus 2 will progress to the first pre-deposit state with a non-zero state time. If Cygnus 2 is in the Crucible Switch state, waiting for Turret Feedback Input, and CLOCK HOLD is activated, when the turret positioned input is activated, Cygnus 2 will progress to the next pre-deposit state having a non-zero state time. Cygnus 2 is prevented from continuing state processing until the CLOCK HOLD action is turned OFF.

**CONTINUE DEP ##** . . . . . . . . . . . . . 0 (any Material) to 6

Maintains the designated Material ## in the Deposit state but does not zero the thickness. This action cannot be done from a Ready, Idle, Stop, Crystal Switching, or Crucible Switch state. If the crystal is failed, this action will put the associated Source into the Time Power state if the previous state was Non-Deposit Hold, otherwise it is not allowed.

**EXTERN OUT (ON/OFF) ##** . . . . . . 1 to 38

Designates a hardware output ## and places it into its ON or OFF state. Outputs can be given names up to 15 characters long. Outputs are named in the I/O Map display.

**GO TO NON-DEP ##** . . . . . . . . . . . . 0 (any Material) to 6

Places the designated Material ## into the Non-Deposit Control state. This cannot be done from the Ready, Idle, Stop, or Crucible Switch states. If the crystal is failed, this action will place the Material into the Non-Deposit Hold state if the previous state was Time Power, otherwise it is not allowed.

**GO TO POST-DEP ##** . . . . . . . . . . . 0 (any Material) to 6

This action places the designated Material ## into the Feed Ramp state. This action cannot be done if in Crucible Switch, Ready or Stop.

**INCREMENT COUNT ##** . . . . . . . . . 1 to 20

Increases the count by one in the designated counter ##.

**MESSAGE (ON/OFF) ##** . . . . . . . . . 1 to 10

Designates the user-defined message ## and displays the message on the screen (or removes it from being displayed). The message is displayed in the message section of the display. Messages are defined in the General/ Message page.

**PRECOND S/H (ON/OFF) ##** . . . . . . . . . . . . . 0 (any Material) to 6

If active (ON), the designated Material ## will pause execution and maintain PreCondition power until Pre Cond S/H (Soak Hold) is turned OFF. Commands from Remote Comm and Logic will be independent.

**RESET ##**. . . . . . . . . . . . . . . . . . . . . . . . . . . 0 (any Material) to 6

This action is identical to pressing the RESET button on the front panel.

**RWS INHIBIT (ON/OFF) ##** . . . . . . . 0 (Any Material) to 6

When active (ON), this will prevent the designated Material ## from entering the RateWatcher Sample state. If Sample is already active, remains in Sample until Accuracy requirement is met. When OFF, RateWatcher Sample will be enabled. Commands from Remote Comm and Logic will be independent.

**RWS INITIATE (ON) ##** . . . . . . . . . . 0 (any Material) to 6

**RWS INIT (OFF) ##** . . . . . . . . . . . . . 0 (any Material) to 6

When active (ON), this will start the RateWatcher sampling interval for the designated Material ##. When OFF, RateWatcher sampling will take place at the programmed interval based on the RateWatcher time unless RWS INHIBIT is on. Commands from Remote Comm and Logic will be independent.

**SOAK 1 HOLD (ON/OFF) ##** . . . . . 0 (any Material) to 6

If active (ON), the designated Material ## will pause execution and maintain Soak Power 1 until Soak Hold 1 is turned OFF. Commands from Remote Comm and Logic will be independent.

**SOAK 2 HOLD  (ON/OFF) #** . . . . . . 0 (any Material) to 6

If active (ON), the designated Material # will pause execution and maintain Soak Power 2 until Soak Hold 2 is turned OFF. Commands from Remote Comm and Logic will be independent.

**START ##**...........................................0(any Material) to 6

This action is identical to pressing the START button on the front panel.

**START DEPOSIT ##** . . . . . . . . . . . . 0 (any Material) to 6

This function is used to place the designated Material ## into Deposit from the NONDEP CNTL state and zero the thickness. If the crystal is failed, this command will make the Material go into Time Power if the previous state was Non-Deposit Hold, otherwise the action is not allowed. Cannot be done from Ready, Idle, Stop, Crystal Switch, or Crucible Switch. When in Ready or Stop, use the Start action.

**START INHBT (ON/OFF)** . . . . . . . . ON/OFF

This feature, when active, prohibits the START of a Material. It does not inhibit the START DEPOSIT function. Once START INHIBIT is ON, a Material cannot be started until the START INHIBIT is deactivated (set to OFF). Commands from Remote Comm and Logic will be independent. START INHIBIT <u>will</u> carry through a power cycle

**START TIMER  ##** . . . . . . . . . . . . . . 1 to 20

Starts the designated timer ##.

**STOP ##** . . . . . . . . . . . . . . . . . . . . . 0 (all Materials) to 6

Sets Source power for the designated Material ## to zero and freezes its rate and thickness values until a Start is received.

**SWITCH XTAL ##** . . . . . . . . . . . . . . 1 to 6

This action activates the Crystal Switch output for the Sensor number # indicated. It indexes to the next crystal position listed when using a multi-position sensor. This function is available only if a multi-position sensor type is chosen in Sensor Set Up.

**TRIG FNL THICK ##** . . . . . . . . . . . . . 0 (any Material) to 6

This action triggers Final Thickness for the designated Material ## and the Material proceeds to the Feed Ramp or Idle Ramp state. This action is ignored if not in the Deposit state.

**XTL FL INHB (ON/OFF) ##** . . . . . . .  0 (any Sensor) to 6

When set to On, this action prohibits the Crystal Fail logic event from becoming active for the designated Sensor number, but has no effect on crystal switching or Sensor failure action. This is useful when changing crystals. Commands from Remote Comm and Logic will be independent.

**ZERO DEP TIME ##** . . . . . . . . . . . . 0 (any Material) to 6

This action will zero the Material Deposit time for the designated Material ## being deposited. If two or more Materials are in deposit simultaneously, the time will zero for all Materials. If an output is triggered on a Time Limit, the output will remain triggered even after resetting the Material Time

**ZERO THICKNESS ##**. . . . . . . . . . . 0 (any Material) to 6

This action is identical to selecting the ZERO THICKNESS panel function key in the OPERATE display. The Action will zero the thickness accumulated on the display for the designated Material # being deposited, provided it is not in Stop.

## 8.5  Logic Statement Example

The logic statement capability of Cygnus 2 allows for automation of a thin film process. For example, it is possible to start any Material without manually pressing START. One way to accomplish this is:

IF:          External Input 1 and $\overline{\text{Stop}}$ on Material 1

THEN:      Start 1

To enter this statement follow this procedure:

*1*  On the MAIN MENU screen, make sure the Material state is READY. If it is not, press STOP, then press RESET.

*2*  Move the cursor to Logic, then press the MENU key.

*3*  Using the down arrow, move to one of the Logic x-y pages.

*4*  From the Logic x -y page, press the right arrow key to move to the statements.

*5*  Place the cursor on any blank logic statement, using the up and down cursor keys.

*6*  Press F1 EDIT.

*7*  Press F1 EVENT/ACTION.

*8*  Cursor to External Input. Press F3 INSERT. In the upper left of the screen, External Input ### will appear after IF. Press F1 IF/THEN.

*9*  Cursor to ### and enter 1 (the input to use). Press ENTER

*10*  Press F1 EVENT/ACTION. Move the cursor to Stop.

*11*  Press F3 Insert. ccc Stop will appear in the IF line. Press F4 Negate. Then insert Material, specify #1 and insert "On" connector.

*12*  Press F1 IF/THEN and cursor back to ccc. Press the TOGL key until "and" appears, then press ENTER.

*13*  Cursor to the THEN line, press F1 EVENT/ACTION.

**14**  Cursor down to START. Press F3 INSERT. Start ### will appear.

**15**  Press F1 IF/THEN.Cursor to ### behind Start and enter 1(the Material to start). Press ENTER.

**16**  Press F4 SAVE & EXIT to return to the Logic page. At this point the Logic Statement is entered into memory.

**17**  To return to the OPERATE display, press Menu.

This example allows starting Material 1 only if it is in Ready or Idle but not when Material 1 is in Stop.

# Chapter 9
# Remote Communications

## 9.1 Remote Communication Configuration Overview

Cygnus 2 may be remotely controlled, programmed or interrogated. This is accomplished through remote communications and the use of a remote command set. Cygnus 2 will respond to messages that contain these commands. It will accept and operate on messages one at a time. It will respond to each command by carrying out valid operations and/or returning a message to the sender. A host/server relationship is established in remote communications. Cygnus 2, as server, responds to the remote host's commands.

## 9.2 Physical Connections

You may choose to use one of two types of data communications hardware ports.

◆ Standard equipment includes a bit serial RS-232C port.

◆ Optionally, a TCP/IP port may be added.

Both RS-232C and TCP/IP ports can be used simultaneously.

Both the host and server must have the same form of communications equipment and complementary set up. For serial communications, baud rates must match and so must the data word format.

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

### 9.2.1 RS-232C Serial Port

RS-232C serial communications are accomplished through an industry standard 9-pin female connector found on the rear panel of Cygnus 2. A mating male connector is required for attachment of a host interface. The host and Cygnus 2 can be separated by up to fifty feet using multiconductor shielded data cable.

Cygnus 2 is configured as DCE (Data Communication Equipment).

**NOTE:** Unpredictable RS-232 hardware/software combinations may occasionally cause a command to not be recognized by Cygnus 2. Consequently, all communications should include an automatic retry procedure. If a command sent via RS-232 does not produce a response from the Cygnus 2 within three seconds, the command should be sent again.

### 9.2.2 TCP/IP Ethernet Port

The optional TCP/IP interface supports only the Standard Ethernet TCP/IP protocol. Cygnus 2 will communicate via TCP/IP on TCP port number 2101. The interface supports static addressing, DHCP is not supported. Ethernet parameters allowed to be set are the IP address and the net mask.

#### 9.2.2.1 Network Connection

If Cygnus 2 is connected through a network or hub connection, a standard "straight" Ethernet cable is required.

#### 9.2.2.2 How to Set Up the Network Protocol on the PC

Most personal computers (PC) are configured to obtain the IP address, an address which defines the computer on the Internet, automatically from a server.

To communicate directly with Cygnus 2, the Internet protocol (IP) on the PC must be configured manually and an Ethernet crossover cable (for example, IPN 600-1211-P5) must be connected between the PC and Cygnus 2. Some PC's will auto-configure and work with either straight or crossover cable. Instructions are provided here for manually configuring the Internet protocol.

**NOTE:** If the PC only has one Ethernet port (that is, one network connection) then setting the PC for direct communications will prohibit it from accessing the Internet until that setting is reversed.

**NOTE:** These instructions will set two values, the IP address and the Subnet mask, which will most likely prohibit access to the Internet. If these values already contain information then this information should be recorded somewhere for use in restoring the Internet connection.

To access the Network Connection on the PC, select **Network Connections** from the Windows® **Start** menu or from the **Control Panel**. See Figure 9-1.

*Figure 9-1  Accessing network connections*
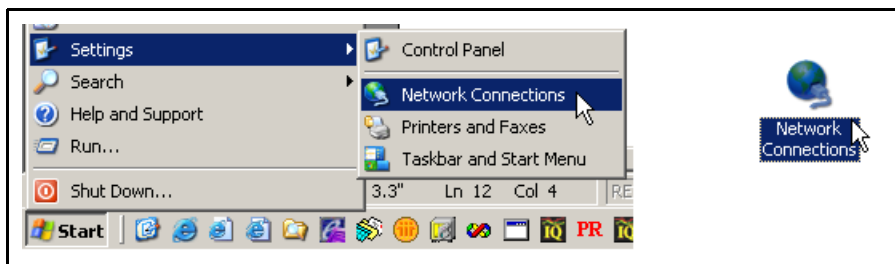
Select the **Local Area Connection** to be changed, right-click and select **Properties**. See Figure 9-2.

*Figure 9-2  Local area connection properties*
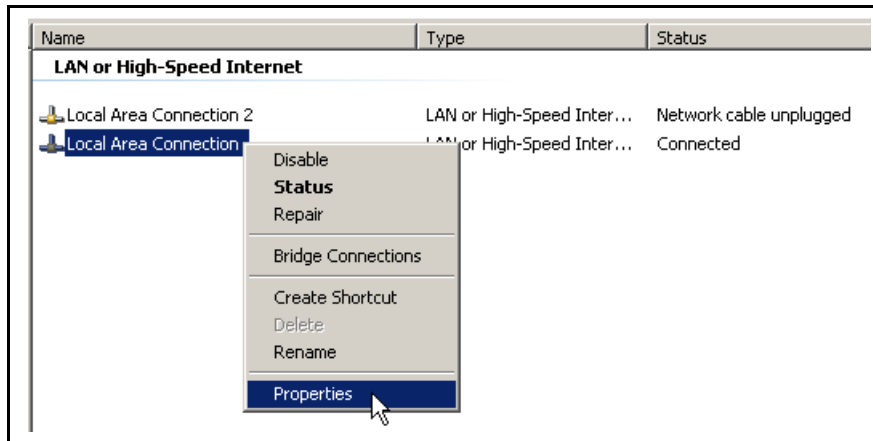


On the **General** tab, select **Internet Protocol (TCP/IP)** and select the **Properties** button. See Figure 9-3.

*Figure 9-3  Internet protocol (TCP/IP) properties*
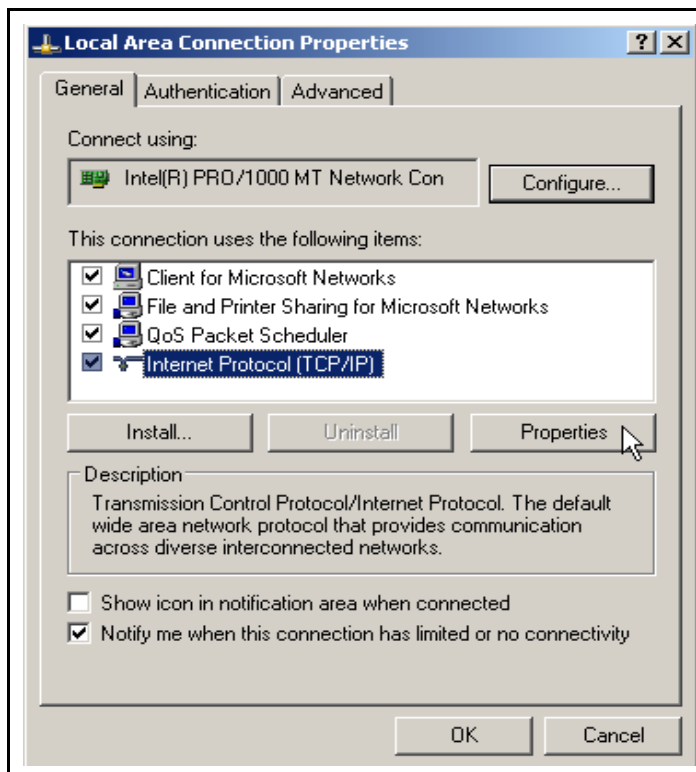
Select the button for **Use the following IP address**, enter the **IP address** and **Subnet mask** shown in Figure 9-4, and select **OK**. With this selection, the PC is assigned an IP address to use when communicating with Cygnus 2. Cygnus 2 is shipped from INFICON with a pre-assigned address of 10.211.72.203. To communicate directly with Cygnus 2 from a PC, the PC must also be assigned an address that starts with 10.211.72 but *cannot* be set to 10.211.72.203. The example in Figure 9-4 uses the address 10.211.72.100 for the PC.

*Figure 9-4  Entering the IP address and subnet mask*
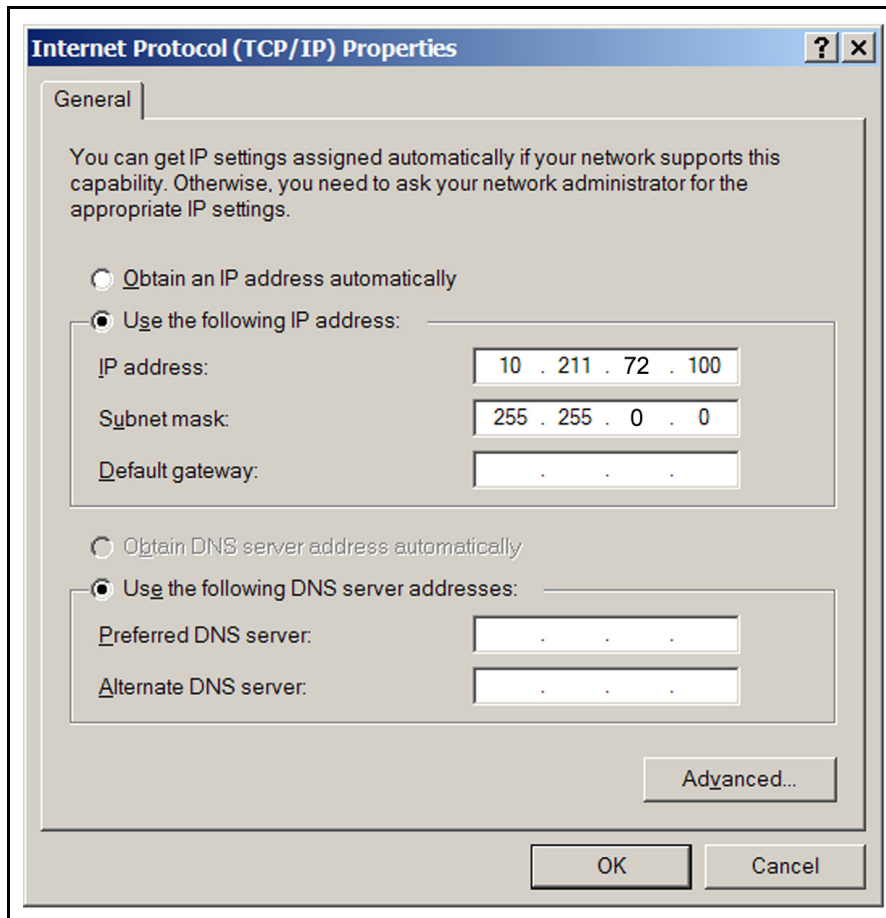


Click **OK** to all open dialogs to close out the Internet Protocol setup for the Local Area Connection.

## *9.3 Message Format*

The Standard message protocol serves as a structure for the contained command or response information. It also can provide a level of acknowledgment between the host and server and a mechanism for verifying the information content. Cygnus 2 supports the following RS-232 protocols: Standard, Dlog Comma and Dlog Page. The Dlog protocols only provide for one-way transmission of layer data from Cygnus 2.

Hardware handshaking is not supported.

Remote Communications parameters are set up in the General screen Comm page.

**NOTE:** Communication returns "can not do now", Response Error "F", 0x46, when Source Maintenance mode is enabled.

TCP/IP will always operate using the Standard protocol command set. It is not affected by the RS-232 Protocol selection.

### *9.3.1 Protocol*

**Key:**

<> . . . . . . Enclosed element further defined below (or above, if repeated use)

() . . . . . . . Optional Element

I . . . . . . . Or

x...x. . . . . One or more of x included

#### *9.3.1.1 Command Packet (Host to Cygnus 2 Message)*

<length><message><checksum>

**Length** . . . . . . . . . . . . . . . . . . . . . . 2 bytes Low / High (not including checksum or length bytes). Numeric value from 0 to 57,800 (two bytes) representing the number of characters in the command. In order of transmission, the low byte will precede the high byte. For most commands, the number for characters will be less than 256. In this situation the low byte will contain the character count while the high byte will have zero value.

**Message** . . . . . . . . . . . . . . . . . . . . . <Command>(<Command>...<Command>)

**Checksum** . . . . . . . . . . . . . . . . . . . . 1 byte, sum, modulo 256, of all bytes, not including length.  Modulo 256 is the numeric value from 0 to 255 representing the modulo 256 remainder of the sum of the values of the ASCII codes that comprise the response.

**Command** = <Command Group> (<Command Sub-group>) (<Command ID>) (<Parameter>...<Parameter>)

**Command Group** = 1 ASCII byte, specifying category of command:

> H - Hello
> Q - Query
> R - Remote action
> S - Status
> U - Update

**Command Sub-group** = 1 ASCII byte, used with some command groups to further specify commands.

> **Command Sub-groups for command Q and U**:

> C - Source
> G - General
> I - Input Name.
> L - Logic
> M - Material
> N - Material Name
> O - Output Name
> P - Process
> S - Sensor
> T - Type of Output
> V – User Message

> **Command Sub-groups for command R and S:**

> G - General
> L – Material
> S – Sensor

**Command ID** = 1 binary byte. Defines specific command within some command groups and sub-groups.

**Parameter** = <Byte>|<Integer>|<Float>|<String>|

> Byte = 1 byte
> Integer = 4 byte, low to high
> Float = 4 byte, ANSII standard, single precision, low to high
> String = Null terminated series of ASCII characters

### 9.3.1.2 Data Type Codes

All parameters are stored internally as four byte words. The data type codes indicate how individual parameters are represented in the four bytes (and how they need to be passed via remote communications).

*Table 9-1  Data type codes*

| Format Code | Displays the value as |
|---|---|
| REAL_3F20 | X.XX or XX.X or XXX |
| REAL_3X1 | XX.X |
| REAL_4F21 | XX.XX or XXX.X |
| REAL_4F31 | X.XXX or XX.XX or XXX.X |
| REAL_4X1 | XXX.X |
| REAL_4X2 | XX.XX |
| REAL_4X3 | X.XXX |
| REAL_5F32 | XX.XXX or XXX.XX |
| REAL_5X2 | XXX.XX |
| REAL_5X3 | XX.XXX |
| REAL_6F32 | XXX.XXX or XXXX.XX |
| TIME | MM:SS (Minutes:Seconds) |
| ENCODE | Displays text from a Toggle list |
| INTEGER | Whole number (no decimal point) |
| LOCKCODE | XXXX |

**REAL_xXx, REAL_xFx**

Real numbers contain a decimal point.

The resolution (or decimal precision) of the real number displayed depends on the format code.

The stored value is a floating-point number.

**TIME**

Time format is used for times with minutes and seconds.

Time parameters are displayed as MM:SS.

They are stored in memory as integer seconds.

**ENCODE**

Encode parameters have a defined list of acceptable values.

Usually two to five values are allowed.

As the user toggles through the list the encoded text is displayed on the screen.

The value stored is an integer.

**INTEGER**

Integers are 32-bit words.

Although they are stored as signed integers, all current parameters have a lower limit greater than or equal to 0.

**LOCKCODE**

The lock code parameter is displayed as "XXXX".

The value is stored as an integer.

Unlock code is 0.

### 9.3.1.3  Response Packet (Cygnus 2 to Host Message)

<Length><CCB><Timer><Response Message><Checksum>

**Length** . . . . . . . . . . . . . . . . . . . . . . . Number of bytes including CCB, Timer, and Response Message. Length bytes and Checksum are not included in Length Count. Numeric value from 0 to 65,500 (two bytes) representing the number of characters in the response. Two byte values, high and low order, are required to represent this number. In order of transmission, the low byte will precede the high byte.

**CCB** . . . . . . . . . . . . . . . . . . . . . . . . . (Condition Code Byte) = 1 byte binary. MSB set indicates command packet error.

**Timer** . . . . . . . . . . . . . . . . . . . . . . . . 1 byte binary, number between 0 and 255, increments every tenth second.

**Response Message** . . . . . . . . . . . . <Command Response>...<Command Response>|<Packet Error Code>

**NOTE:** Number of command responses equals number of commands sent.

If CCB MSB is set, indicating a command packet error, the response message will be a single packet response error.

If the CCB MSB is clear, the command packet was parsed and a valid command packet format was detected.

**Checksum** . . . . . . . . . . . . . . . . . . . . 1 byte, sum, modulo 256, of all bytes, including CCB, Timer, and Response Message but not including length. Modulo 256 is the numeric value from 0 to 255 representing the modulo 256 remainder of the sum of the values of the ASCII codes that comprise the response.

**Command Response** = <ACK><response>|<response error code>

**NOTE:** ACK is the ASCII code with decimal or hex value 6 indicating Positive Acknowledgment of a command. It is not sent when a Response Error Code is returned.

**Response** = (<integer>|<float>|<string>|<other>......<integer>|<float>|<string>|<other>)

**Response Error Code** = 1 byte ASCII

A = Illegal Command
B = Illegal parameter value
D = Illegal ID
E = Data not available
F = Cannot do now (some commands require Cygnus 2 to be in Ready/Stop).
L = Length Error, must be greater than 0 and equal to or less than 65,500 bytes.
P = Prior command failed (if one command of a multiple command packet fails, none of the following commands will be done, and this error code will be returned).

**Packet Error Code** = 1 byte ASCII.

C = invalid checksum
F = illegal format (The command could not be processed because a byte in the command packet did not fit the recognized format)
I = invalid message (Unrecognized command in the packet)
M = too many commands (Only 100 allowed)
O = Response length is larger than response buffer

### 9.3.1.4  Timeouts

If more than 3 seconds pass between characters of a command packet, Cygnus 2 will time out. No response packet is sent, Cygnus 2 will clear its buffers and assume any future characters are the beginning of a new packet.

## 9.4  Communication Commands

The following only include the command portion of the command packet and the response portion of the response packet. The headers/trailers are assumed. (See for their definition.)

**General definitions**

<Float> = 4 byte, single precision ANSII standard floating point, low end first

<Integer> = 4 byte, signed integer, low end first

<String> = variable length, null terminated ASCII characters.

### 9.4.1  Query and Update Commands

Query commands are used to request established parameter values. There is a specific query command for each parameter group. Depending on the actual hardware configuration, the response to some Query commands may be an E error code indicating there is no data available. Each command has one to three arguments.

Update commands are used to change a specified parameter to a new value or condition. Some parameters are order dependent in that they cannot be updated prior to certain other parameters. There is a specific update command for each parameter group.

The command variations include:

*Table 9-2  QUERY and UPDATE commands*

| QUERY command | Parameter | UPDATE Command |
|---|---|---|
| QC | Source Parameters | UC |
| QG | General Parameters | UG |
| QI | Input Name | UI |
| QL | Logic Statements | UL |
| QM | Material Parameters | UM |
| QN | Material Name | UN |
| QO | Output Name | UO |
| QP | Process-Layer Parameters | UP |
| QS | Process Sensor Parameters | US |
| QT | Output Type | UT |
| QV | User Message | UV |

### 9.4.2 Status Commands

Status commands return pertinent information based on a specific request made. Commands are provided to determine global information which is system level, Material or Sensor information. A status code is required for each command. See Status General on page 9-37 to Status Sensor on page 9-42.

The command variations include:

*Table 9-3  Status commands*

| Status command | Parameter |
|---|---|
| SG | General System Level |
| SL | Material Information |
| SS | Sensor Information |

Remote commands perform an action based on the specific command given. Commands are provided to affect global features which are system level oriented (RG commands, see Remote General Action on page 9-44) or Material oriented (RL commands see Remote Material Action on page 9-47). Every command requires a remote code and may require a value.

Command variations include:

**RG** = Affects system or Cygnus 2 level conditions.

**RL** = Affects conditions for a specified Material

### 9.4.3 HELLO Command

H <Command ID> given in hex format

Hex form example for H1 including length and checksum: 0200480149,

Response:

*Table 9-4  Hello command response*

| Command ID | Meaning | Response |
|---|---|---|
| (0x01) | ASCII name and version | <String> = Cygnus 2 Version x.xx |
| (0x02) | Version numbers Structure Version Compatibility Version, Range Version | <Integer><Integer><Integer> |
| (0x03) | Firmware version number | <Float> |

### 9.4.4 Query General Parameter

**Command** = QG <Command ID>

**Command ID** = <Byte> See Cmnd ID in Table 9-5

**Response** = <Integer> | <Float>

**Description** = Type of response depends on command ID, see Data Type column in Table 9-5.

### 9.4.5 Update General Parameter

**Command** = UG <Command ID> <Parameter Value>

**Command ID** = <Byte> See Table 9-5

**Parameter Value** = <Integer> | <Float> Type of value depends on command ID, see "Data Type" column in Table 9-5.

**Response** = None (Just header and trailer)

General Parameters

*Table 9-5  General parameters*

| QG & UG Cmnd ID | Name (Units) | Range: Low Limit/ High Limit/ Default | Data Type | Notes | Update Restrictions and Display Notes |
|---|---|---|---|---|---|
| 9 (0x09) | Thickness Eq 1 | 0/ 654321/ 0 | Integer | Values are the Sources whose thicknesses are summed | No duplicate numbers allowed |
| 10 (0x0a) | Thickness Eq 2 | | | | |
| 11 (0x0b) | Thickness Eq 3 | | | | |
| 12 (0x0c) | Test | 0/ 1/ 0 | Encode | 0 = Off 1 = On | |
| 13 (0x0d) | Time Compressed (10x time acceleration) | 0/ 1/ 0 | Encode | 0 = No 1 = Yes | Gray font when Test = Off |
| 14 (0x0e) | Advanced Test (Crystal Fails active) | 0/ 1/ 0 | Encode | 0 = Off 1 = On | |
| 15 (0x0f) | Audio Feedback | 0/ 1/ 0 | Encode | 0 = No 1 = Yes | |
| 16 (0x10) | LCD Dimmer Time (Minutes) | 0/ 99/ 0 | Integer | 0 = Always On Non 0 = Minutes till off | |
| 17 (0x11) | Date Format | 0/ 1/ 0 | Encode | 0 = mm/dd/yyyy 1 = dd/mm/yyyy | |
| 18 (0x12) | USB Datalog Format | 0/ 2/ 0 | Encode | 0 = Log Off 1 = Page 2 = Comma | |

*Table 9-5  General parameters (continued)*

| QG & UG Cmnd ID | Name (Units) | Range: Low Limit/ High Limit/ Default | Data Type | Notes | Update Restrictions and Display Notes |
|---|---|---|---|---|---|
| 19 (0x13) | Datalog Xtal Info | 0/ 1/ 0 | Encode | 0 = No<br>1 = Yes | |
| 20 (0x14) | Graph Scale | 0/ 2/ 2 | Encode | 0 = Power    1 = ±10 Å/s<br>2 = ±20 Å/s | Update will change all Material graphs (Materials 1 to 6) to the Graph Scale choices 0 = Power, 1 = ±10 Å/s, or 2 = ±20 Å/s, only. |
| 21 (0x15) | Graph Scan Rate | 0/ 3/ 0 | Encode | 0 = Auto    1 = Slow<br>2 = Med    3 = Fast | |
| 22 (0x16) | RS-232 Baud Rate | 0/ 4/ 4 | Encode | 0 = 9600   1 = 19200<br>2 = 38400    3 = 57600<br>4 = 115200 | Cannot update via RS-232 communications |
| 23 (0x17) | RS-232 Protocol | 0/ 2/ 0 | Encode | 0 = Standard 2 = Dlog Page<br>1= Dlog Comma | |

*Table 9-5  General parameters (continued)*

| QG & UG Cmnd ID | Name (Units) | Range: Low Limit/ High Limit/ Default | Data Type | Notes | Update Restrictions and Display Notes |
|---|---|---|---|---|---|
| 24 (0x18) | DAC 1 Scale | 0.1/ 10.0/ 10.0 | REAL_3X1 | | Update not allowed if Material using DAC is running. |
| 25 (0x19) | DAC 2 Scale | | | | |
| 26 (0x1a) | DAC 3 Scale | | | | |
| 27 (0x1b) | DAC 4 Scale | | | | |
| 28 (0x1c) | DAC 5 Scale | | | | |
| 29 (0x1d | DAC 6 Scale | | | | |
| 30 (0x1e) | DAC 7 Scale | | | | |
| 31 (0x1f) | DAC 8 Scale | | | | |
| 32 (0x20) | DAC 9 Scale | | | | |
| 33 (0x21) | DAC 10 Scale | | | | |
| 34 (0x22) | DAC 11 Scale | | | | |
| 35 (0x23) | DAC 12 Scale | | | | |

*Table 9-5  General parameters (continued)*

| QG & UG Cmnd ID | Name (Units) | Range: Low Limit/ High Limit/ Default | Data Type | Notes | Update Restrictions and Display Notes |
|---|---|---|---|---|---|
| 36 (0x24) | DAC 1 Polarity | 0/ 1/ 1 | Encode | 0 = Negative<br>1 = Positive | Update not allowed if Material using DAC is running. |
| 37 (0x25) | DAC 2 Polarity | | | | |
| 38 (0x26) | DAC 3 Polarity | | | | |
| 39 (0x27) | DAC 4 Polarity | | | | |
| 40 (0x28) | DAC 5 Polarity | | | | |
| 41 (0x29) | DAC 6 Polarity | | | | |
| 42 (0x2a) | DAC 7 Polarity | | | | |
| 43 (0x2b) | DAC 8 Polarity | | | | |
| 44 (0x2c) | DAC 9 Polarity | | | | |
| 45 (0x2d) | DAC 10 Polarity | | | | |
| 46 (0x2e) | DAC 11 Polarity | | | | |
| 47 (0x2f) | DAC 12 Polarity | | | | |

*Table 9-5 General parameters (continued)*

| QG & UG Cmnd ID | Name (Units) | Range: Low Limit/ High Limit/ Default | Data Type | Notes | | Update Restrictions and Display Notes |
|---|---|---|---|---|---|---|
| 49 (0x31) | Channel 1 Graph Scale | 0/ 9/ 8 | Encode | 0 = Power<br>2 = ±0.5 Å/s<br>4 = ±2 Å/s<br>6 = ±5 Å/s<br>8 = ±20 Å/s | 1 = ±0.1 Å/s<br>3 = ±1 Å/s<br>5 = ±3 Å/s<br>7 = ±10 Å/s<br>9 = ±50 Å/s | |
| 50 (0x32) | Channel 2 Graph Scale | 0/ 9/ 8 | Encode | 0 = Power<br>2 = ±0.5 Å/s<br>4 = ±2 Å/s<br>6 = ±5 Å/s<br>8 = ±20 Å/s | 1 = ±0.1 Å/s<br>3 = ±1 Å/s<br>5 = ±3 Å/s<br>7 = ±10 Å/s<br>9 = ±50 Å/s | |
| 51 (0x33) | Channel 3 Graph Scale | 0/ 9/ 8 | Encode | 0 = Power<br>2 = ±0.5 Å/s<br>4 = ±2 Å/s<br>6 = ±5 Å/s<br>8 = ±20 Å/s | 1 = ±0.1 Å/s<br>3 = ±1 Å/s<br>5 = ±3 Å/s<br>7 = ±10 Å/s<br>9 = ±50 Å/s | |
| 52 (0x34) | Channel 4 Graph Scale | 0/ 9/ 8 | Encode | 0 = Power<br>2 = ±0.5 Å/s<br>4 = ±2 Å/s<br>6 = ±5 Å/s<br>8 = ±20 Å/s | 1 = ±0.1 Å/s<br>3 = ±1 Å/s<br>5 = ±3 Å/s<br>7 = ±10 Å/s<br>9 = ±50 Å/s | |
| 53 (0x35) | Channel 5 Graph Scale | 0/ 9/ 8 | Encode | 0 = Power<br>2 = ±0.5 Å/s<br>4 = ±2 Å/s<br>6 = ±5 Å/s<br>8 = ±20 Å/s | 1 = ±0.1 Å/s<br>3 = ±1 Å/s<br>5 = ±3 Å/s<br>7 = ±10 Å/s<br>9 = ±50 Å/s | |
| 54 (0x36) | Channel 6 Graph Scale | 0/ 9/ 8 | Encode | 0 = Power<br>2 = ±0.5 Å/s<br>4 = ±2 Å/s<br>6 = ±5 Å/s<br>8 = ±20 Å/s | 1 = ±0.1 Å/s<br>3 = ±1 Å/s<br>5 = ±3 Å/s<br>7 = ±10 Å/s<br>9 = ±50 Å/s | |

### 9.4.6 Query Material Parameter

**Command** = QM <Command ID> <Material Number>

**Command ID** = <Byte> See Table 9-6

**Material Number** = <Byte> 1- 6

**Response** = <Integer> | <Float>

Type of response depends on command ID, see Data Type column in Table 9-6.

### 9.4.7 Update Material Parameter

**Command** = UM <Command ID> <Material Number> <Parameter Value>

**Command ID** = <Byte> See Table 9-6.

**Material Number** = <Byte> 1- 6

**Parameter Value** = <Integer> | <Float> Type of value depends on command ID, see Data Type column in Table 9-6.

**Response** = None (Just header and trailer)

*Table 9-6  Material parameters*

| QM & UM Cmnd ID | Name (Units) | Range: Low Limit/ High Limit/ Default | Data Type | Notes | Update Restrictions and Display Notes |
|---|---|---|---|---|---|
| 1 (0x01) | Density (g/cc) | 0.1/ 99.999/ 1.0 | REAL_5X3 | | |
| 2 (0x02) | Z-Ratio | 0.1/ 15.0/ 1.0 | | | |
| 3 (0x03) | Master Tooling (%) | 1.0/ 999.9/ 100.0 | REAL_4X1 | | |
| 4 (0x04) | Control Loop | 0/ 2/ 0 | Encode | 0 = NonPID  1 = PI 2 = PID | |
| 5 (0x05) | Process Gain (Å/s/%) | 0.01/ 999.99/ 10.0 | REAL_ 5F32 | | |
| 6 (0x06) | Time Constant (seconds) | 0.01/ 9999.99/ 1.0 | REAL_ 6F32 | Gray font if Control Loop = NonPID | |
| 7 (0x07) | Dead Time (seconds) | 0.01/ 9999.99/ 1.0 | REAL_ 6F32 | Gray font if Control Loop = NonPID | |

*Table 9-6  Material parameters (continued)*

| QM & UM Cmnd ID | Name (Units) | Range: Low Limit/ High Limit/ Default | Data Type | Notes | Update Restrictions and Display Notes |
|---|---|---|---|---|---|
| 9 (0x09) | Maximum Power (%) | 0.01/ 99.99/ 90.0 | REAL_4X2 | | |
| 10 (0x0a) | Minimum Power (%) | 0.00/ 99.98/ 0.0 | REAL_4X2 | | |
| 11 (0x0b) | Max Power Option | 0/ 3/ 3 | Encode | 0 = Continue<br>1 = Post-Dep<br>2 = Stop All<br>3 = Stop Matl | |
| 12 (0x0c) | PreCond Soak Power (%) | 0.0/ 99.99/ 0.0 | REAL_4X2 | | |
| 13 (0x0d) | PreCond Rise Time (seconds) (mm:ss) | 0/ 5999/ 0 0/ 99:59/ 0 | Time | **Time Note:** Times are displayed as mm:ss. Times are stored as seconds. The maximum number of seconds is 5999. This would be displayed as 99:59. | |
| 14 (0x0e) | PreCond Soak Time (seconds) (mm:ss) | 0/ 5999/ 0 0/ 99:59/ 0 | Time | | |
| 15 (0x0f) | Soak Power 1 % | 0.0/ 99.99/ 0.0 | REAL_4X2 | | |
| 16 (0x10) | Rise Time 1 (seconds) (mm:ss) | 0/ 5999/ 0 0/ 99:59/ 0 | Time | See Time Note | |
| 17 (0x11) | Soak Time 1 (seconds) (mm:ss) | 0/ 5999/ 0 0/ 99:59/ 0 | Time | See Time Note | |
| 18 (0x12) | Soak Power 2 % | 0.0/ 99.99/ 0.0 | REAL_4X2 | | |

*Table 9-6  Material parameters (continued)*

| QM & UM Cmnd ID | Name (Units) | Range: Low Limit/ High Limit/ Default | Data Type | Notes | Update Restrictions and Display Notes |
|---|---|---|---|---|---|
| 19 (0x13) | Rise Time 2 (seconds) (mm:ss) | 0/ 5999/ 0 0/ 99:59/ 0 | Time | See Time Note | |
| 20 (0x14) | Soak Time 2 (seconds) (mm:ss) | 0/ 5999/ 0 0/ 99:59/ 0 | Time | | |
| 21 (0x15) | Auto Soak 2 | 0/ 1/ 0 | Encode | 0 = No 1 = Yes | |
| 22 (0x16) | Dep After Pre-Dep | 0/ 1/ 1 | Encode | 0 = No 1 = Yes | |
| 23 (0x17) | Delay Option | 0/ 3/ 0 | Encode | 0 = None, 1 = Shutter 2 = Control, 3 = Both | |
| 24 (0x18) | Control Delay Time (seconds) (mm:ss) | 0/ 5999/ 0 0/ 99:59/ 0 | Time | See Time Note | Gray font unless Delay option is set to control or both. |
| 25 (0x19) | Shutter Delay Accur (%) | 1/ 99/ 5 | Integer | | Gray font unless Delay option is set to shutter or both. |
| 28 (0x1c) | Feed Power (%) | 0.0/ 99.99/ 0.0 | REAL_4X2 | | |
| 29 (0x1d) | Feed Ramp Time (seconds) (mm:ss) | 0/ 5999/ 0 0/ 99:59/ 0 | Time | See Time Note | |
| 30 (0x1e) | Feed Time (seconds) (mm:ss) | 0/ 5999/ 0 0/ 99:59/ 0 | Time | See Time Note | |
| 31 (0x1f) | Idle Power (%) | 0.0/ 99.99/ 0.0 | REAL_4X2 | | |
| 32 (0x20) | Idle Ramp Time (seconds) (mm:ss) | 0/ 5999/ 0 0/ 99:59/ 0 | Time | See Time Note | |
| 33 (0x21) | Rate (Å/s) | 0/ 999.9/ 0 | REAL_ 4F31 | | |

*Table 9-6  Material parameters (continued)*

| QM & UM Cmnd ID | Name (Units) | Range: Low Limit/ High Limit/ Default | Data Type | Notes | Update Restrictions and Display Notes |
|---|---|---|---|---|---|
| 34 (0x22) | Time Limit (seconds) (mm:ss) | 0/ 5999/ 0 0/ 99:59/ 0 | Time | See Time Note | |
| 35 (0x23) | Rate Filter Time (seconds) | 0/ 6/ 0 | Encode | 0 = 0.1  1 = 0.4  2 = 1.0  3 = 4.0  4 = 10.0  5 = 20.0  6 = 30.0 | |
| 36 (0x24) | Time Power Avg Time (Minutes) | 0/ 30/ 0 | Integer | | |
| 37 (0x25) | Ion Assist Deposit | 0/ 1/ 0 | Encode | 0 = No,  1 = Yes | Update not allowed if Material is running. |
| 38 (0x26) | On Final Thickness | 0/ 2/ 1 | Encode | 0 = Continue,  1 = Post-Dep  2 = NonDepCont | |
| 39 (0x27) | Ramp 1 Rate (Å/s) | 0/ 999.9/ 0 | REAL_4F31 | | |
| 40 (0x28) | Start Ramp 1 (KÅ) | 0/ 999.999/ 0 | REAL_4F31 | Value must be less than Start Ramp 2 thickness value if Start Ramp 2 thickness value is non-zero. | |
| 41 (0x29) | Ramp 1 Time (seconds) (mm:ss) | 0/ 5999/ 0 0/ 99:59/ 0 | Time | See Time Note | |
| 42 (0x2a) | Ramp 2 Rate (Å/s) | 0/ 999.9/ 0 | REAL_4F31 | | |
| 43 (0x2b) | Start Ramp 2 (KÅ) | 0/ 999.999/ 0 | REAL_4F31 | Value must be greater than Start Ramp 1 thickness value. | |
| 44 (0x2c) | Ramp 2 Time (seconds) (mm:ss) | 0/ 5999/ 0 0/ 99:59/ 0 | Time | See Time Note | |
| 45 (0x2d) | RateWatcher Option | 0/ 1/ 0 | Encode | 0 = No,  1 = Yes | |
| 46 (0x2e) | RateWatcher Time (seconds) (mm:ss) | 0/ 5999/ 0 0/ 99:59/ 0 | Time | See Time Note | Grey font unless RateWatcher option set to Yes. |
| 47 (0x2f) | RateWatcher Accuracy (%) | 1/ 99/ 5 | Integer | | |

*Table 9-6  Material parameters (continued)*

| QM & UM Cmnd ID | Name (Units) | Range: Low Limit/ High Limit/ Default | Data Type | Notes | Update Restrictions and Display Notes |
|---|---|---|---|---|---|
| 115 (0x73) | Failure Action | 1/ 4/ 3 | Encode | 1 = PostDp    2 = Stop All 3 = Stop Matl 4 = TimePw | |
| 116 (0x74) | CrystalTwo Tooling (%) | 1.0/ 999.9/ 100.0 | REAL_4X1 | Gray font if Sensor Type is not CrystalTwo | |
| 117 (0x75 | Xtal Position First | 0/ 12/ 0 | Integer | Gray font if Sensor Type is Single, CrystalTwo or Generic | |
| 118 (0x76) | Xtal Position Last | 0/ 12/ 0 | Integer | Gray font if Sensor Type is Single, CrystalTwo, or Generic | |
| 121 (0x79) | Quality Percent (%) | 0/ 99/ 0 | Integer | | |
| 122 (0x7a) | Quality Counts | 0/ 99/ 0 | Integer | | |
| 123 (0x7b) | Stability Single (Hz) | 0/ 9999/ 0 | Integer | | 1-24 are excluded |
| 124 (0x7c) | Stability Total (Hz) | 0/ 9999/ 0 | Integer | | 1-24 are excluded |
| 125 (0x7d) | Recorder Output | 0/ 12/ 0 | Integer | 0 = No recorder | Not allowed to be the same as a Source DAC |
| 126 (0x7e) | Recorder Function | 0/ 3/ 0 | Encode | 0 = Filtered Rate 1 = Thick 2 = RateDev    3 = Power | Gray font if recorder output set to 0 |
| 127 (0x7f) | Recorder Range | 0/ 99999/ 100 | Integer | Gray font if recorder output is set to 0 or Recorder Function is Power or Rate Deviation | |
| **Time Note:** Times are displayed as mm:ss. Times are stored as seconds. The maximum number of seconds is 5999. This would be displayed as 99:59. | | | | | |

### 9.4.8  Query Sensor Parameter

**Command** = QS <Command ID> <Sensor Number>

**Command ID** = <Byte> See Table 9-7.

**Sensor Number** = <Byte> Sensor number 1 - 6

**Response** = <Integer> | <Float>

Type of response depends on command ID, see "Data Type" column in Table 9-7.

### 9.4.9  Update Sensor Parameter

**Command: =** US <Command ID> <Sensor Number> <Parameter Value>

**Command ID** = <Byte> See Table 9-7

**Sensor Number** = <Byte> Sensor number 1 - 6

**Parameter Value** = <Integer> | <Float> Type of value depends on command ID, see Data Type column in Table 9-7.

**Response** = None (Just header and trailer)

*Table 9-7  Sensor parameters*

| QS & US Cmnd ID | Name (Units) | Range: Low Limit/ High Limit/ Default | Data Type | Notes | Update Restrictions and Display Notes |
|---|---|---|---|---|---|
| 1 (0x01) | (Sensor) Shutter Out(put) | 0/ 38/ 0 | Integer | 0 = not defined  Update not allowed if the Sensor is running. Not accepted if output in use by other hardware | |
| 2 (0x02) | Sensor Type | 0/ 4/ 0 | Encode | 0 = Single     1 = XtalTwo  2 = XtalSix     3 = Xtal12  4 = Generic | Update not allowed if the Sensor is running. |
| 3 (0x03) | (Sensor) Switch Out(put) | 0/ 38/ 0 | Integer | 0 = not defined  Gray font if Sensor Type = Single | Update not allowed if the Sensor is running. Not accepted if output in use by other hardware. |
| 4 (0x04) | Auto-Z | 0/ 1/ 0 | Encode | 0 = No, 1 = Yes | |

*Table 9-7  Sensor parameters (continued)*

| QS & US Cmnd ID | Name (Units) | Range: Low Limit/ High Limit/ Default | Data Type | Notes | Update Restrictions and Display Notes |
|---|---|---|---|---|---|
| 5 (0x05) | # of  Positions | 1/ 12/ 1 | Integer | Visible only when Sensor Type = 4 | Update not allowed if the Sensor is running. |
| 6 (0x06) | # of Pulses | 1/ 10/ 1 | Integer | | |
| 7 (0x07) | Pulse On (Time) (Seconds) | 0.1/ 9.9 /1 | REAL_3X1 | | |
| 8 (0x08) | Pulse Off (Time) (Seconds) | 0.1/ 9.9 /1 | REAL_3X1 | | |
| 9 (0x09) | Recorder Output | 0/ 12/ 0 | Integer | 0 = not defined | Not allowed to be the same as a Source DAC |
| 10 (0x0a) | Recorder Function | 0/ 2/ 0 | Encode | 0 = Unfiltered Rate 1 = Thick 2 = RateDev | Note: Rate is not affected by Rate Filter Time |
| 11 (0x0b) | Recorder Range | 0/ 99999/ 100 | Integer | | Gray font when Recorder Function = Rate Deviation |

## 9.4.10  Query Source Parameter

**Command** = QC <Command ID> <Source number>

**Command ID** = <Byte> See Table 9-8.

**Source Number** = <Byte> Source number 1 - 6

**Response** = <Integer> | <Float>

Type of response depends on command ID, see Data Type column in Table 9-8.

## 9.4.11  Update Source Parameter

**Command** = UC <Command ID> <Source number> <Parameter Value>

**Command ID** = <Byte> See Table 9-8.

**Source Number** = <Byte> Source number 1 - 6

**Parameter Value** = <Integer> | <Float>

Type of value depends on command ID, see Data Type column in Table 9-8.

**Response** = None (Just header and trailer)

*Table 9-8  Source parameters*

| QC & UC Cmnd ID | Name (Units) | Range: Low Limit/ High Limit/ Default | Data Type | Notes | Update Restrictions and Display Notes |
|---|---|---|---|---|---|
| 1 (0x01) | DAC Output | 0/ 12/ # | Integer | 0 = not defined. Default for Source 1 is 1, Source 2 is 2, etc. | Update not allowed if Source is running. Not allowed to set if the DAC is set as a recorder output. |
| 2 (0x02) | (Source) Shutter Output | 0/ 38/ 0 | Integer | 0 = not defined.Update not allowed if Source is running. | |
| 3 (0x03) | Number of Crucibles | 0/ 5/ 0 | Encode | 0 = 1    1 = 4    2 = 8<br>3 = 16    4 = 32    5 = 64 | Update not allowed if Source is running. |
| 4 (0x04) | Crucible Output | 0/ 38 /0 | Integer | 0 = not defined Gray font if Number of Crucibles = 0 | |
| 5 (0x05) | Turret Feedback | 0/ 1/ 0 | Encode | 0 = No    1 = Yes Gray font if Number of Crucibles = 0 | |
| 6 (0x06) | Turret Input | 0/ 28/ 0 | Integer | 0 = not defined Gray font if Turret Feedback = No or if Number of Crucibles = 1 | |
| 7 (0x07) | Turret Delay (Seconds) | 2/ 180/ 5 | Integer | Time out interval with feedback.Delay interval without feedback. Gray font if Number of Crucibles = 0 or if Number of Crucibles = 1 | |

### 9.4.12 Query Process Material Parameter

**Command:** QP <Command ID> <Process Number><Material Number>

**Command ID** = <Byte> See Table 9-9.

**Process Number** = <Byte> 1

**Material Number** = <Byte> 1 - 6

**Response** = <Integer> | <Float>

Type of response depends on command ID, see Data Type column in Table 9-9.

### 9.4.13 Update Process Material Parameter

**Command** = UP <Command ID> <Process Number><Material Number> <Parameter Value>

**Command ID** = <Byte> See Table 9-9.

**Process Number** = <Byte> 1

**Material Number** = <Byte> 1 to 6

**Parameter Value** = <Integer> | <Float> Type of value depends on command ID, see Data Type column in Table 9-9.

**Response** = None (Just header and trailer)

*Table 9-9  Process material parameters*

| QP & UP Cmnd ID | Name (Units) | Range: Low Limit/ High Limit/ Default | Data Type | Notes | Update Restrictions and Display Notes |
|---|---|---|---|---|---|
| 2 (0x02) | (Final Thickness) Final Thick (KÅ) | 0.0/ 999.999/ 0.0 | REAL_5F32 | | |
| 3 (0x03) | (Thickness Limit) Thick Limit (KÅ) | 0.0/ 999.999/ 0.0 | REAL_5F32 | | |
| 4 (0x04) | (Crucible) Cruc | 1/ 64/ 1 | Integer | | Update not allowed if Material is running |

### 9.4.14  Query Material Name

**Command** = QN <Material Number>

**Material Number** = <Byte> 1-6

**Response** = < Material Name>

**Material Name** = <String> Up to 15 characters, null terminated. The string returned will be a blank if the default Material # name has not been changed.

### 9.4.15  Update Material Name

**Command** = UN < Material Number> < Material Name>

**Material Number** = <Byte> 1 - 6

**Material Name** = <String> Up to 15 characters, null terminated

**Response** = None (Just header and trailer)

### 9.4.16  Query Input Name

**Command =** QI <Input Number>

**Input Number** = <Byte> 1 - 28

**Response** = <Input Name>

**Input Name** = <String> Up to 15 characters, null terminated

### 9.4.17  Update Input Name

**Command** = UI <Input Number> <Input Name>

**Input Number** = <Byte> 1 - 28

**Input Name** = <String> Up to 15 characters, null terminated

**Response** = None (Just header and trailer)

Input Names may only be updated if Cygnus 2 is in Ready or Stop.

**NOTE:**  UI changes are not allowed while a Material is running. The UI command will not allow updating a name set by hardware designation, unless it is identical to the defined hardware name.

### 9.4.18  Query Output Name

**Command** = QO <Output Number>

**Output Number** = <Byte> 1 - 38

**Response** = <Output Name>

**Output Name** = <String> Up to 15 characters, null terminated

### *9.4.19 Update Output Name*

**Command** = UO <Output Number> <Output Name>

**Output Number** = <Byte> 1 - 38

**Output Name** = <String> Up to 15 characters, null terminated

**Response** = None (Just header and trailer)

Output Names may only be updated if Cygnus 2 is in Ready or Stop.

**NOTE:** UO changes are not allowed while a Material is running. The UO command will not allow updating a name set by hardware designation, unless it is identical to the defined hardware name

### *9.4.20 Query Output Type*

**Command** = QT <Output Number>

**Output Number** = <Byte> 1 - 38

**Response** = <Output Type>

**Output Type** = <Byte> 0 or 1 (0 = NO, 1 = NC)

### *9.4.21 Update Output Type*

**Command** = UT <Output Number> <Output Type>

**Output Number** = <Byte> 1 - 38

**Output Type** = <Byte> 0 or 1 (0 = NO, 1 = NC)

**Response:** None (Just header and trailer)

**NOTE:** UT changes are not allowed while a Material is running.

### *9.4.22 Query User Message*

**Command** = QV <User Message Number>

**User Message Number** = <Byte> 1 - 10

**Response** = < User Message>

**User Message** = <String> Up to 19 characters, null terminated

### 9.4.23  Update User Message

**Command** = UV < User Message Number> < User Message Name>

**User Message Number** = <Byte> 1 - 10

**User Message # Name** = <String> Up to 19 characters, null terminated

**Response** = None (Just header and trailer)

**NOTE:**  A user message that is currently displayed will not be changed on the screen until the message area is refreshed.

### 9.4.24  Query Logic Statement

**Command** = QL <Statement Number>

**Statement Number** = <Byte> 1 - 100

**Response** = <Length of logic elements> <Set of elements>

**NOTE:**  This length is NOT the same as the length of the packet. It tells how many bytes follow in the "event/action" <set of elements>.

Response can be made up of the following elements. All elements except Numeric 2 are one byte. Numeric 2 is a 4-byte integer.

AND connector. . . . . . . . . . . . . . . . . 0x26

Or connector  . . . . . . . . . . . . . . . . . 0x7C

Left parenthesis . . . . . . . . . . . . . . . . 0x28

Right Parenthesis. . . . . . . . . . . . . . . 0x29

On connector . . . . . . . . . . . . . . . . . . 0x40

Event code . . . . . . . . . . . . . . . . . . . . <byte> (See note 1)

Negated Event code. . . . . . . . . . . . . <byte> (See note 1)

Numeric 1  . . . . . . . . . . . . . . . . . . . . <byte> (See note 2)

Numeric 2. . . . . . . . . . . . . . . . . . . . . <integer> (See note 3)

Space. . . . . . . . . . . . . . . . . . . . . . . . 0x20 separates "if" and "then"

Action code  . . . . . . . . . . . . . . . . . . . <byte> (See note 1)

Action Numeric. . . . . . . . . . . . . . . . . <byte> (See note 4)

Terminator  . . . . . . . . . . . . . . . . . . . . (ETX) 0x03 Indicates end of "then"

**Note 1:** For definition of event and action codes see for the Event list and for the Action list. The codes sent via communications would be the number listed there. If the event is to be negated, the event code will be negated as well. For example, the code for external input is 0x41. To indicate not external input (that is, input not set) the code is 0xBF. Action codes may not be negated.

**Note 2:** Numeric 1 is present if the event code requires a numeric. The range is dependent on the specific code.

**Note 3:** Numeric 2 is present if the event code requires a second numeric. It is a 4-byte integer. The range is dependent on the specific code.

**Note 4:** The Action Numeric is present if the action code requires a numeric. The range is dependent on the specific code.

The ordering of the logic elements is as follows: (The term Event Code includes Negated Event Code)

<u>**Event Terms**</u>

*1*   First element of term can be '(', a space, or an Event code

*2*   If space, there are no events, go straight to Action Terms. (see below)

*3*   if '(', next element must be event code

*4*   If event code, if numerals are required for specific code, they must be next

*5*   After event code, with its numerals, there may or may not be a ')'

*6*   Next must be either a connector or a space.

*7*   If a space, move on to Action Terms.

*8*   If connector, start next event (go to point 3. above).

   **NOTE:**   The last term cannot have a connector

<u>**Action Terms**</u>

Up to five action codes make up the action terms. Each code will be followed by a numeric if it is required. There are no connectors passed with the actions, as all actions are anded together.

The logic statement ends with a 0x03 (ETX).

### 9.4.25 Update Logic Statement

**Command** = UL<Statement Number><Length of logic elements> <Set of elements>

**Statement Number** = <Byte> 1 - 100

**Length of logic elements** = <Byte> number of bytes of the Logic element for each statement, including the 0x03 (ETX) terminator.

**Set of elements** = See description in QL above.

**Example**: IF External Input 21 and External Input 2 and External Input 18 and External Input 8

THEN Start Timer 1 and Extern Out On 10

Hex code for above including length and checksum:
1500554C0111411526410226411226410820510141 0A031A

**Response** = None (Just header and trailer)

Logic changes are not allowed while a process is running or if Cygnus 2 is in a stop.

### 9.4.26 Cygnus 2 Event List

Events used in the Logic Statement IF section. Logic codes are used in the remote communication query and update commands. The Logic codes start at 0x41 because there are formatting codes (for connectors, parentheses, etc.) used in the logic statements that are ASCII codes below 0x41. See Table 9-10.

*Table 9-10  Event list*

| Events | 1st numeric (1 Byte) (XXX) | Min | Max | 2nd numeric (Integer) (YYY) | Min | Max | Logic Code | Logic Code Negated |
|---|---|---|---|---|---|---|---|---|
| Parenthesis | | | | | | | | |
| External Input | Input # | 1 | 28 | | | | 0x41 | 0xBF |
| Pre-Deposit | | | | | | | 0x42 | 0xBE |
| In Deposit | | | | | | | 0x43 | 0xBD |
| Post-Deposit | | | | | | | 0x44 | 0xBC |
| Non Deposit | | | | | | | 0x45 | 0xBB |
| Ready | | | | | | | 0x46 | 0xBA |
| Crucible Switch | | | | | | | 0x47 | 0xB9 |
| PreCond Rise | | | | | | | 0x48 | 0xB8 |
| PreCond Soak | | | | | | | 0x49 | 0xB7 |

*Table 9-10  Event list (continued)*

| Events | 1st numeric (1 Byte) (XXX) | Min | Max | 2nd numeric (Integer) (YYY) | Min | Max | Logic Code | Logic Code Negated |
|---|---|---|---|---|---|---|---|---|
| Rise 1 | | | | | | | 0x4A | 0xB6 |
| Soak 1 | | | | | | | 0X4B | 0xB5 |
| Rise 2 | | | | | | | 0x4C | 0xB4 |
| Soak 2 | | | | | | | 0x4D | 0xB3 |
| Shutter Delay | | | | | | | 0x4E | 0xB2 |
| Deposit | | | | | | | 0x4F | 0xB1 |
| Rate Ramp 1 | | | | | | | 0x50 | 0xB0 |
| Rate Ramp 2 | | | | | | | 0x51 | 0xAF |
| Manual | | | | | | | 0x52 | 0xAE |
| Time Power | | | | | | | 0x53 | 0xAD |
| Non-Dep Control | | | | | | | 0x54 | 0xAC |
| Non-Dep Hold | | | | | | | 0x55 | 0xAB |
| Feed Ramp | | | | | | | 0x56 | 0xAA |
| Feed | | | | | | | 0x57 | 0xA9 |
| Idle Ramp | | | | | | | 0x58 | 0xA8 |
| Idle | | | | | | | 0x59 | 0xA7 |
| Stop | | | | | | | 0x5A | 0xA6 |
| Final Thick | | | | | | | 0x5C | 0xA4 |
| Thick Limit | | | | | | | 0x5D | 0xA3 |
| Thick Sum XXX See Note 4 | Equation # | 1 | 3 | Thickness xxx.xxx | 0 | 999.9 | 0x5E | 0xA2 |
| Time Limit | | | | | | | 0x5F | 0xA1 |
| Material XXX | Material # | 1 | 6 | | | | 0x64 | 0x9C |
| Material End XXX | Material # 0 = Any | 0 | 6 | | | | 0x66 | 0x9A |
| Timer Minutes (See Notes 2 & 3) | Timer # | 1 | 20 | Number of minutes | 00:00 | 99:59 | 0x69 | 0x97 |

*Table 9-10  Event list (continued)*

| Events | 1st numeric (1 Byte) (XXX) | Min | Max | 2nd numeric (Integer) (YYY) | Min | Max | Logic Code | Logic Code Negated |
|---|---|---|---|---|---|---|---|---|
| Timer Seconds (See Note 1) | Timer # | 1 | 20 | Time in Tenths of Seconds | 0 | 999.9 | 0x6A | 0x96 |
| Count limit | Counter # | 1 | 20 | Counter value | 0 | 999 | 0x6B | 0x95 |
| Statement | Logic Statement # | 1 | 100 | | | | 0x6C | 0x94 |
| Xtal Fail | Sensor # 0 = any | 0 | 6 | | | | 0x6D | 0x93 |
| Xtal Switching | Sensor # 0 = any | 0 | 6 | | | | 0x6E | 0x92 |
| Max Power | | | | | | | 0x6F | 0x91 |
| Min Power | | | | | | | 0x70 | 0x90 |
| Not Used | | | | | | | 0x71 | 0x8F |
| Not Used | | | | | | | 0x72 | 0x8E |
| Ion Assist Dep | | | | | | | 0x73 | 0x8D |
| Auto-Z Fail | Sensor # 0 = any | 0 | 6 | | | | 0x74 | 0x8C |
| Cruc Sw Fail | | | | | | | 0x75 | 0x8B |
| Rate < 0.1 | | | | | | | 0x76 | 0x8A |
| Shutter Dly Error | | | | | | | 0x77 | 0x89 |
| Not Used | | | | | | | 0x78 | 0x88 |
| Not Used | | | | | | | 0x79 | 0x87 |
| Xtal Life > xxx | Sensor # 0 = any | 0 | 6 | % Life | 1 | 99 | 0x7A | 0x86 |
| Xtal Activity < xxx | Sensor # 0 = any | 0 | 8 | Activity | 1 | 999 | 0x7B | 0x85 |
| Computer Cntrl | | | | | | | 0x7C | 0x84 |
| Test | | | | | | | 0x7D | 0x83 |

*Table 9-10  Event list (continued)*

| Events | 1st numeric (1 Byte) (XXX) | Min | Max | 2nd numeric (Integer) (YYY) | Min | Max | Logic Code | Logic Code Negated |
|--------|----------------------------|-----|-----|-----------------------------|-----|-----|------------|--------------------|
| Not Used | | | | | | | 0x7E | 0x82 |
| Rate Dev(iation) Err(or) | | | | | | | 0x7F | 0x81 |
| **Note 1:** Seconds are entered via remote communications as tenths of seconds. Seconds are entered by keyboard as whole numbers. **Note 2:** The time is entered via remote communications as whole minutes. 99 hours = 5940 minutes, so 99 hours + 59 minutes = 5999 minutes maximum. The time entered by keyboard is in hours and minutes. **Note 3:** Maximum number of minutes is 59. The entry of '00:65' is invalid. That time can be entered as '01:05'. **Note 4:** Thick Sum will be sent as an integer Angstroms (the number multiplied by 1000). ||||||||||

### 9.4.27 Cygnus 2 Action List

Actions are triggered in the Logic Statement THEN section. Logic codes are used in the remote communication query and update commands. Some actions that require a numeric may act on all items by entering a zero, as noted in Table 9-11.

*Table 9-11 Action list*

| Actions | Numeric (Byte) | Min | Max | Logic Code |
|---|---|---|---|---|
| Extern Out On XXX | Output # | 1 | 38 | 0x41 |
| Extern Out Off XXX | | | | 0x42 |
| Not Used | Material # | 0 | 6 | 0x43 |
| Not Used | | | | 0x44 |
| Start XXX | | | | 0x45 |
| Reset XXX | | | | 0x46 |
| Stop XXX | | | | 0x47 |
| Zero Deposit Time XXX | | | | 0x48 |
| Zero Thick XXX | | | | 0x49 |
| Trig Fnl Thick XXX | | | | 0x4A |
| Continue Dep XXX | | | | 0X4B |
| Start Deposit XXX | | | | 0x4C |
| Go to NonDep XXX | | | | 0x4D |
| Go to PostDep XXX | | | | 0x4E |
| Increment Count XXX | Counter # | 1 | 20 | 0x4F |
| Clear Counter XXX | | | | 0x50 |
| Start Timer XXX | Timer # | 1 | 20 | 0x51 |
| Cancel Timer XXX | | | | 0x52 |
| Switch Xtal XXX | Sensor # | 1 | 6 | 0x53 |

*Table 9-11  Action list (continued)*

| Actions | Numeric (Byte) | Min | Max | Logic Code |
|---|---|---|---|---|
| * PreCond S/H Off XXX | Material # | 0 | 6 | 0x54 |
| * PreCond S/H On XXX | | | | 0x55 |
| * Soak 1 Hold Off XXX | | | | 0x56 |
| * Soak 1 Hold On XXX | | | | 0x57 |
| * Soak 2 Hold Off XXX | | | | 0x58 |
| * Soak 2 Hold On XXX | | | | 0x59 |
| * Clock Hold Off | | | | 0x5A |
| * Clock Hold On | | | | 0x5B |
| * Start Inhbt Off ** | | | | 0x5C |
| * Start Inhbt On ** | | | | 0x5D |
| * Xtl Fl Inhbt Off | Sensor # | 0 | 6 | 0x5E |
| * Xtl Fl Inhibt On | | | | 0x5F |
| * RWS Inhibit Off XXX (RWS = RateWatcher Sample) | Material # | 0 | 6 | 0x60 |
| * RWS Inhibit On XXX | | | | 0x61 |
| * RWS Init(iate) Off XXX | | | | 0x62 |
| * RWS Initiate On XXX | | | | 0x63 |
| Message On XXX See Note | Message # | 1 | 10 | 0x64 |
| Message Off XXX See Note | | | | 0x65 |
| **Note:** There are ten User Messages available for the user to construct. These messages can be displayed and cleared via logic actions. User Messages are constructed on the General page Message screen. | | | | |
| **Note:** * = Remote Comm and Logic will be independent. Methods used to set action must be used to clear action. ** = Start Inhibit will carry through a power cycle | | | | |

### 9.4.28 Status General

Command = SG <Command ID><Option>

Command ID = <Byte> See "Description" in Table 9-12.

Option = <Byte> |< Integer > | <32 Bit Word> | <48 Bit Word>

Response = <Byte>… <Byte> | <Integer>…<Integer

*Table 9-12 Status general commands*

| SG Command ID | Description | Option | Number of bytes in the response | Data Returned | Notes |
|---|---|---|---|---|---|
| 0 (0x00) | N/A | | | | |
| 3 (0x03) | Output status | | 5 | <Byte><Byte><Byte> <Byte><Byte> Each bit represents an output, bit set means output active. | MSB of first byte is output 1.MSB of the fifth byte is output 33. |
| 4 (0x04) | Input status | | 4 | <Byte><Byte><Byte> <Byte> Each bit represents an input. Bit set means input active. | MSB of first byte is input 1. MSB of the fourth byte is input 25. |
| 5 (0x05) | Logic statement status | | 13 | <Byte><Byte><Byte> <Byte><Byte><Byte> <Byte><Byte><Byte> <Byte><Byte><Byte> <Byte> Each bit represents a logic statement, bit set means logic statement is true. | MSB of first byte is logic statement 1.MSB of the thirteenth byte is logic statement 97. |
| 6 (0x06) | Status Messages | | 8 | <Byte><Byte><Byte> <Byte><Byte><Byte> <Byte><Byte> | See encodes in section 13.1 on page 13-1. One bit is set for each error. Multiple bits may be set. |

*Table 9-12  Status general commands (continued)*

| SG Command ID | Description | Option | Number of bytes in the response | Data Returned | Notes |
|---|---|---|---|---|---|
| 7 (0x07) | Status Message Designators | <Status Message Word> 8 bytes | 1-13 (Can have 12 DAC recorders) | <Byte>\| <Byte>....<Byte> | Status Message Word corresponding to one of the status messages, as encoded in the SG 6 command. |
| | This indicates which status message designators are to be returned. Note that only one bit may be set, that is, only the designators for one error can be requested per command.Returns a string of bytes. First byte is the number of bytes following. The following bytes indicate the designators for the requested status message.If there are no designators, the first byte returned will be zero. | | | | |
| 9 (0x09) | Transient Messages | | 1 | <Byte> | See encodes in section 13.4 on page 13-6. |
| 10 (0x0a) | Sensor Status | | 6 | <Byte><Byte><Byte> <Byte><Byte><Byte> | One byte for each Sensor Range between 0 and 5. |
| | 0 = Good Crystal and active. 1 = Failed Crystal and active. 2 = Invalid Measurement on Crystal and active. 3 = Good Crystal and inactive. 4 = Failed Crystal and inactive. 5 = Invalid Measurement on Crystal and inactive. | | | | |
| 11 (0x0b) | Timer Status | Timer Number <Integer> 1 - 20 | 1 | <Byte> | Response:0 = Timer inactive1 = Timer active |
| 12 (0x0c) | Timer Value | Timer Number <Integer> 1 - 20 | 4 | <Integer> | Response is in tenths of seconds. Max Time = 99:59:59.0 (3599990 tenths of seconds) |
| 13 (0x0d) | Counter Value | Counter Number <Integer> 1 - 20 | 4 | <Integer> | |
| 14 (0x0e) | Thickness Sum | Equation number <Integer> 0 - 3 | 4 or 12 | <Float> or <Float><Float> <Float> | 0 = All thickness equations 1 - 3 = the number of the equation to return. |
| 15 (0x0f) | Get date | | 12 | <Integer><Integer> <Integer> | Integers for month, day, year or day, month year, depending on date format general parameter. |

*Table 9-12  Status general commands (continued)*

| SG Command ID | Description | Option | Number of bytes in the response | Data Returned | Notes |
|---|---|---|---|---|---|
| 16 (0x10) | Get time | | 12 | \<Integer>\<Integer> \<Integer> | Integers for the hour, minute and the seconds. |
| 17 (0x11) | System Configuration (What boards are present.) | | 2 | \<Byte>\<Byte> | Bit |
| | 0x0001 = Measurement Bd 1 0x0002 = Measurement Bd 2 0x0004 = Measurement Bd 3, 0x0010 = I/O Board 1, 0x0020 = I/O Board 2, 0x0040 = I/O Board 3, 0x0080 = Optional DAC Board, 0x0100 = Temperature Control Board 1, 0x0200 = Temperature Control Board 2, 0x0400 = Ethernet Board, 0x0800 = {Reserved}, 0x1000 = {Reserved}, 0x2000 = {Reserved}, 0x4000 = {Reserved}, 0x8000 = {Reserved} | | | | |

## 9.4.29 Status Material

**Command** = SL <Command ID><Material>

**Command ID** = <Byte> See "Description" in Table 9-13.

**Material** = <Byte>Material number (0 – 6)

◆ Material = 0 will return the status of six Materials. The response will include all active Materials.

**Response** = See Data Returned in Table 9-13.

*Table 9-13  Status material*

| SL Command ID | Description | Number of bytes in the response | Data Returned | Notes |
|---|---|---|---|---|
| 0 (0x00) | N/A | | | |
| 1 (0x01) | Filtered Rate | 4 or 24 | <Float> | Å/S |
| 2 (0x02) | Displayed Rate | 4 or 24 | <Float> | Å/S Averaged over one second |
| 3 (0x03) | Source Power Output | 4 or 24 | <Float> | % |
| 4 (0x04) | Thickness | 4 or 24 | <Float> | incremented while the source or substrate shutter is open as in Deposit, KÅ |
| 5 (0x05) | State | 1 or 6 | <Byte>or <Byte><Byte><Byte> <Byte><Byte><Byte> | See encodes in section 3.4 on page 3-23 |
| 6 (0x06) | State Time | 4 or 24 | <Integer> | Seconds in the current state |
| 7 (0x07) | Active Sensors | 1 or 6 | <Byte> or <Byte><Byte><Byte> <Byte><Byte><Byte> | Active Sensors Byte is a six-bit word where each bit represents a Sensor |
| | Any bit set indicates a Sensor is active for the requested Material. Bit 0 = Sensor 1, bit 1 = Sensor 2, thru bit 5 = Sensor 6. | | | |
| 8 (0x08) | Power Source Number | 1 or 6 | <Byte> or <Byte><Byte><Byte> <Byte><Byte><Byte> | Source number for the requested Material. |
| 9 (0x09) | Accumulated Layer Time | 4 or 24 | <Integer> | Seconds since "Ready" |

*Table 9-13  Status material (continued)*

| SL Command ID | Description | Number of bytes in the response | Data Returned | Notes |
|---|---|---|---|---|
| 10 (0x0a) | Deposit Average Rate | 4 or 24 | <Float> | KÅ   Based on Averaging Time parameter.  Only available when in a control state. |
| 11 (0x0b) | Deposit Average Power | 4 or 24 | <Float> | %    Based on Averaging Time parameter. Only available when in a control state. |
| 12 (0x0c) | Raw Rate | 4 or 24 | <Float> | Å/S |
| 13 (0x0d) | One Minute Averages for Rate & Power | 8 or 48 | <Float><Float> | Returns a 'No Data Error' if not enough data to do a one minute average of the rate or the power |
| 14 (0x0e) | Rate Deviation / power output trend | Varies with # of data points | <Integer><Float>… <Float> | Number of bytes in the response. Average values from the operate screen graph. Format of each data point. |
| 15 (0x0f) | State before Stop | 1 or 6 | <Byte> or <Byte><Byte><Byte> <Byte><Byte><Byte> | See encodes in section 3.4 on page 3-23. If not currently in Suspend, will return "No Data Error" |
| 16 (0x10) | Data Log | 64 or 384 | Multiple pieces of information | See section 3.5.9 on page 3-35 for order of data. |
| 17 (0x11) | Data Log with Xtal History | 448 or 2,688 | <Data Log + Crystal data for 12 crystals per Sensor>. | See section 3.5.9 on page 3-35 for order of data. Length of response = 64 bytes Data Log + 384 bytes Xtal History Xtal History = 32 bytes per crystal, 12 crystals in 6 Sensors = 32*12*6=2304 bytes |
| 18 (0x12) | Cause of Stop | 1 or 6 | <Byte> or <Byte><Byte><Byte> <Byte><Byte><Byte> | See encodes in section 13.3 on page 13-5. If not currently in Stop, "Data not available" error will be returned. |

### 9.4.30 Status Sensor

**Command** = SS <Command ID><Sensor>

**Command ID** = <Byte> See "Description" in Table 9-14.

**Sensor** = <Byte> Sensor number (0 - 6)

If the Sensor number is zero the response will give the value for all six Sensors.

**Response** = See Data Returned in Table 9-14.

*Table 9-14  Status sensor*

| SS Command ID | Description | Number of bytes in the response | Data Returned | Notes |
|---|---|---|---|---|
| 0 (0x00) | Crystal Life | 1 or 6 | <Byte> or <Byte><Byte><Byte> <Byte><Byte><Byte> | One byte for each Sensor. Range will be 0 - 100 |
| 1 (0x01) | Crystals Remaining | 1 or 6 | <Byte> or <Byte><Byte><Byte> <Byte><Byte><Byte> | One byte for each Sensor. Range between 0 and 12. Number of good crystals on a CrystalTwo, Crystal6 or Crystal12 Sensor. Returns either a 0 (current crystal failed) or a 1 (current crystal good) for a Single sensor. The command is not intended to be used for Generic sensor - returns NO_DATA . |
| 2 (0x02) | Crystal Position | 1 or 6 | <Byte> or <Byte><Byte><Byte> <Byte><Byte><Byte> | One byte for each Sensor. Range between 1 and 12. The current crystal position on a CrystalTwo, Crystal6 or Crystal12. |
| 3 (0x03) | Sensor Status | 1 or 6 | <Byte> or <Byte><Byte><Byte> <Byte><Byte><Byte> | One byte for each Sensor.<br>Bit1 Bit 0<br>0 0 Good Crystal<br>0 1 Failed Crystal<br>1 0 Invalid Measurement on Crystal<br>1 1 Undefined<br>Bit 7 Bit 6<br>0 0 Auto-Z-Ratio<br>0 1 Sensor Z-Ratio<br>1 0 Material Z-Ratio<br>1 1 Undefined |
| 4 (0x04) | Fundamental Frequency | 8 or 48 | <Long> or <Long><Long><Long> <Long><Long><Long> | One long integer for each Sensor. Unconverted. To convert to Hz, multiply by 0.000873114913702011 |

*Table 9-14  Status sensor (continued)*

| SS Command ID | Description | Number of bytes in the response | Data Returned | Notes |
|---|---|---|---|---|
| 5 (0x05) | Fundamental Activity | 4 or 24 | <Integer> or <Integer><Integer> <Integer><Integer> <Integer><Integer> | One integer for each Sensor Range 0 - 999 |
| 6 (0x06) | Current Z-Ratio | 4 or 24 | <Float> or <Float><Float><Float> <Float><Float><Float> | Z-Ratio currently in use. |
| 7 (0x07) | Anharmonic Frequency | 8 or 48 | <Long> or <Long><Long><Long> <Long><Long><Long> | One long integer for each Sensor. Unconverted, to convert to Hz, multiply by 0.000873114913702011 |
| 8 (0x08) | Anharmonic Activity | 4 or 24 | <Integer> or <Integer><Integer> <Integer><Integer> <Integer><Integer> | One Integer for each Sensor Range 0 - 999 |
| 9 (0x09) | New crystal Frequency | 16 or 96 | <Long><Long> or < Long>x12 | Returns the Fundamental and Anharmonic "NEW" crystal frequencies |
| 10 (0x1a) | LCQ value | 4 or 24 | <Float> or <Float><Float><Float> <Float><Float><Float> | Returns the LCQ running value (for factory diagnostic use only) |
| 11 (0x0b) | N/A | | | |
| 12 (0x0c | Sensor Thickness | 4 or 24 | <Float> or <Float><Float><Float> <Float><Float><Float> | kÅ Returns Sensor thickness, increments in all states including Ready & Stop. Reset zeros it. |

### 9.4.31 Remote General Action

**Command** = RG <Command ID> (<Action Value>)

**Command ID** = <Byte> See Table 9-15.

**Action Value** = <Byte>… <Byte> | <Integer>…<Integer>|<Float>…<Float>

See Table 9-15 for commands that require an action value.

**Response** = None (Just header and trailer)

*Table 9-15  Remote general*

| RG Command ID | Meaning | Action Value | Notes |
|---|---|---|---|
| 1 (0x01) | Stop All | | Duplicates the equivalent front panel action |
| 2 (0x02) | Reset All | | Duplicates the equivalent front panel action |
| 3 (0x03) | Remote Lock On | | No parameters can be updated from the front panel "R Lock" displayed |
| 4 (0x04) | Remote Lock Off | | Cancel RG 3 command |
| 5 (0x05) | Set Logic Statement <Statement Number> to True | <Byte> | Range is 1-100. Only does something if logic statement event "Computer Control" set.  Otherwise, ignored. |
| 6 (0x06) | Clear Logic Statement <Statement Number> to False. | <Byte> | Range is 1-100. Only does something if logic statement event "Computer Control" set. Otherwise, ignored. |
| 7 (0x07) | Crystal Fail Inhibit On | <Byte> | Range is 0-6 (0 = All) "Crystal Fail" output always set to FALSE, even during crystal fail |
| 8 (0x08) | Crystal Fail Inhibit Off | <Byte> | Range is 0-6 (0 = All) "Crystal Fail" output has normal meaning |
| 9 (0x09) | Set date (Month, Day, Year) or (Day, Month, Year) Depending on General parameter 17 (Date Format). | <Integer> <Integer> <Integer> | Range as follows:Month = 1 to 12 Day = 1 to 31 Year = 2000 to 2099 |
| 10 (0x0a) | Set time (Hour, Minute, Second) | <Integer> <Integer> <Integer> | Range as follows Hour = 0 to 23 Minute = 0 to 59 Second = 0 to 59 |

*Table 9-15  Remote general (continued)*

| RG Command ID | Meaning | Action Value | Notes |
|---|---|---|---|
| 11 (0x0b) | Zero Counter <Counter> | <Byte> | Counter Range is 0-20<br>0 = All |
| 12 (0x0c) | Zero Timer <Timer> | <Byte> | Timer Range is 0-20<br>0 = All |
| 13 (0x0d) | Start Timer <Timer> | <Byte> | Timer Range is 1-20 |
| 14 (0x0e) | Cancel Timer <Timer> | <Byte> | Timer Range is 0-20<br>0 = All |
| 15 (0x0f) | Clock Hold On <Material> | <Byte> | Stops timer in Pre-Deposit or Post-Deposit.  Keeps in current state at current power setting.<br>Material Range 0-6 (0 = all Materials) |
| 16 (0x10) | Clock Hold Off <Material> | <Byte> | Restarts timer in Pre-Deposit or Post-Deposit<br>Material Range 0-6 (0 = all Materials) |
| 17 (0x11) | User message on <Message #> | <Byte> | Message Range is 1-10 |
| 18 (0x12) | User message off <Message #> | <Byte> | Message Range is 1-10 |
| 19 (0x13) | Soak Hold 1 on <Material> | <Byte> | Material Range is 0-6<br>(0 = all Materials) |
| 20 (0x14) | Soak Hold 1 off <Material> | <Byte> | Material Range is 0-6<br>(0 = all Materials) |
| 21 (0x15) | Soak Hold 2 on <Material> | <Byte> | Material Range is 0-6<br>(0 = all Materials) |
| 22 (0x16) | Soak Hold 2 off <Material> | <Byte> | Material Range is 0-6<br>(0 = all Materials) |
| 23 (0x17) | Switch Sensor<Sensor #> to <Crystal #> | <Byte><Byte> | Sensor Range = 1 - 6<br>Crystal Range = 0 to maximum allowed crystals for the requested Sensor. If Crystal # = 0, will switch to the "next" crystal. If the Sensor is not used in a Material currently running, the next crystal will be the next one in the sequence. If the Sensor is used in a Material that is running, the next crystal will be the next one from the XL Position parameters sequence. If a Sensor is used in a Material that is running, the value of "Crystal #" must be zero, otherwise, an error will occur. |

*Table 9-15  Remote general (continued)*

| RG Command ID | Meaning | Action Value | Notes |
|---|---|---|---|
| 24 (0x18) | Clear Failed Crystals X | <Byte> | Clears all failed crystals except the current crystal for the requested Sensor. X = Sensor (1- 6) |
| 25 (0x19) | | | Reserved for future use. |
| 26 (0x1a) | Rotate head X | <Byte> | If the requested Sensor is a multi crystal sensor and the Material for that Sensor is in Ready, Stop or all active Materials are in Idle, the sensor head will rotate. X = Sensor (1 - 6) |
| 27 (0x1b) | Default all Parameters | | Sets all parameters except the communication parameters to default values. |
| 29 (0x1d) | Soak Hold Pre Con on <Material > | <Byte> | Material Range is 0 - 6 (0 = All Materials) |
| 30 (0x1e) | Soak Hold Pre Con off <Material > | <Byte> | |
| 31 (0x1f) | Start Inhibit On | | Disallows a Start command to be executed. |
| 32 (0x20 | Start Inhibit Off | | Allows a Start command to be executed. |
| 33 (0x21) | RateWatcher Sampling Inhibit On <Material > | <Byte> | Will immediately cause the Deposit state to leave sampling and not return until turned off. |
| 34 (0x22) | RateWatcher Sampling Inhibit Off <Material > | <Byte> | Allows the Deposit state to go into the RateWatcher algorithm. |
| 35 (0x23) | RateWatcher Sample Initiate On <Material > | <Byte> | Allows the Deposit state to enter RateWatcher sampling |
| 36 (0x24) | RateWatcher Sample Initiate Off <Material > | <Byte> | Turns RateWatcher sampling off. |
| 37 (0x25) | Clear Q and S counts for Sensor X | <Byte> | Clear Q and S counts for specified Sensor X |
| 38 (0x26) | Name Material <Material><Library Entry> | <Byte><Byte> | Give Material number <Material> (1-6) the name corresponding to Material entry <Library Entry> (0-254). Library entries range from 0 (Ag) to 254 ($ZrO_2$), with numbers corresponding to the alphabetical listing in the library. The density and Z-Ratio will be changed accordingly. |

## 9.4.32  Remote Material Action

**Command** = RL <Command ID> <Material Number> (<Action Value>)

**Command ID** = <Byte>.

**Material Number** = <Byte> 1- 6

**Action Value** = <Byte> | <Integer> | <Float>

See Table 9-16 for commands that require an action value.

**Response** = None (Just header and trailer)

*Table 9-16  Remote material*

| RL Command ID | Meaning | Action Value | Notes |
|---|---|---|---|
| 0  (0x00) | Stop Material | | |
| 1 (0x01) | Zero Thickness | | Cannot do from Stop |
| 2 (0x02) | Start Deposit | | Will always zero thickness on entry.This cannot be done from Ready, Idle, Stop, Crystal Switching or Crucible Switch. When there is no good crystal, this command will go to "Time Power" if previous state was Non-Deposit Hold, otherwise, is not allowed. |
| 3 (0x03) | Go to Non-Deposit Control | | This cannot be done from Ready, Stop, or Crucible Switch. When there is no good crystal, this command will go to "Non-Deposit Hold" if the previous state was Time Power, otherwise, is not allowed. |
| 4 (0x04) | Go to Post-Deposit (Feed Ramp) | | Cannot be done if in Crucible Switch |
| 5 (0x05) | Continue Deposit | | Go to Deposit, but don't zero thickness.This cannot be done from Ready, Idle, Stop, Crystal Switching or Crucible Switch.When there is no good crystal, this command will go to "Time Power" if the previous state was Non-Deposit Hold, otherwise, is not allowed. |
| 6 (0x06) | Go to Manual. | | (Source shutter does not change position) Cannot be done if in STOP, Non-Dep Hold or Crucible Switch, or there is not a good crystal. |
| 7 (0x07) | Set Power Level | <Float> | Range is 0-99.99. Only allowed if in Manual, Time Power, or Non-Deposit Hold State.  If the value is greater than the Max Power or less than the Min Power, a value error is returned. |
| 8 (0x08) | Open Source shutter | | Only allowed if in Manual |
| 9 (0x09) | Close Source shutter | | Only allowed if in Manual |

*Table 9-16  Remote material (continued)*

| RL Command ID | Meaning | Action Value | Notes |
|---|---|---|---|
| 10 (0x0a) | Set Averaged Rate | <Float> | Range is 0-999.9. Only in Time power or Non Deposit Hold - the estimated rate used. |
| 11 (0x0b) | Start | | |
| 12 (0x0c) | Reset Material | | |

### 9.4.33 Cygnus 2 Communications Examples

#### 9.4.33.1 General Command Packet Format

**<Length**(low/high, 2 byte)**><Message**(command)**><Checksum**(1 byte Hex)**>**

#### 9.4.33.2 General Response Packet Format

**<Length**(low/high, 2 byte)**><CCB**(1 byte, no errors returns 00)**><Timer**(1 byte binary)**><Response Message**(Command Response)**><Checksum**(1 byte Hex)**>**

#### 9.4.33.3 HELLO Command, ASCII name and version

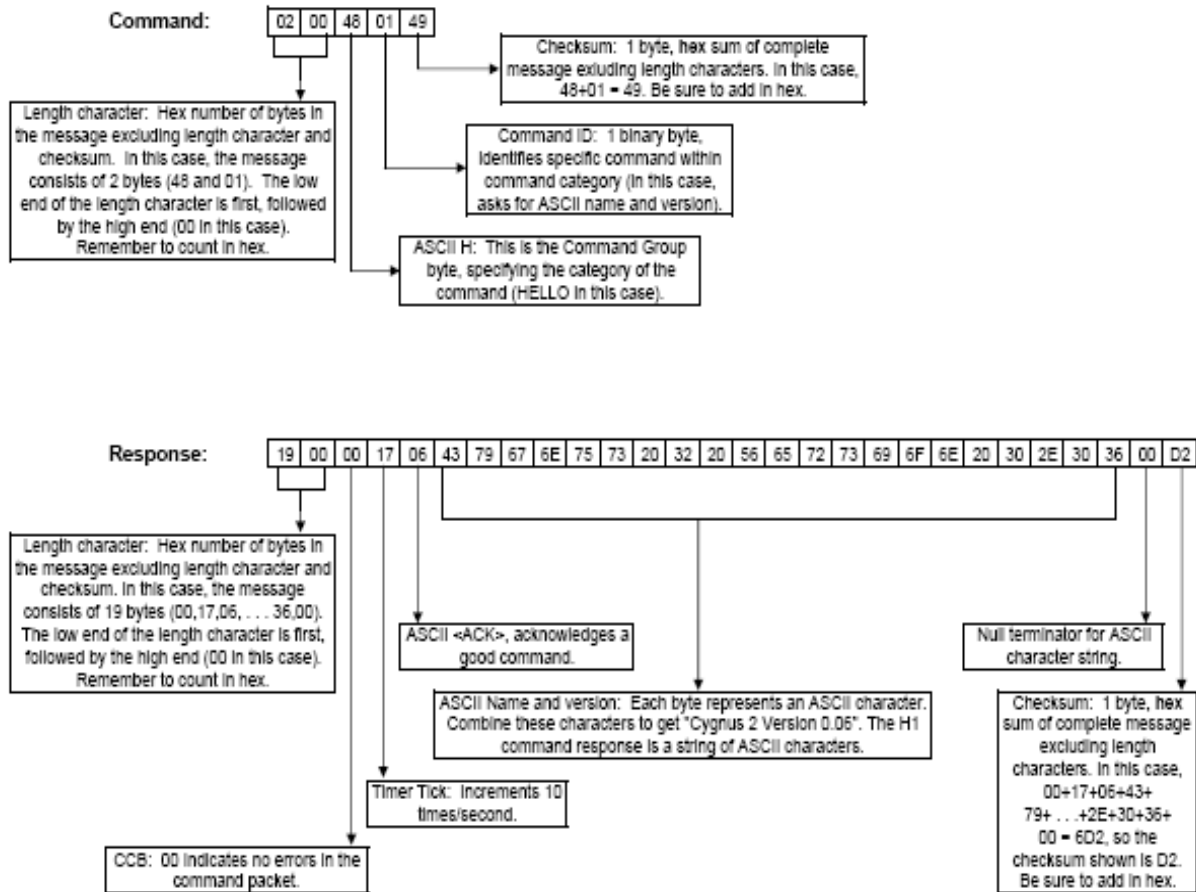Command Format: H <Command ID>

H1

Command H1: `0200480149`

Response:
`19000017064379676E75732032205665727369696F6E20302E303600D2`



Example: H1 command
HELLO Command, ASCII name and version

### 9.4.33.4  Query Material Parameter, Z-Ratio (2), Material 1

Command Format:  QM <Command ID> <Material Number>

QM2 1

Command QM2 1: `0400514D0201A1`

Response: `070000F10648E1BA3E18`

### 9.4.33.5  Update Material Parameter, Control Loop (4), Material 1, PID (2)

Command Format:  UM <Command ID> <Material Number> <Parameter Value>

UM4 1 2

Command UM4 1 2: `0800554D040102000000A9`

Response: `0300000D0613`

### 9.4.33.6  Query Sensor Parameter, Shutter Output (1), Sensor 1

Command Format:  QS <Command ID> <Sensor Number>

QS1 1

Command QS1 1: `040051530101A6`

Response: `070000870600000008D`

### 9.4.33.7  Update Sensor Parameter, Sensor Type (2), Sensor 1, CrystalTwo (1)

Command Format:  US <Command ID> <Sensor Number> <Parameter Value>

US2 1 1

Command US2 1: `08005553020101000000AC`

Response: `0300002F0635`

### 9.4.33.8  Query Source Parameter, Shutter Output (2), Source 1

Command Format:  QC <Command ID> <Source Number>

QC2 1

Command QC2 1: `04005143020197`

Response: `0700003F060000000045`

### 9.4.33.9  Update Source Parameter, Number of crucibles (3), Source 1, 4 crucibles (1)

Command Format:  UC <Command ID> <Source Number> <Parameter Value>

UC3 1 1

Command UC3 1 1: `08005543030101000000 9D`

Response: `03000054065A`

### 9.4.33.10  Query Material Name, Material 1

Command Format:  QN <Material Number>

QN 1

Command QN 1: **0300514E01A0**

Response: **0A0000470653494C5645520022**

### 9.4.33.11  Update Material Name, Material 1, "SILVER"

Command Format:  UN <Material Number> <Material Name>

UN 1 SILVER

Command UN 1 SILVER: **0A00554E0153494C5645520079**

Response: **030000E806EE**

### 9.4.33.12  Query Input Name, Input 1

Command Format:  QI <Input Number>

QI 1

Command QI 1: **03005149019B**

Response: **060000BB0650310042**

### 9.4.33.13  Update Input Name, Input 1, "P1"

Command Format:  UI <Input Number> <Input Name>

UI 1 P1

Command: **060055490150310020**

Response: **030000A306A9**

### 9.4.33.14  Query Output Name, Output 1

Command Format:  QO <Output Number>

QO 1

Command Q0 1: **0300514F01A1**

Response: **0B0000E206534855545445520017**

### 9.4.33.15  Update Output Name, Output 1, "SHUTTER"

Command Format:  UO <Output Number> <Output Name>

UO 1 SHUTTER

Command U0 1: **0B00554F015348555454455200D4**

Response: **030000E306E9**

### 9.4.33.16 Query Output Type, Output 1

Command Format: QT <Output Number>

QT 1

Command QT 1: `0300515401A6`

Response: `040000BF0600C5`

### 9.4.33.17 Update Output Type, Output 1, Normally Closed (1)

Command Format: UT <Output Number> <Output Type>

UT 1 1

Command UT 1 1: `040055540101AB`

Response: `030000FA0600`

### 9.4.33.18 Query User Message, Message 1

Command Format: QV <User Message Number>

QV 1

Command QV 1: `0300515601A8`

Response: `0A0000C80648454C4C4F210063`

### 9.4.33.19 Update User Message, Message 1, "HELLO!"

Command Format: UV <User Message Number> <User Message Name>

UV 1 HELLO!

Command UV 1 HELLO!: `0A0055560148454C4C4F210041`

Response: `030000CD06D3`

### 9.4.33.20 Query Logic Statement, Statement 1

Command Format: QL <Statement Number>

QL 1

Command QL 1: `0300514C019E`

Response: `090000B00605410120450365`

### 9.4.33.21  Update Logic statement, Statement 1, "IF External Input 1 THEN Start 1"

Command Format:  UL <Statement Number> <Length of logic elements> <set of elements>
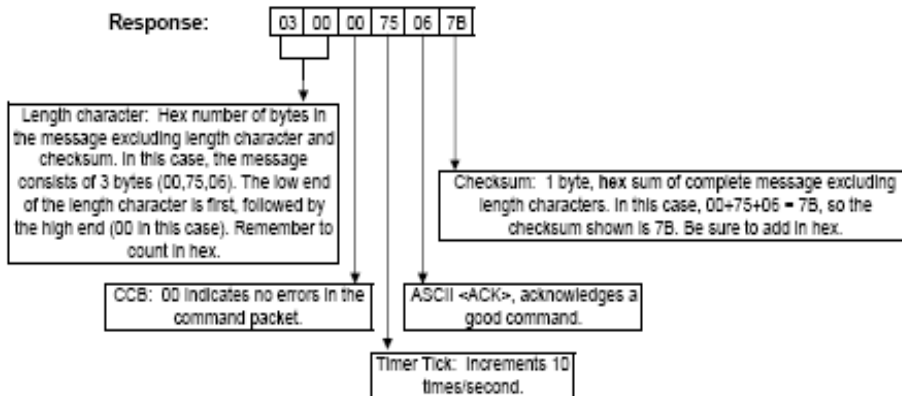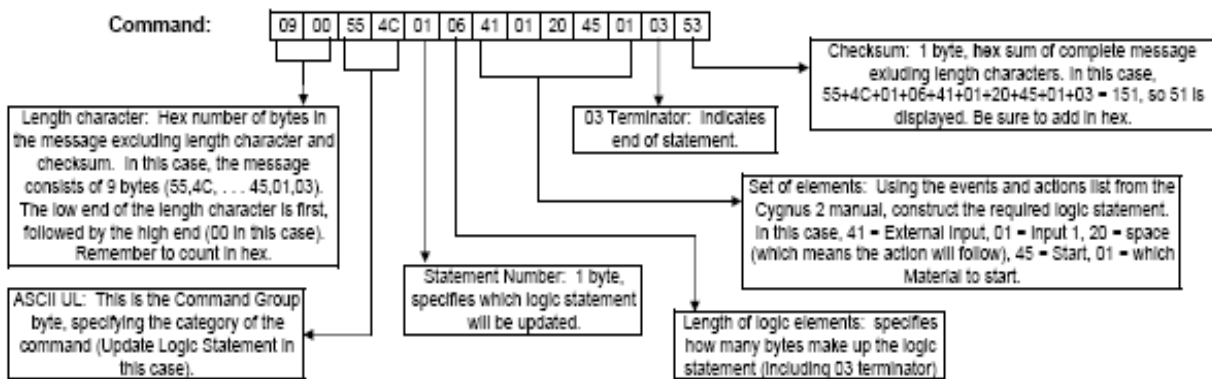
UL 1 IF EXTERNAL INPUT 1 THEN START 1

Command UL 1 IF EXTERNAL INPUT 1 THEN START 1:
**0A00554C010641012045010358**

Response: **03000075067B**



Example:  UL 1 IF EXTERNAL INPUT 1 THEN START 1 command

Update Logic statement, Statement 1, "IF External Input 1 THEN Start 1"

**Command:** 09 00 55 4C 01 06 41 01 20 45 01 03 53

Length character: Hex number of bytes in the message excluding length character and checksum. In this case, the message consists of 9 bytes (55,4C, . . . 45,01,03). The low end of the length character is first, followed by the high end (00 in this case). Remember to count in hex.

ASCII UL:  This is the Command Group byte, specifying the category of the command (Update Logic Statement in this case).

Statement Number:  1 byte, specifies which logic statement will be updated.

03 Terminator:  Indicates end of statement.

Checksum:  1 byte, hex sum of complete message exluding length characters. In this case, 55+4C+01+06+41+01+20+45+01+03 = 151, so 51 is displayed. Be sure to add in hex.

Set of elements:  Using the events and actions list from the Cygnus 2 manual, construct the required logic statement. In this case, 41 = External Input, 01 = Input 1, 20 = space (which means the action will follow), 45 = Start, 01 = which Material to start.

Length of logic elements:  specifies how many bytes make up the logic statement (including 03 terminator).

**Response:** 03 00 00 75 06 7B

Length character:  Hex number of bytes in the message excluding length character and checksum. In this case, the message consists of 3 bytes (00,75,06). The low end of the length character is first, followed by the high end (00 in this case). Remember to count in hex.

CCB:  00 indicates no errors in the command packet.

Checksum:  1 byte, hex sum of complete message excluding length characters. In this case, 00+75+06 = 7B, so the checksum shown is 7B. Be sure to add in hex.

ASCII <ACK>, acknowledges a good command.

Timer Tick:  Increments 10 times/second.

### 9.4.33.22  Status Material, Thickness (4), Material 1

Command Format:  SL <Command ID> <Material>

SL4 1

Command SL4 1: `0400534C0401A4`

Response: `070000980689418C4236`

### 9.4.33.23  Status Sensor, Crystal Life (0), Sensor 1

Command Format:  SS <Command ID> <Sensor>

SS0 1

Command SS0 1: `040053530001A7`

Response: `040000C10600C7`

### 9.4.33.24  Remote General Action, Stop All

Command Format:  RG <Command ID> (<Action Value>)

RG1

Command RG1: `03005247019A`

Response: `030000D706DD`

### 9.4.33.25  Remote Material Action, Open Source Shutter (8)

Command Format:  RL <Command ID> <Material Number> (<Action Value>)

RL8 1

Command RL8 1: `0400524C0801A7`

Response: `0300004B0651`

### 9.4.33.26  Example for Interpreting Float Responses

Command used:  SS 6 1, Status Sensor, Z-Ratio, Sensor 1

**NOTE:** Data is shown in Hex format for convenience.  Actual data transmission is in binary. Commas have been inserted for clarity.

Sent to IC6:  `04,00,53,53,06,01,AD`

Response from IC6:  `07,00,00,AA,06,1F,85,45,41,DA`

Float portion of response from IC6 (low to high):  `1F,85,45,41`

Reverse the float response, so it is now high to low:  `41,45,85,1F`

Convert each byte to its binary equivalent (you can do this using a scientific calculator) to produce the 32 bit float response:

| 41 | 45 | 85 | 1F |
|---|---|---|---|
| 01000001 | 01000101 | 10000101 | 00011111 |
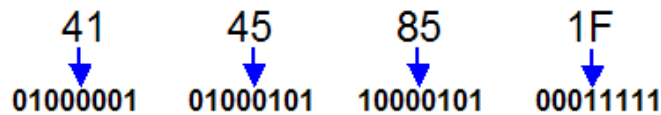
Rearrange the 32 bits making up the float response into packets of 1, 8, and 23 bits, representing the Sign, Exponent, and Mantissa, respectively:

| Sign | Exponent | Mantissa |
|---|---|---|
| 0 | 10000010 | 10001011000010100011111 |

Rewrite the current value in binary scientific notation.

The Sign "`0`" means that the sign of the decimal number is positive.

Using a scientific calculator, convert the Exponent value to decimal.  In this case, the decimal value will be `130`. Now, subtract `127` from `130` and you get `3`, the actual exponent value (You must always subtract `127` from the exponent decimal value).

Insert the Mantissa to the right of the decimal point.



**Positive Sign** $+1.10001011000010100011111 \times 2^3$ **Exponent Value**

Will always be a 1 for binary scientific notation | **Mantissa** | Binary is base 2
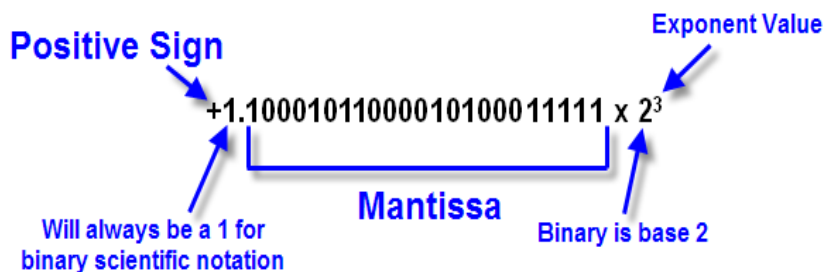
Rewrite each individual "**1**" in the value above in exponent form:

**1.10001011000010100011111 x 2$^3$**

$$= (2^0 + 2^{-1} + 2^{-5} + 2^{-7} + 2^{-8} + 2^{-13} + 2^{-15} + 2^{-19} + 2^{-20} + 2^{-21} + 2^{-22} + 2^{-23}) \times 2^3$$

Distribute the **2$^3$** (Add the exponents, so for example, **2$^{-2}$ x 2$^3$ = 2$^1$** etc) :

$$= 2^3 + 2^2 + 2^{-2} + 2^{-4} + 2^{-5} + 2^{-10} + 2^{-12} + 2^{-16} + 2^{-17} + 2^{-18} + 2^{-19} + 2^{-20}$$

Expand the exponents in their decimal form:

```
= 8 + 4 + 0.25 + 0.0625 + 0.03125 + 0.0009765625
+ 0.000244140625 + 0.0000152587890625 + 0.00000762939453125
+ 0.000003814697265625 + 0.0000019073486328125
+ 0.00000095367431640625
```

Compute the sum and round appropriately.

In this case, this is the Z-Ratio of sensor 1.

**= 12.34500026702880859375**

**= 12.345**

# Chapter 10
# Maintenance and Calibration Procedures

## 10.1  Importance of Density, Tooling and Z-Ratio

The quartz crystal microbalance is capable of precisely measuring the mass added to the face of the oscillating quartz crystal sensor. Cygnus 2's knowledge of the density of this added material (specified in the density parameter in Material Set-Up) allows conversion of the mass information into thickness. In some instances, where highest accuracy is required, it is necessary to make a density calibration as outlined in section 10.2.

Because the flow of material from a deposition is not uniform, it is necessary to account for the different amount of material flow onto the sensor compared to the substrates. This factor is accounted for in the tooling parameter in Material Set-Up. The tooling factor can be experimentally established by following the guidelines in section 10.3 on page 10-2.

In Cygnus 2, if the Z-Ratio is not known it could be estimated from the procedures outlined in section 10.4 on page 10-3, or, typically, the Auto-Z function can be used to determine the Z-Ratio.

## 10.2  Determining Density

**NOTE:**  The bulk density values retrieved from the Material Library are sufficiently accurate for most applications.

Follow the steps below to determine density value.

*1*  Place a substrate (with proper masking for film thickness measurement) adjacent to the sensor, so that the same thickness will be accumulated on the crystal and substrate.

*2*  Set density to the bulk value of the film material or to an approximate value.

*3*  Set Z-Ratio to 1.000 and tooling to 100%.

*4*  Place a new crystal in the sensor and make a short deposition (1000-5000 Å) using manual control.

*5*  After deposition, remove the test substrate and measure the film thickness with either a multiple beam interferometer or a stylus-type profilometer.

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

$$\text{Density}(g/cm^3) \;=\; D_1\!\left(\frac{T_x}{T_m}\right) \tag{1}$$

where:

$D_1$ = Initial density setting

$T_x$ = Thickness reading on Cygnus 2

$T_m$ = Measured thickness

**7**  A quick check of the calculated density may be made by programming Cygnus 2 with the new density value and observing that the displayed thickness is equal to the measured thickness, provided that Cygnus 2's thickness has not been zeroed between the test deposition and entering the calculated density.

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

## 10.3  Determining Tooling

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

**2**  Make a short deposition and determine actual thickness.

**3**  Calculate tooling from the relationship shown in equation [2]:

$$\text{Tooling } (\%) \;=\; TF_i\!\left(\frac{T_m}{T_x}\right) \tag{2}$$

where

$T_m$ = Actual thickness at substrate holder

$T_x$ = Thickness reading in Cygnus 2

$TF_i$ = Initial tooling factor

**4**  Round off percent tooling to the nearest 0.1%.

**5**  When entering this new value for tooling into the program, $T_m$ will equal $T_x$ if calculations are done properly.

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

## 10.4  Laboratory Determination of Z-Ratio

**NOTE:** On Cygnus 2, the Auto-Z function is available to automatically calculate the Z-Ratio. Especially when precise Z-Ratio values are significant, Auto-Z is recommended. See section 14.1.6 on page 14-9 for a description of Auto-Z theory.

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

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

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

where:

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

$\mu_f$ = shear modulus (dynes/cm2) of deposited film

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

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

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

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

**1**  Establish the correct density value as described in section 10.2 on page 10-1.

**2**  Install a new crystal and record its starting frequency $F_{co}$. It will be necessary to send the SS 4 n command to get this information (refer to section 9.4.30, Status Sensor, on page 9-42).

**3**  Make a deposition on a test substrate such that the percent crystal life display will read approximately 50%, or near the end of crystal life for the particular material, whichever is smaller.

**4**  Stop the deposition and record the ending crystal frequency $F_c$ using the SS 4 n command.

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

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

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

where:

$T_f$ = thickness of deposited film (kÅ)

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

$F_c$ = Final frequency of the sensor crystal (Hz)

$F_q$ = Nominal blank frequency = 6045000 (Hz)

z = Z-Ratio of deposited film material

$Z_q$ = Specific acoustic impedance of quartz = 8765000 (MKS units)

p = density of deposited film (g/cc)

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

◆ If the thickness of Material 1 is large compared to Material 2, use material 1 Z-value for both Materials.

◆ If the thickness of Material 1 is thin compared to Material 2, use material 2 Z-value for both Materials.

◆ If the thickness of both Materials is similar, use a value for Z-Ratio which is the weighted average of the two Z values for deposition of Material 2 and subsequent Materials.

## 10.5  Source Maintenance

The Source Maintenance page allows toggling Source and Sensor shutters and rotating the crucible indexer associated with a selected Material. Source power may be manually adjusted using the hand-held controller.

Cygnus 2 must be in Ready or Idle mode to Enable Source Maintenance and it must be Disabled to exit back to normal operation. If in Manual mode, Stop must be activated to Enable Source Maintenance.

*Figure 10-1  Source maintenance page*

## 10.5.1  Source Maintenance Parameters

**NOTE:**  Remote Comm is not allowed while in Source Maintenance.

**SOURCE MAINTENANCE**  . . . . . . . Enabled/Disabled

Cygnus 2 must be in Ready to Enable and must be Disabled to return to normal operation. Default is Disabled.

**MATERIAL NUMBER**  . . . . . . . . . . . 1 to 6

While in Maint Stop, select the Material associated with the Source or Sensor to be checked. Material cannot be changed while in Manual.

### 10.5.1.1  Crucible Rotation

If Cygnus 2 has been configured for a multi-position crucible indexer, pressing the F1 key will advance it to the next position. Setting the "Switch to Crucible" parameter to one of the positions before pressing F1 will activate the programmed crucible indexer outputs to rotate to the specified position.

The F1 key is grayed out for a single position crucible to indicate it is not active.

### 10.5.1.2  Toggle Sensor and Source Shutter

Press the F2 key to toggle Sensor shutter associated with this Material.

Press the F3 key to toggle the Source shutter for this Material's Source.

### 10.5.1.3  Start/Stop Manual Power

Press the F4 key to start Manual mode. Once in manual mode, use the optional hand-held controller to increase or decrease the power.

## 10.6  System Status

*Figure 10-2  System status display*



The System Status display shows installed option boards and firmware versions. There are no user parameters.

# Chapter 11
# Counters and Timers

## 11.1 Introduction

Cygnus 2 has twenty counters and twenty timers. These counters and timers enable you to customize logic statements. Timers and counters are "up/increasing" value variables. You can increment a counter or start a timer on any event via a logic statement. These counters and timers can then be checked via other logic statements to initiate one or more actions at a given count or when an elapsed amount of time has passed. On the counter/timer screen, see Figure 11-1, you can monitor all the counters and timers and by positioning the cursor on the counter or timer number, manually zero a timer/counter (F1) or start timer (F2) or cancel a timer (F3) using the function keys.

*Figure 11-1  Counter/Timer screen*

# Chapter 12
# USB Storage

## 12.1 File Handling (USB)

File handling is achieved via a USB port. Three types of files are used, configuration files which contain all user programmed parameters, screen capture files and data log files. Configuration files can be written to and retrieved from the USB port storage device. Data log files and bitmap files of screen captures can only be written to the USB port storage device. To prevent loss of data, no more than 500 data log files should be written to the USB device. Cygnus 2 will only display the first 120 files (15 per page) and a message "More Files on the USB". All files will be displayed on a computer.

The USB port is not set up for any other use. USB file handling allows for only eight characters in a file name with an optional three-character extension.

### 12.1.1 USB Storage Devices

The following USB 2.0 storage devices have been tested for use with Cygnus 2:

- Memorex® TravelDrive 512 MB Flash Drive
- SanDisk® SDCZ2-1024-A10 1 GB Cruzer Mini Flash Drive
- Lexar® 1 GB Sport Flash Drive
- Lexar 4 GB Lightning Flash Drive
- Kingston® 32 GB DataTraveler 150 Flash Drive

**NOTE:** The USB storage device is to be plugged directly into the Cygnus 2 front panel USB port. Use of USB extension cables is **not** supported.

## 12.2 Directory Structure

All files will be written to and read from pre-defined directories. Three directories will be defined for the three types of files written by Cygnus 2.

- CYG2conf will hold configuration files
- CYG2scrn will hold screen capture files
- CYG2dlog will hold data log files

If the directories don't exist on the storage device attached to the USB port, Cygnus 2 will create them at the first attempt to access the directory.

## 12.3 Configuration Files

With all Materials in the READY or STOP state, the configuration of Cygnus 2 may be sent to a storage device attached to the USB port. Configuration files will be written with the default name CYGNUS2.ISC. The configuration file can be named within the eight-character limitation that exists in the USB file handling firmware. File names cannot contain the space character. Cygnus 2 will use the .ISC extension to identify configuration files. Cygnus 2 will ignore or reject IC/5 IC6, and Cygnus.ISC configuration files—these files are not compatible with Cygnus 2.

*Figure 12-1  Configuration files*



**NOTE:** All Materials must be in Stop, READY or Idle mode to save a configuration file.

# 12.4  Data Logs

**NOTE:** To prevent loss of data, do not allow the number of files on the USB storage device to exceed 500.

Data log files will be sent to the USB port storage device when the USB Datalog Format parameter located on the datalog page of the USB STORAGE screen is set to either Page or Comma by using the TOGL key. The error message "USB Disk Error" appears if datalogging is turned on and a USB flash drive is not present.

As the Materials create the datalog file, they will be sent to the CYG2dlog directory on the storage device attached to the USB port. The files will be named DDMMYYC#.IDL or MMDDYYC#.IDL depending on the date format setting. DD = day of month, MM = month, YY = year, C# represents the Material# where # is from 1 to 6. If a file with the same name exists, the new data log information will be appended to the existing file. Cygnus 2 will use the .IDL extension to identify Datalog files. See Figure 12-2.

See for the details of the data log data.

*Figure 12-2  Datalog files*



**USB DATALOG FORMAT** . . . . . . . . Logoff (0), Page (1), Comma (2)

The LogOff setting turns off datalogging, Use the TOGL key to enable "Page" or "Comma" delimited datalogging or disable it with the "Logoff" setting. Default setting is Logoff (0).

## 12.5  Screen Captures

A BMP file of the screen can be sent to the USB port storage device. Pressing the Print key will send a BMP file of the screen to the CYG2scrn directory on the storage device attached to the USB port. The Screen captures will be named as either DDMMYYxx.BMP or MMDDYYxx.BMP depending on the date format setting.  DD = day of month, MM = month, YY = year, xx is a number that increments from 0 to 99, resetting to 0 every day. Cygnus 2 will use the .BMP extension to identify screen capture files. The +++ indicates that additional files exist on the USB device beyond those displayed. Use the Up/Down arrows keys to navigate.

Individual screen shots can be deleted by cursoring to the specific file and selecting the F3 function key.

*Figure 12-3  Screen capture files*

# Chapter 13
# Troubleshooting, Status and Error Messages

## 13.1 Status Messages

Some Cygnus 2 status messages will have designators to indicate the Material, Source or Sensor the status refers. Table 13-1 indicates designators and to what they refer. If there is a message that has multiple occurrences, it will display on one line with multiple designators after it.

There are a few status messages that have a designated area in the status message area. These messages are noted in Table 13-1.

*Table 13-1 Status messages*

| Status Message | Set | Cleared | Screen | Remote Comm. Encode |
|---|---|---|---|---|
| Crystal Fail X…X | One or more of the Sensors that are called out in currently active Materials fails to measure a crystal. X = Sensor | When all Sensors in use are good. When any Sensor in use is good the Sensor number clears from the numeric list. | All<br><br>Designated area | 0x8000,0000 0000,0000 |
| Max Power X…X | Whenever the Source power reaches the maximum power programmed for an active Material. X = Material number | Whenever the Source power is reduced from the maximum power for an active Material. | All Note: This message will display in the cause of stop area whenever it is TRUE. Designated area | 0x4000,0000 0000,0000 |
| Test | The general parameter Test has been set to Yes | The general parameter Test has been set to No | All. Designated area | 0x2000,0000 0000,0000 |
| A TEST | The general parameter Advanced Test has been set to yes. | The general parameter Advanced Test has been set to No. | All. Designated area | 0x1000,0000 0000,0000 |
| R Lock | A command was received via remote communications to lock Cygnus 2. NOTE: R Lock supersedes L Lock) | A command was received via remote communications to unlock Cygnus 2. | All<br><br>Designated area | 0x0800,0000 0000,0000 |
| L Lock | A lock code has been programmed via the keyboard and the lock has been set. NOTE: R Lock supersedes L Lock) | The lock code has been entered via the keyboard to unlock Cygnus 2. | All<br><br>Designated area | 0x0400,0000 0000,0000 |

*Table 13-1  Status messages (continued)*

| Status Message | Set | Cleared | Screen | Remote Comm. Encode |
|---|---|---|---|---|
| Min Power X..X | While in a rate control state, whenever the Source power reaches the programmed minimum power. This message doesn't appear if the Minimum power is programmed for 0.0%. X = Material | When the Source power is greater then the programmed minimum power or when Cygnus 2 leaves rate control. | All | 0x0200,0000 0000,0000 |
| Crystal Switch(ing) X..X | A multi crystal sensor is switching to a new crystal. X = Sensor | The Sensor switching has reached its next position. When replaced with Switcher Error message | All | 0x0100,0000 0000,0000 |
| Crystal Sw(itcher) Fail X..X | A crystal position was not reached in the time allotted for a crystal switch. X = Sensor | The Sensor switching has reached its next position.When replaced with switcher error message | All | 0x0080,0000 0000,0000 |
| Carousel Open X..X | The Crystal12 carousel is not detected as in place. X = Sensor | When the carousel is detected or when the Sensor type is set to something other than Crystal12. | All | 0x0040,0000 0000,0000 |
| Control Delay X..X | When the Delay option is set to Control and a Material enters the control delay. X = Material | The control delay is complete. | All | 0x0020,0000 0000,0000 |
| RateWatcher Delay X..X | When RateWatcher is turned on, the active state is displayed. Only one state per Material can be active at a time. X= Material | When RateWatcher is inactive or as the RateWatcher state changes. | All | 0x0008,0000 0000,0000 |
| RateWatcher Hold X..X | | | | 0x0004,0000 0000,0000 |
| RateWatcher Sample X..X | | | | 0x0002,0000 0000,0000 |
| Soak Hold Pre Con Y.....Y | A Soak Hold condition is active Y = Material | The Soak Hold condition is no longer active | | 0x0001,0000 0000,0000 |
| Soak Hold 1 Y …Y | | | All | 0x0000,8000 0000,0000 |
| Soak Hold 2 Y …Y | | | | 0x0000,4000 0000,0000 |

*Table 13-1  Status messages (continued)*

| Status Message | Set | Cleared | Screen | Remote Comm. Encode |
|---|---|---|---|---|
| Abbr(eviated) Average X..X | During a rate control state, a crystal failure occurred after more then one minute but before the number of minutes specified in the parameter Time Power Averaging Time. The time to average the rate and power is less then requested. X = Material | When a new Material is started. Stop/Reset | All | 0x0000,2000 0000,0000 |
| No or Neg. Average X ... X | Then entering time power of non deposit control and there is not enough data to calculate and average rate or power. X = Material | As the Material is unloaded | All | 0x0000,1000 0000,0000 |
| Time Pwr (Power) Complete X | Time Power was active when the Material completed. X = Material | Another Material overloads the Material that completed in Time Power | All | 0x0000,0800 0000,0000 |
| Clock Hold | A clock hold has been set via a Digital Input, Logic Action or remote communication command. | A clock hold has been cleared via a Digital Input, Logic Action or remote communication command. | All | 0x0000,0400 0000,0000 |
| Recoder Conflict | A DAC output is set as a Recorder output on two or more loaded Materials or Sensors. | Conflict has been removed. | All | 0x0000,0008 0000,0000 |
| Unable to Auto-Z X ... X | An active Sensor is unable to Auto-Z. X = Sensor | A Sensor is no longer active or is able to Auto-Z. Sensor Parameter Auto-Z is set to No. | All | 0x0000,0004 0000,0000 |
| DAC Error X | DAC monitoring has detected an error in a DAC used for a recorder. X = DAC | On Reset | All | 0x0000,0002 0000,0000 |
| Testing XIU X | When XIU test begun. X = Sensor Number | When XIU test finished | Sensor Info | 0x0000,0001 0000,0000 |

## *13.2  User Messages*

Table 13-2 messages are a subgroup of status messages. The user defines these messages. They are displayed and cleared via logic actions. The messages will display in the same screen area as other status messages.

*Table 13-2  User messages*

| Status Message | Set | Cleared | Screen | Remote Comm. Encode |
|---|---|---|---|---|
| User Message 1 | Logic event "Message On 1" | Logic event "Message Off 1" | All | 0x0000,0000,0000,0200 |
| User Message 2 | Logic event "Message On 2" | Logic event "Message Off 2" | All | 0x0000,0000,0000,0100 |
| User Message 3 | Logic event "Message On 3" | Logic event "Message Off 3" | All | 0x0000,0000,0000,0080 |
| User Message 4 | Logic event "Message On 4" | Logic event "Message Off 4" | All | 0x0000,0000,0000,0040 |
| User Message 5 | Logic event "Message On 5" | Logic event "Message Off 5" | All | 0x0000,0000,0000,0020 |
| User Message 6 | Logic event "Message On 6" | Logic event "Message Off 6" | All | 0x0000,0000,0000,0010 |
| User Message 7 | Logic event "Message On 7" | Logic event "Message Off 7" | All | 0x0000,0000,0000,0008 |
| User Message 8 | Logic event "Message On 8" | Logic event "Message Off 8" | All | 0x0000,0000,0000,0004 |
| User Message 9 | Logic event "Message On 9" | Logic event "Message Off 9" | All | 0x0000,0000,0000,0002 |
| User Message 10 | Logic event "Message On 10" | Logic event "Message Off 10" | All | 0x0000,0000,0000,0001 |

## 13.3  STOP messages

When a Cygnus 2 Material goes into STOP, a cause of stop message appears on the line above STOP if the "Show Graph" Operate screen is selected. Some of these messages will have designators to indicate the Material, Source or Sensor that caused the Stop. Table 13-3 indicates which messages have designators and what the designator indicates.

*Table 13-3  Stop messages*

| Cause of STOP Message | Set | Clear | Screen | Remote Comm. Encodes |
|---|---|---|---|---|
| Max Power X | Maximum power was reached and held there for more then 5 seconds and the Material parameter Max Power Option is set to Stop on Max Power. X = Material | | | 1 |
| Crystal Fail X | There was a crystal failure and the Material parameter Failure Action is set to stop on fail. X = Sensor. | | | 2 |
| Hand Controller | STOP command was received from the handheld controller. | | | 3 |
| Front Panel | Keyboard STOP key was pressed. | | | 4 |
| Communication | A STOP command was received from remote communications. | A RESET command received from the keyboard, digital input, remote communications or a Logic action. A Start, if the condition causing the stop has been cleared and the Material layer can resume. | All | 5 |
| Crucible Fail X | Cygnus 2 failed to detect a good crucible in the time allowed. X = Source | | | 6 |
| Switcher Fail X | A crystal switch failed. X = Sensor | | | 7 |
| Logic Eqn #N | A STOP command was received from logic statement number #. | | | 8 |
| Power Loss | Cygnus 2 lost power. | | | 10 |
| Shutter Fail X | The desired Rate Accuracy has not been achieved in the allotted time in Shutter Delay. X = Material. | | | 13 |
| DAC Failure | Monitoring of the DAC output via an ADC determined that the output voltage is incorrect. | | | 15 |

## 13.4  Transient Messages

Transient messages, see Table 13-4, are displayed as the condition happens. The messages are removed from the screen on any key press or if another transient message appears. Only one transient message will be displayed at a time. These messages will appear on all screens. A single line is assigned in the message box.

*Table 13-4  Transient messages*

| Transient Message | Set | Clear | Screen | Remote Comm. Encodes |
|---|---|---|---|---|
| Locks Cleared | Local Lock, Remote lock cleared on power up. | The message is removed from the screen on any key press or if another transient message appears | All | 1 |
| Already Switching | Crystal is already switching when a request to switch the crystal is received. | | | 2 |
| Parameter Default | All parameters were set to their default values on power- up. | | | 4 |
| Process Variables Default | All process variables were set to their default values on power- up.  Process variables include current rates, thicknesses, Materials, crystals, states and other information needed to continue a process after a power loss. | | | 5 |
| Manual Not Allowed | Cannot enter manual state while in idle, stop or suspend states, or while crystal failed. | | | 6 |
| No Good Xtal to switch | There are no good crystals left in the crystal list.  Only when trying to switch while the Sensor is in use on an active Material. | | | 8 |
| No Switch Output | No switch output defined for a crystal switch. | | | 9 |
| No Switch Single | Cannot switch a single sensor. | | | 10 |

*Table 13-4 Transient messages (continued)*

| Transient Message | Set | Clear | Screen | Remote Comm. Encodes |
|---|---|---|---|---|
| Datalog Failure | Cygnus 2 is sending the Datalog information faster then the receiving device can accept the data. The data is lost. | The message is removed from the screen on any key press or if another transient message appears | All | 11 |
| Ethernet In Use | Ethernet port is active and the Ethernet parameters can't be changed. The command sent to the Ethernet card did not go through or the Ethernet card did not send a valid message indicating the update of values was completed. | | General | 12 |
| No Rotate: CrystalTwo | Cannot rotate a CrystalTwo. | | Sensor Info | 13 |
| No Rotate: Layer Running | Cannot rotate a Sensor while a Material is running. | | Sensor Info | 14 |
| Invalid Equation | An attempt was made to save an invalid logic statement. Logic statements must have connectors and any required numeric before exiting Logic editing. | | Logic edit | 15 |
| Power Not Zero | A Source maintenance crucible switch was requested when the Source power is not zero. | | Maintenance | 16 |
| RS232 Test Failed | RS-232 loop back test failed. | | General/Comm | 17 |
| RS232 Test Passed | RS-232 loop back test passed. | | General/Comm | 18 |
| XIU Test Failed | XIU test failed | | Sensor Info/Type | 19 |
| XIU Test Passed | XIU test passed. | | Sensor Info/Type | 20 |
| No XIU Test: Switching | Cannot test an XIU while a crystal switch is in process. | | Maintenance | 21 |
| Edit In Process | When an edit is process and the menu key is pressed. | | All | 22 |
| USB Disk Error | Fault Conditions: No Disk, Folder/File Read Only, Firmware Invalid, Firmware No Upgrade, Exceeded max. file count | | Storage | 23 |
| USB error: Disk Full | Disk is Full | | Storage | 24 |

*Table 13-4  Transient messages (continued)*

| Transient Message | Set | Clear | Screen | Remote Comm. Encodes |
|---|---|---|---|---|
| USB (File Check Sum) Error: Data Corrupt | | The message is removed from the screen on any key press or if another transient message appears | Storage | 25 |
| USB error: Bad Conf. File | | | Storage | 26 |
| USB DataLog Fast Out Error | | | | 27 |
| USB Error (generic) | USB Interface system error | | All | 28 |
| (USB: Conf. file:) Structure Version Change | Structure version updated because of the new configuration. | | Storage | 29 |
| (USB:) Parameter Value Changed | Parameter value has been adjusted during the Range Check verification procedure. | | Storage | 30 |
| USB Busy | Any key is pressed while the USB is busy. | | All | 31 |
| (USB:) No Such File (Available) | Attempt to access non- existing or folder non-specific file. | | Storage | 32 |
| (USB: Too many files) Archive Old Files | Too many files in a directory | | All | 33 |
| Logic Edit In Progress | Key press (STOP,RESET,START, MENU) while in logic edit mode: | | Logic Edit | 53 |
| No Paren on Empty Term | Parentheses are not allowed on an empty term. | | Logic Edit | 54 |
| No Left Paren on Last Term. | Cannot insert Left (opening) parenthesis on the last term. | | Logic Edit | 55 |
| Select an Event to Edit | Attempt to edit a non-event assigned label. | | Logic Edit | 56 |
| Select an Action to Edit | Attempt to edit a non-action assigned label. | | Logic Edit | 57 |
| Select an Event to Delete | Attempt to delete a non-event assigned label. | | Logic Edit | 58 |
| Select an Action to Delete | Attempt to delete a non-action assigned label. | | Logic Edit | 59 |
| Max Terms: Cannot Insert | An attempt was made to enter an equation with more then the allowed event or action terms. | | Logic Edit | 60 |
| Cannot Negate Empty Term | Attempt to negate an empty term. | | Logic Edit | 61 |
| Meas. Board Comm Error | Bad communications with the measurement card. | | All | 62 |
| No Switch: No XIU | No XIU attached, cannot do a switch. | | All | 63 |

*Table 13-4  Transient messages (continued)*

| Transient Message | Set | Clear | Screen | Remote Comm. Encodes |
|---|---|---|---|---|
| In Crucible Switch | An attempt was made to navigate or change a parameter in the Source Maintenance screen while a crucible switch was in process. | The message is removed from the screen on any key press or if another transient message appears | Source Maintenance | * Not available |
| Maintenance Enabled | An attempt was made to leave a Maintenance screen while Source Maintenance was enabled | | Source Maintenance | Not available from Remote Comm |
| Crucible Switch Fail | Crucible switch fail while in Source Maintenance. | | Source Maintenance | Not available from Remote Comm |
| * Remote communications are not permitted while in Source Maintenance. | | | | |
| Power Loss | Post Power cycle | | Operate | 69 |

## 13.5  Input Error Messages

Keyboard Input Error Messages come up on the entry of invalid parameters. These messages will appear on the transient error message line in the message box. The font color of the parameter value being updated will change to a different color to denote an input error has been made. They will clear when the clear key is pressed. The original stored value will then be re-displayed. See Table 13-5.

*Table 13-5  Input error messages*

| Input Error Message | Set | Cleared | Screen |
|---|---|---|---|
| Value Too High | The value entered is larger than the maximum value allowed. | Each input error message is taken down by pressing the clear key. | Any Parameter edit |
| Value Too Low | The value entered is lower than the minimum value allowed. | | Any Parameter edit |
| Duplicate Source | Can use each Source number only once for thickness sum. | | General |
| Invalid Mask | An attempt was made to enter an incorrect Ethernet net mask. | | General |
| Incorrect Time | An attempt was made to enter more then 59 seconds or 99 minutes into a time parameter. | | Material |
| Ramp 1 > Ramp 2 | Invalid Material parameter 'Ramp', values were entered. Start Ramp 1 thickness value must be less then Start Ramp 2 value when the Start Ramp 2 value is non-zero. | | Material |
| Ramp 2 < Ramp 1 | Invalid Material parameter 'Ramp', values were entered. Start Ramp 2 thickness value must be greater then Start Ramp 1 value. | | Material |
| DAC Used Material ## Or DAC Used Sensor ## | The DAC number has been previously defined as a recorder output in the Material or the Sensor set up. | | Source parameter |
| DAC Used Source XX | The DAC number has been previously defined as a Source DAC output in one of the Source set ups | | Material, Sensor and Source parameter |
| Input in use | An attempt was made to enter an input that is already reserved for use in Source setup or one of the logic statements. | | Source parameter |
| Output in use | An attempt was made to enter an output that is already reserved for use. The output is already reserved for use in Sensor or Source set up or in one of the logic statements. | | Sensor, Source parameter and Logic Edit |
| Invalid Lock Code | An incorrect lock code was used to attempt to unlock Cygnus 2. | | Menu |

*Table 13-5  Input error messages (continued)*

| Input Error Message | Set | Cleared | Screen |
|---|---|---|---|
| Output Used In Logic Equ # | An attempt was made to use an Output that is programmed in Logic Statement #. | Each input error message is taken down by pressing the clear key. | Source Sensor General |
| Reset Required First | An attempt was made in Source Maintenance to enable a Material that is running. | | Source Maintenance |
| Material(s) Running | An attempt was made to save a Config file while a Material is running. | | USB Storage |

## 13.6  Troubleshooting Guide

If Cygnus 2 fails to work, or appears to have diminished performance, the following Symptom/Cause/Remedy charts may be helpful.

⚠️ **WARNING - Risk Of Electric Shock**

**There are no user serviceable components within the Cygnus 2 case.**

**Potentially lethal voltages are present when the line cord, Inputs or Outputs are connected.**

**Refer all maintenance to qualified personnel.**

**This Cygnus 2 contains delicate circuitry which is susceptible to transients. Disconnect the line cord whenever making any interface connections. Refer all maintenance to qualified personnel.**

## 13.6.1 Troubleshooting Cygnus 2

*Table 13-6  Troubleshooting Cygnus 2*

| SYMPTOM | CAUSE | REMEDY |
|---------|-------|--------|
| 1. Power on LED not illuminated | a. Blown fuse/circuit breaker tripped | a.Have qualified personnel replace fuse/reset circuit breaker |
| | b. Electrical cord unplugged from wall or back of Cygnus 2 | b. Reconnect power cord |
| | c. Incorrect line voltage | c. Have qualified personnel verify line voltage, verify Cygnus 2 is configured for the correct voltage |
| 2. Cygnus 2 "locks" up | a. Cover or back panels not attached to Cygnus 2 | a. Ensure all covers and panels are in place and securely fastened |
| | b. High electrical noise environment | b. Reroute cables to reduce noise pickup (1 ft [30 cm] away from high power conducting lines makes a sizable reduction in the amount of noise entering Cygnus 2), keep all ground wires short with large surface area to minimize ground impedance (solid copper strap with 5 to 1 length to width ratio is recommended) |
| | c. Poor grounds or poor grounding practice | c. Verify proper earth ground, use appropriate ground strap, (solid copper strap with 5 to 1 length to width ratio is recommended), eliminate ground loops by establishing the correct system grounding, verify proper Cygnus 2 grounding |
| 3. Cygnus 2 does not retain parameters on power down (loss of parameters on power up) | a. Lithium battery is dead | a. Lithium battery has a normal life expectancy of seven years, contact INFICON service department |
| | b. Power supply or Processor board problem | b. Contact INFICON service department |

*Table 13-6  Troubleshooting Cygnus 2 (continued)*

| SYMPTOM | CAUSE | REMEDY |
|---|---|---|
| 4. Some keys on front panel function while others do not | a. Faulty keypad or faulty keypad ribbon cable | a. Contact INFICON service department |
| 5. All keys on the front panel fail to function | a. Cygnus 2 is "locked" up | a. Turn power OFF and then ON using the power switch on the back of Cygnus 2, see item 2 above |
| 6. Control voltage output does not function properly | a. DAC board damaged from applying voltage to the control voltage output | a. Ensure cable connection to the DAC board does not have a potential across the contacts, contact INFICON service department |
| | b. Reversed polarity of control voltage relative to that accepted by the Source power supply | b. Verify Source output polarity of the DAC and the required input polarity of the Source power supply, refer to the instruction manual to reconfigure Cygnus 2 if necessary |
| | c. Improper control cable fabrication | c. Check for correct cable wiring in the appropriate section of the manual |
| 7. LCD display dull or blank | a. LCD or LCD Interface board problem. | a. Contact INFICON service department |
| | b. LCD Dimmer Time not 0 and expired, see section 6.9 | b. Press cursor key to activate display |
| 8. Poor rate control | a. Control loop parameters improperly selected | a. Refer to the instruction manual section on tuning control loop parameters |
| | b. Electron beam sweep frequency "beating" with the Cygnus 2's measurement frequency | b. Adjust the sweep frequency so it is not a multiple of the Cygnus 2's measurement frequency |

*Table 13-6  Troubleshooting Cygnus 2 (continued)*

| SYMPTOM | CAUSE | REMEDY |
|---|---|---|
| 9 Crystal fail message is always on | a. XIU/oscillator not connected | a. Verify proper sensor/oscillator connections. See items c, d, e, f, g, h below. |
| | b. XIU/oscillator malfunctioning | b. Use Test XIU diagnostic function to determine if cause is Cygnus 2 / XIU / XIU cables or if cause is Feedthrough / Sensor / Crystal. If available, insert a known working XIU/oscillator in place of suspect one; if XIU/oscillator is confirmed bad, contact INFICON service department |
| | c. Defective cable from feedthrough to XIU/oscillator or from Cygnus 2 to XIU/oscillator | c. Use an ohm meter or DVM to check electrical continuity or isolation as appropriate |
| | d. Poor electrical contact in the transducer, feedthroughs, or in-vacuum cable | d. Use an ohm meter or DVM to check electrical continuity or isolation as appropriate |
| | e. Failed crystal/no crystal | e. Replace crystal/insert crystal |
| | f. Two crystals placed into the crystal holder | f. Remove one of the crystals |
| | g. Frequency of crystal out of range | g. Verify that the crystal frequency is within the required range, use INFICON crystals. |
| | h. S & Q values exceed programmed values | h. Clear S & Q via Remote Comm or Function Key F3 on Sensor Information page, see |

### 13.6.2  *Troubleshooting Transducers/Sensors*

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

A somewhat more thorough diagnosis may be performed with the optional Crystal Sensor Emulator, 760-601-G1. See for a discussion of its use and diagnostic capabilities.

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

*Table 13-7   Troubleshooting transducers/sensors*

| SYMPTOM | CAUSE | REMEDY |
|---|---|---|
| 1. Large jumps of thickness reading during deposition | a. Stress causes film to peel from crystal surface | a. Replace crystal or use Alloy crystal; consult factory |
| | b. Particulate or "spatter" from molten source striking crystal | b. Thermally condition the source thoroughly before deposition, use a shutter to protect the crystal during source conditioning |
| | c. Scratches or foreign particles on the crystal holder seating surface (improper crystal seating) | c. Clean and polish the crystal seating surface on the crystal holder; refer to appropriate sensor manual |
| | d. Small pieces of material fell on crystal (for crystal facing up sputtering situation) | d. Check the crystal surface and blow it off with clean air |
| | e. Small pieces of magnetic material being attracted by the sensor magnet and contacting the crystal (sputtering sensor head) | e. Check the sensor cover's aperture and remove any foreign material that may be restricting full crystal coverage; refer to appropriate sensor manual |

*Table 13-7 Troubleshooting transducers/sensors (continued)*

| SYMPTOM | CAUSE | REMEDY |
|---|---|---|
| 2. Crystal ceases to oscillate during deposition before it reaches the end its normal life | a. Crystal struck by particulate or spatter from molten source | a. Thermally condition the source thoroughly before deposition, use a shutter to protect the crystal during source conditioning |
| | b. Material on crystal holder partially masking crystal cover aperture | b. Clean crystal holder; refer to appropriate sensor manual |
| | c. Existence of electrical short or open condition | c.Using an ohm meter or DVM, check for electrical continuity in the sensor cable, connector, contact springs, connecting wire inside sensor, and feedthroughs |
| | d. Check for thermally induced electrical short or open condition | d. See C above |
| **NOTE:** Crystal life is highly dependent on process conditions of rate, power radiated from source, location, material, and residual gas composition. | | |
| 3. Crystal does not oscillate or oscillates intermittently (both in vacuum and in air) | a. Intermittent or poor electrical contact (contacts oxidized) | a. Use an ohm meter or DVM to check electrical continuity, replace Ceramic Retainer |
| | b. Leaf springs have lost retentivity (ceramic retainer, center insulator) | b. Bend leaves to approx. 45°; refer to appropriate sensor manual |
| | c. RF interference from sputtering power supply | c. Verify earth ground, use ground strap adequate for RF ground, (solid copper strap with 5 to 1 length to width ratio is recommended), change location of Cygnus 2 and oscillator cabling away from RF power lines, connect Cygnus 2 to a different power line |
| | d. Cables/oscillator not connected, or connected to wrong sensor input | d. Verify proper connections, and inputs relative to programmed sensor parameter |

*Table 13-7  Troubleshooting transducers/sensors (continued)*

| SYMPTOM | CAUSE | REMEDY |
|---|---|---|
| 4. Crystal oscillates in vacuum but stops oscillation after open to air | a. Crystal was near the end of its life; opening to air causes film oxidation which increases film stress | a. Replace crystal |
| | b. Excessive moisture accumulates on the crystal | b. Turn off cooling water to sensor prior to venting, flow warm water through sensor while chamber is open |
| 5. Thermal instability: large changes in thickness reading during source warm-up (usually causes thickness reading to decrease) and after the termination of deposition (usually causes thickness reading to increase) | a. Inadequate cooling water/cooling water temperature too high | a. Check cooling water flow rate, be certain that cooling water temperature is less than 30 °C; refer to appropriate sensor manual |
| | b. Excessive heat input to the crystal | b. If heat is due to radiation from the evaporation source, move sensor further away from source and use sputtering crystals for better thermal stability; install radiation shield |
| | c. Crystal not seated properly in holder | c. Clean or polish the crystal seating surface on the crystal holder; refer to appropriate sensor manual |
| | d. Crystal heating caused by high energy electron flux (often found in RF sputtering) | d. Use a sputtering sensor head |
| | e. Poor thermal transfer from water tube to body (XtalSix sensor) | e. Use a new water tube whenever the clamping assembly has been removed from the body; if a new water tube is not available, use a single layer of aluminum foil between the cooling tube and sensor body, if your process allows |
| | f. Poor thermal transfer (Bakeable) | f. Use Al or Au foil washer between crystal holder and sensor body |

*Table 13-7  Troubleshooting transducers/sensors (continued)*

| SYMPTOM | CAUSE | REMEDY |
|---|---|---|
| 6. Poor thickness reproducibility | a. Variable source flux distribution | a. Move sensor to a more central location to reliably sample evaporant, ensure constant relative pool height of melt, avoid tunneling into the melt |
| | b. Sweep, dither, or position where the electron beam strikes the melt has been changed since the last deposition | b. Maintain consistent source distribution by maintaining consistent sweep frequencies, sweep amplitude and electron beam position settings |
| | c. Material does not adhere to the crystal | c. Make certain the crystal surface is clean; avoid touching crystal with fingers, make use of an intermediate adhesion layer |
| | d. Cyclic change in rate | d. Make certain source's sweep frequency is not "beating" with the Cygnus 2's measurement frequency |
| 7. Large drift in thickness (greater than 200 Å for a density of 5.00 g/cc) after termination of sputtering | a. Crystal heating due to poor thermal contact | a. Clean or polish the crystal seating surface on the crystal holder; refer to appropriate sensor manual |
| | b. External magnetic field interfering with the sensor's magnetic field (sputtering sensor) | b. Rotate sensor magnet to proper orientation with external magnetic field, refer to the sputtering sensor manual IPN 074-157 |
| | c. Sensor magnet cracked or demagnetized (sputtering sensor) | c. Check sensor magnetic field strength, the maximum field at the center of the aperture should be 700 gauss or greater |

*Table 13-7  Troubleshooting transducers/sensors (continued)*

| SYMPTOM | CAUSE | REMEDY |
|---|---|---|
| 8. XtalSix, Xtal12, or Generic crystal switch problem (does not advance or not centered in aperture) | a. No relay or incorrect relay output programmed | Program relay |
| | b. Loss of pneumatic supply, or pressure is insufficient for proper operation | b. Ensure air supply is regulated at 80-90 psi |
| | c. Operation has been impaired as a result of material accumulation on cover | c. Clean material accumulation as needed, refer to XtalSix manual IPN 074-155 or Crystal12 manual IPN 074-398-P1 for maintenance |
| | d. Improper alignment | d. Realign as per instructions in XtalSix manual IPN 074-155 or Crystal12 manual IPN 074-398-P1 |
| | e. 0.0225" diameter orifice not installed on the supply side of solenoid valve assembly | e. Install orifice as shown in the XtalSix manual IPN 074-155 or Crystal12 manual IPN 074-398-P1 |

## 13.6.3  Troubleshooting Computer Communications

*Table 13-8  Troubleshooting computer communications*

| SYMPTOM | CAUSE | REMEDY |
|---|---|---|
| 1. Communications cannot be established between the host computer and Cygnus 2 | a. Use RS-232 loopback and Test RS-232 diagnostic function to determine if cause is Cygnus 2 or if cause is RS-232 cable / host computer. | a. If cause is RS-232 cable / host computer see Cause/Remedy b and c. If cause is Cygnus 2 contact INFICON service department |
| | b. Improper cable connection | b. Verify for correct cable wiring as described in section 2.3.2.5 on page 2-11. |
| | c. BAUD rate in host computer not the same as Cygnus 2 | c. Verify BAUD rate in the host's applications program, verify BAUD rate in Cygnus 2 |
| | d. Incompatible protocols being used | d. Verify that the Cygnus 2 protocol: RS232, DATALOG, matches host |
| 2. Error code returned | See section 9.3.1.3 | See section 9.3.1.3 |

## 13.7  Replacing the Crystal

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

⚠️ **CAUTION**

> **Always use clean nylon lab gloves and plastic tweezers for handling the crystal (to avoid contamination which may lead to poor adhesion of the film to the electrode).**
>
> **Do not rotate the ceramic retainer assembly after it is seated (as this will scratch the crystal electrode and cause poor contact).**
>
> **Do not use excessive force when handling the ceramic retainer assembly since breakage may occur.**

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

**NOTE:** Thick deposits of some materials, such as 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, replace the crystals.

### 13.7.1  Front Load

Follow the procedure below to replace the crystal in the Front Load sensor: (see Figure 13-1)

1  Gripping the crystal holder with your fingers, pull it straight out of the sensor body.

2  Gently pry the crystal retainer from the holder (or use the Crystal Snatcher; see Figure 13-6 on page 13-25).

3  Turn the retainer over and the crystal will drop out.

4  Install a new crystal, with the patterned electrode face up.

5  Push the retainer back into the holder and replace the holder in the sensor body.

*Figure 13-1  Front load crystal sensor (exploded)*
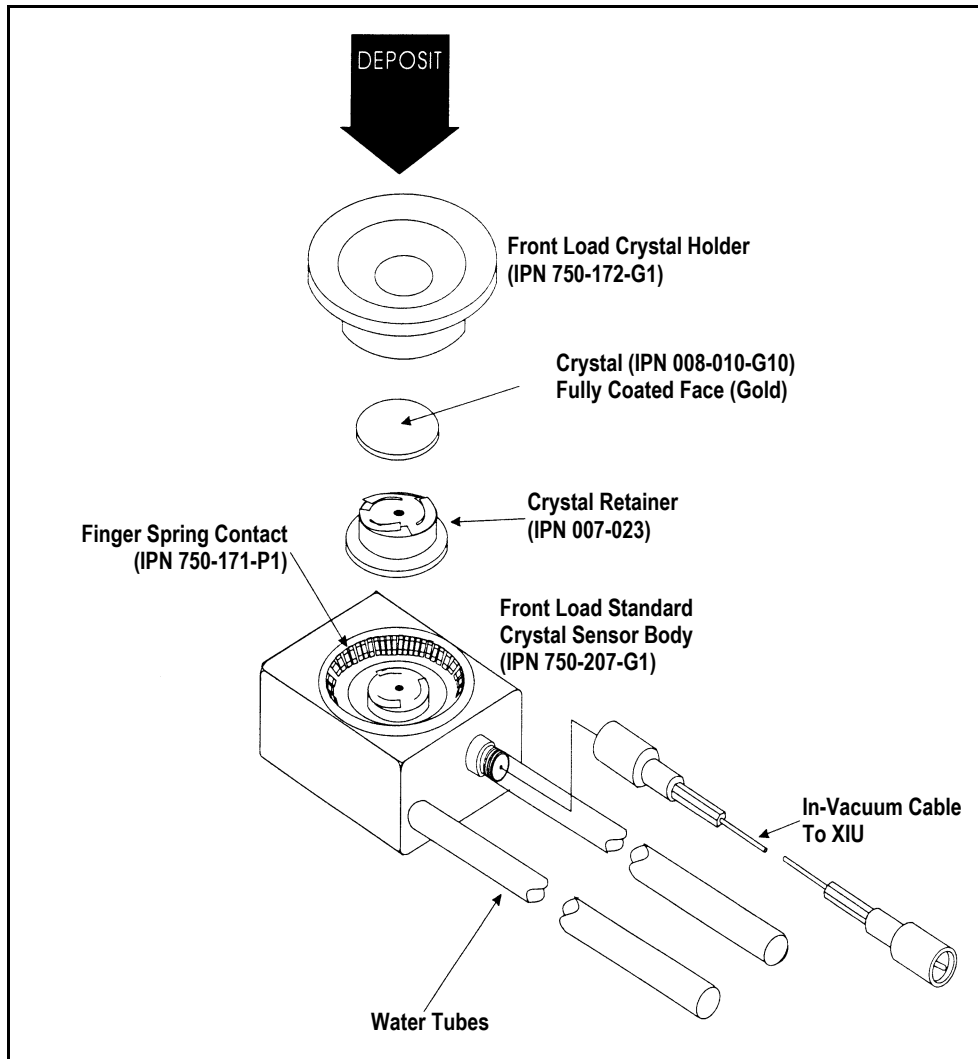


## 13.7.2  Cool Drawer

Follow the procedure below to replace the crystal in a Next Generation Cool Drawer™ sensor:

**1** Using your thumb and index fingers, gently squeeze the sides of the retainer at the mid section then lift it up, away from the drawer, as shown in Figure 13-2.

**2** Hold the drawer by the handle and turn it upside down to remove the spent crystal.

**3** Install a new crystal in the drawer. Observe its orientation. The pattern electrode should face upward as shown in Figure 13-3.

**4** Hold the retainer by its sides. Align its orientation notch with the drawer then gently and evenly push the retainer down until it snaps firmly into the drawer. see Figure 13-3. Never push down (or pull up) on the contact spring, doing so may permanently damage it.

**5** Inspect the whole assembly. The retainer should be even and engage the drawer at all four corners.
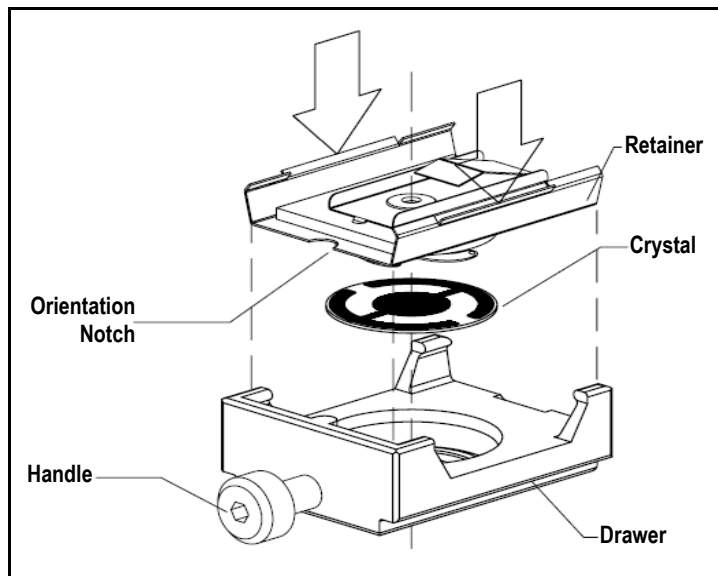
*Figure 13-2  Cool drawer - removing the crystal*
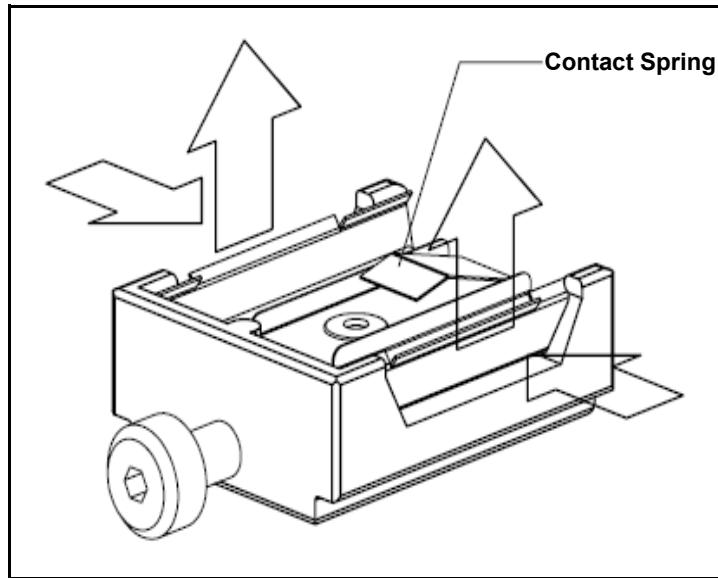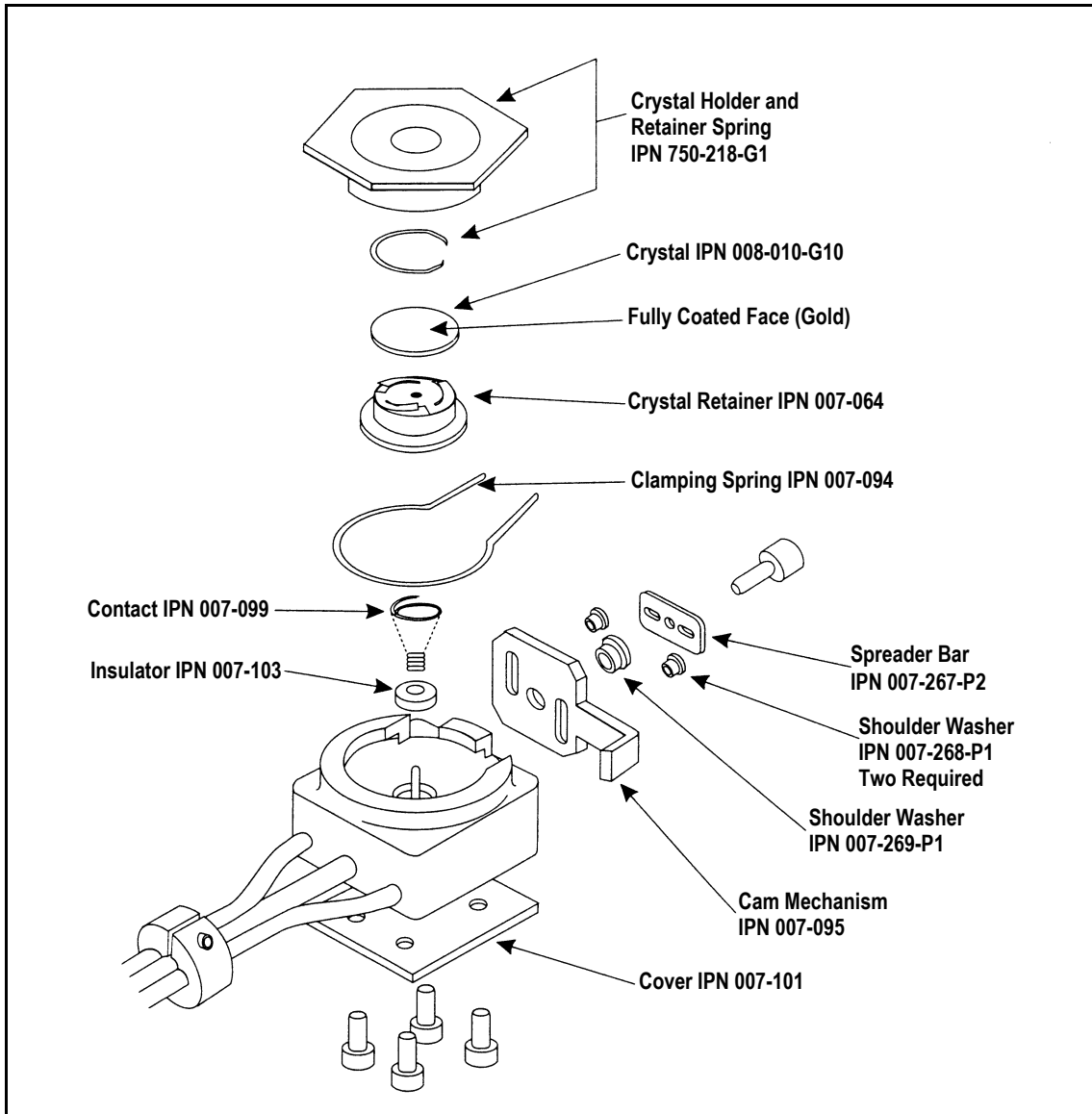


*Figure 13-3  Cool drawer - replacing the crystal*

### 13.7.3  Shuttered and Dual Sensors

There is no difference in the crystal replacement procedure between shuttered and non-shuttered Front Load sensors, since the shutter pivots away from the crystal opening when the shutter is in the relaxed state. This is also the case for Cool Drawer Sensors as the shutter assembly does not obstruct the drawer from being inserted into the sensor body.

### 13.7.4  Bakeable Sensor

For the Bakeable sensor, the procedure is the same as the Front Load sensor except that you must first unlock the cam assembly by flipping it up. Once the crystal has been replaced, place a flat edge of the holder flush with the cam mechanism and lock it in place with the cam. See Figure 13-4.

*Figure 13-4  Bakeable crystal sensor*



Crystal Holder and
Retainer Spring
IPN 750-218-G1

Crystal IPN 008-010-G10

Fully Coated Face (Gold)

Crystal Retainer IPN 007-064

Clamping Spring IPN 007-094

Contact IPN 007-099

Insulator IPN 007-103

Spreader Bar
IPN 007-267-P2

Shoulder Washer
IPN 007-268-P1
Two Required

Shoulder Washer
IPN 007-269-P1
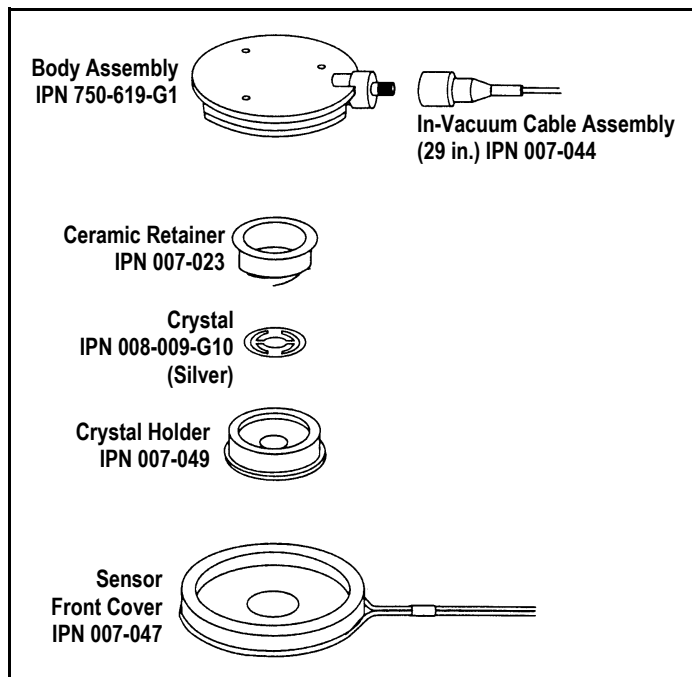
Cam Mechanism
IPN 007-095

Cover IPN 007-101

## 13.7.5  Sputtering Sensor

Observe the general precautions for replacing crystals and follow the instructions below to replace the crystal in a sputtering sensor.

**1**  Grip the body assembly with your fingers and pull it straight out to separate it from the water-cooled front cover. (You may have to disconnect the sensor cable in order to separate the parts.) See Figure 13-5.

**2**  Pull the crystal holder straight out from the front of the body assembly.

**3**  Remove the ceramic retainer from the crystal holder by pulling it straight out with the crystal snatcher (see section 13.7.6 on page 13-25).

**4**  Turn the crystal holder over so that the crystal drops out.

**5**  Install a new crystal into the crystal holder with the patterned electrode facing the back and contacting the leaf springs on the ceramic retainer.

**6**  Put the ceramic retainer back into the crystal holder and put the holder into the body assembly of the sensor.

**7**  Align the position of the body assembly so that the connector matches with the notch on the front cover of the sensor. Snap the two parts together. Reconnect the sensor cable if it has been disconnected.

*Figure 13-5  Sputtering crystal sensor*



Body Assembly
IPN 750-619-G1

In-Vacuum Cable Assembly
(29 in.) IPN 007-044

Ceramic Retainer
IPN 007-023

Crystal
IPN 008-009-G10
(Silver)

Crystal Holder
IPN 007-049

Sensor
Front Cover
IPN 007-047

### 13.7.6 Crystal Snatcher

Use the crystal snatcher, supplied with the sensor, as follows:

**1** Insert crystal snatcher into ceramic retainer (1) and apply a small amount of pressure. This locks the retainer to the snatcher and allows the retainer to be pulled straight out (2). See Figure 13-6.

**2** Reinsert the retainer into the holder after the crystal has been replaced.

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

*Figure 13-6  Use of the crystal snatcher*
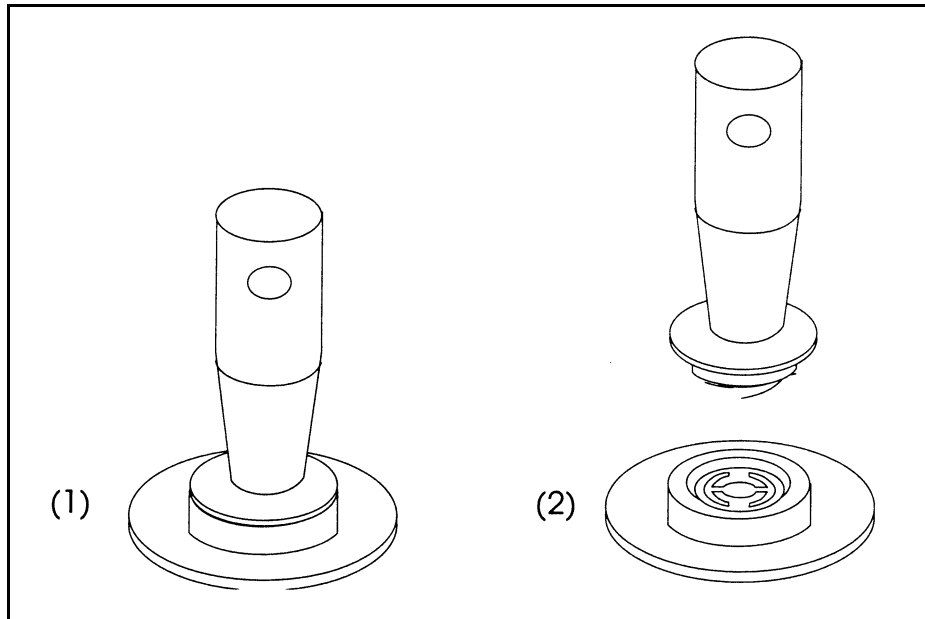


### 13.7.7 CrystalSix (XtalSix)

Refer to the Crystal Six Operating Manual (IPN 074-155) for specific instructions for this device.

## 13.8 Crystal Sensor Emulator
## IPN 760-601-G1 or 760-601-G2

**NOTE:** Crystal Sensor Emulator 760-601-G1 (obsolete) is not compatible for use with a Cygnus 2, IC6, IC/5 and IC/4. 760-601-G2 is fully compatible with all Thin Film Deposition Controllers.
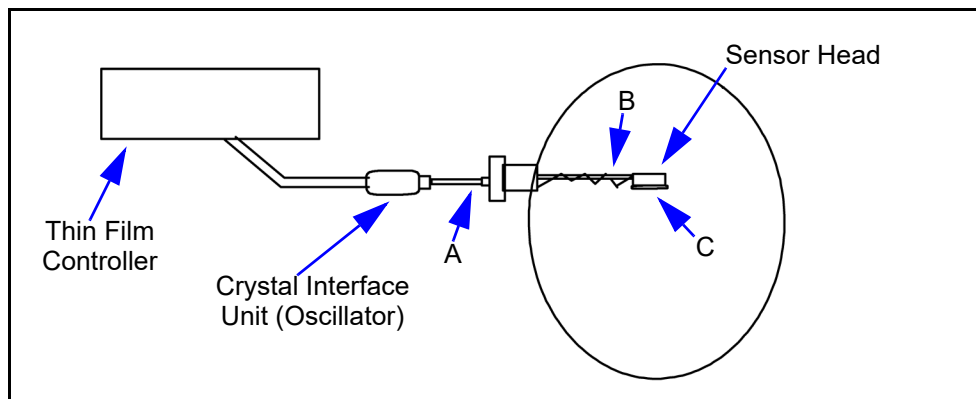
The Crystal Sensor Emulator option is used in conjunction with the Thin Film Deposition Controller to rapidly diagnose problems with the Deposition Controller's measurement system. See Figure 13-7.

*Figure 13-7  Crystal sensor emulator*
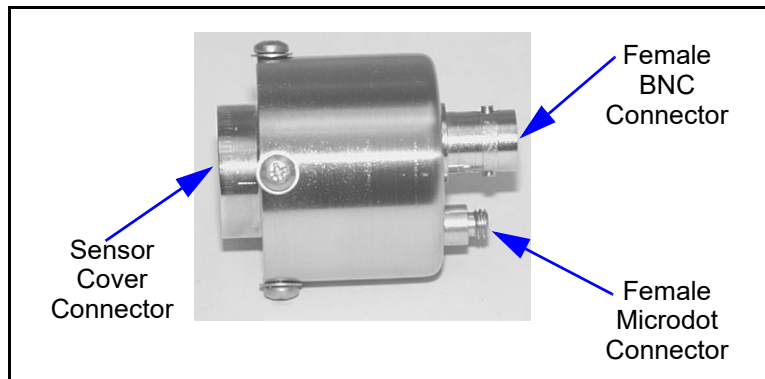


The Crystal Sensor Emulator may be attached at various points in the measurement system, from the oscillator to the sensor head. It provides a known good monitor crystal with known good electrical connections. Using the emulator and the controller in a systematic manner provides a fast means of isolating measurement system, cable, or sensor problems. See Figure 13-8.

*Figure 13-8  Crystal sensor emulator attachment points*



⚠️ **CAUTION**

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

### 13.8.1  Diagnostic Procedures

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

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

#### 13.8.1.1  Measurement System Diagnostic Procedure

1  Refer to Figure 13-8 on page 13-26. Remove the six-inch BNC cable from the feedthrough at point A.

2  Connect the Crystal Sensor Emulator to the 6 inch BNC cable at Point A.

  ◆  If the Crystal Fail message disappears after approximately five seconds, the measurement system is working properly. Re-install the six-inch BNC cable to the feedthrough. Go to section 13.8.1.2.

  ◆  If the Crystal Fail message remains, continue at step 3.

3  Disconnect the six-inch BNC cable from the Oscillator and from the Emulator.

4  Visually inspect the six-inch BNC cable to verify that the center pins are seated properly.

5  Use an Ohm meter to verify the electrical connections on the six-inch BNC cable.

  ◆  There must be continuity (<0.2 ohms, after accounting for resistance of ohmmeter leads) between the center pins.

  ◆  There must be isolation (>10 megohms) between the center pins and the connector shield.

  ◆  There must be continuity between the connector shields.

  Replace the six-inch BNC cable if it is found to be defective and repeat Step 2 of this procedure.

6  If the six-inch BNC cable is not defective, re-connect the six-inch cable to the oscillator and to the Crystal Sensor Emulator. If the Crystal Fail message remains, contact INFICON—refer to section 1.3 on page 1-5.

### 13.8.1.2  Feedthrough Or In-Vacuum Cable Diagnostic Procedure

**1**  Refer to Figure 13-8 on page 13-26. Remove the in-vacuum cable from the Sensor Head at point B.

**2**  Connect the Crystal Sensor Emulator to the in-vacuum cable.

 ◆  If the Crystal Fail message disappears after approximately five seconds, the feedthrough and in-vacuum cable are working properly. Re-install the in-vacuum cable to the Sensor Head. Go to section section 13.8.1.3 on page 13-29.

 ◆  If the Crystal Fail message remains, continue at step 3.

**3**  Disconnect the in-vacuum cable from the feedthrough and the Emulator. Disconnect the six-inch BNC cable from the feedthrough.

**4**  Using an Ohm Meter, verify electrical continuity from the BNC center pin on the feedthrough to the Microdot center pin on the feedthrough. A typical value would be less than 0.2 ohms.

**5**  Verify electrical isolation of the center pin on the feedthrough from the electrical ground (feedthrough body). A typical value would be in excess of 10 megohms.

If the feedthrough is found to be defective, replace the feedthrough, re-attach the BNC and in-vacuum cables, and repeat this procedure starting at Step 2, otherwise continue at step 6.

**6**  Verify electrical continuity from center pin to center pin on the in-vacuum cable.

**7**  Verify that the center pin of the in-vacuum cable is electrically isolated from the in-vacuum cable shield.

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

**8**  Connect the in-vacuum cable to the feedthrough.

**9**  Verify electrical continuity from the center pin on the BNC connector of the feedthrough to the center pin on the un-terminated end of the in-vacuum cable.

**10**  Verify electrical isolation from the center pin to electrical ground (feedthrough body).

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

**11**  Connect the six-inch BNC cable to the feedthrough and disconnect it from the Crystal Interface Unit (or Oscillator)

**12** Verify electrical continuity from the center pin of the Microdot connector on the feedthrough to the un-terminated end of the six-inch BNC cable.

**13** Verify electrical isolation from the center pin to electrical ground (feedthrough body).

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

### 13.8.1.3 Sensor Head Or Monitor Crystal Diagnostic Procedure

**NOTE:** The procedure is for use with front load style sensor heads.

**1** Remove the Crystal Cover from the Sensor Head.

**2** Refer to Figure 13-7 on page 13-26. Connect the Crystal Sensor Emulator to the Sensor Head at Point C.

- ◆ If the Crystal Fail message disappears after approximately 5 seconds the Sensor Head is operating properly. Remove the Crystal Sensor Emulator and re-insert the Crystal Cover into the Sensor Head.

- ◆ If the Crystal Fail message remains, continue at step 3.

**3** Disconnect the in-vacuum cable from the Sensor Head and the feedthrough. Remove the Crystal Sensor Emulator from the Sensor Head.

**4** Using an Ohm meter, verify the electrical connections on the Sensor Head.

- ◆ Verify there is electrical continuity from the center pin contact on the Microdot connector on the Sensor Head to the leaf spring contact in the Sensor Head. Take care not to apply to much pressure on the center pin of the microdot connector as it may become damaged.

- ◆ There must be electrical isolation between the center pin of the Microdot connector and the Sensor Head body.

If the Sensor Head is found to be defective, contact INFICON to have the Sensor Head repaired—refer to section 1.3 on page 1-5.

**5**   Connect the in-vacuum cable to the Sensor Head.

◆   Verify there is continuity (<0.2 ohm) from the leaf spring contact in the Sensor Head to the center pin on the un-terminated end of the in-vacuum cable.

◆   Verify there is isolation (>10 megohm) between the leaf spring contact and the in-vacuum cable shield.

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

**6**   Ensure that the leaf springs in the Sensor Head and those in the ceramic retainer are bent to an angle of approximately 60º and 45º from flat, respectively.

### 13.8.1.4  System Diagnostics Pass But Crystal Fail Message Remains

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

**1**   On the ceramic retainer verify that the center rivet is secure. Repair or replace the Ceramic Retainer as necessary.

**2**   Inspect the inside of the Crystal Holder for build-up of material. Clean or replace the Crystal Holder as necessary.

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

## 13.8.2  % XTAL Life

The Crystal Sensor Emulator contains a quartz crystal having a fundamental frequency at 5.5 MHz. With the Crystal Sensor Emulator connected, the % XTAL Life display should read approximately 30% for Cygnus 2 deposition controllers which allow a 1.5 MHz frequency shift.

### 13.8.3  Sensor Cover Connection

The Crystal Sensor Emulator can be used to verify the measurement system for INFICON Thin Film Deposition Controllers and Monitors.

**NOTE:** The Crystal Sensor Emulator 760-601-G1 is not compatible for use with an Cygnus 2. Use 760-601-G2 for all thin film deposition controllers.

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

#### 13.8.3.1  Compatible Sensor Heads

The Sensor Cover Connection will fit the sensor heads shown in Table 13-9.

*Table 13-9  Compatible sensor heads*

| Sensor Head | Part Number |
|---|---|
| Front Load Single Sensor Head | SL-XXXXX |
| Front Load Dual Sensor Head | DL-AEXX |

#### 13.8.3.2  Incompatible Sensor Heads

The Sensor Heads for which the Crystal Sensor Emulator's Sensor Cover Connector will not fit are shown in Table 13-10.

*Table 13-10  Incompatible sensor heads*

| Sensor Head | Part Number |
|---|---|
| Front Load UHV Bakeable Sensor Head | BK-AXX |
| Cool Drawer Single Sensor Head | CDS-XXXXX |
| Sputtering Sensor Head | 750-618-G1 |
| CrystalSix Sensor Head | 750-446-G1 |
| Cool Drawer Dual Sensor Head | CDD-XXXX |
| Crystal12 Sensor Head | XL12-XXXXXX |
| RSH-600 Sensor Head | 15320X-XX |

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

### *13.8.4 Specifications*

**Dimensions**

1.58 in. diameter x 1.79 in.
(40.13 mm diameter x 45.47 mm)

**Temperature Range**

0 to 50$^{o}$C

**Frequency**

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

**Materials**

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

# Chapter 14
# Measurement and Control Theory

## 14.1  Basics

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

In the late 1950's it was noted by Sauerbrey[1,2] and Lostis[3] that the change in frequency, $DF = F_q - F_c$, of a quartz crystal with coated (or composite) and uncoated frequencies, $F_c$ and $F_q$ respectively, is related to the change in mass from the added material, $M_f$, as follows:

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

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

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

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

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1.G. Z. Sauerbrey, Phys. Verhand .8, 193 (1957)
2.G. Z. Sauerbrey, Z. Phys. 155,206 (1959)
3.P. Lostis, Rev. Opt. 38,1 (1959)

effect provides a means of determining how much material is being deposited on a substrate in a vacuum system, a measurement that was not convenient or practical prior to this understanding.

### 14.1.1  Monitor Crystals

No matter how sophisticated the electronics surrounding it, the essential device of the deposition monitor is the quartz crystal. The quartz crystal shown in Figure 14-1 has a frequency response spectrum that is schematically shown in Figure 14-2. The ordinate represents the magnitude of response, or current flow of the crystal, at the specified frequency.

*Figure 14-1  Quartz resonator*
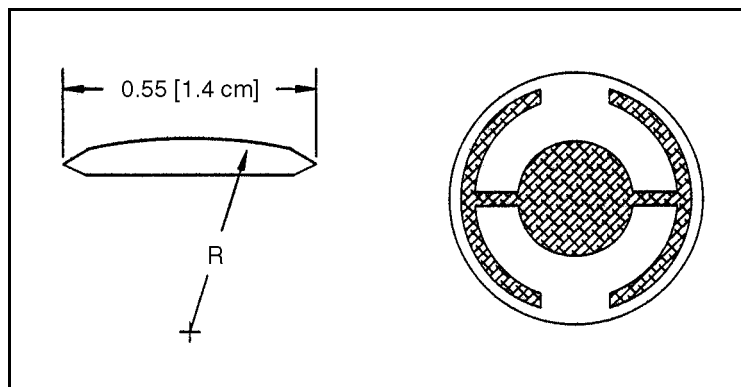


The lowest frequency response is primarily a "thickness shear" mode that is called the fundamental. The characteristic movement of the thickness shear mode is for displacement to take place parallel to the major monitor crystal faces. In other words, the faces are displacement antinodes as shown in Figure 14-3. The responses located slightly higher in frequency are called anharmonics; they are a combination of the thickness shear and thickness twist modes. The response at about three times the frequency of the fundamental is called the third quasiharmonic. There are also a series of anharmonics slightly higher in frequency associated with the quasiharmonic.

The monitor crystal design depicted in Figure 14-1 is the result of several significant improvements from the square crystals with fully electroded plane parallel faces that were first used. The first improvement was to use circular crystals. This increased symmetry greatly reduced the number of allowed vibrational modes. The second set of improvements was to contour one face of the crystal and to reduce the size of the exciting electrode. These improvements have the effect of trapping the acoustic energy. Reducing the electrode diameter limits the excitation to the central area. Contouring dissipates the energy of the traveling acoustic wave before it reaches the edge of the crystal. Energy is not reflected back to the center where it can interfere with other newly launched waves, essentially making a small crystal appear to behave as though it is infinite in extent. With the crystal's vibrations restricted to the center, it is practical to clamp the outer edges of the crystal to a holder and not produce any undesirable effects. Contouring also

reduces the intensity of response of the generally unwanted anharmonic modes; hence, the potential for an oscillator to sustain an unwanted oscillation is substantially reduced.

*Figure 14-2  Frequency response spectrum*
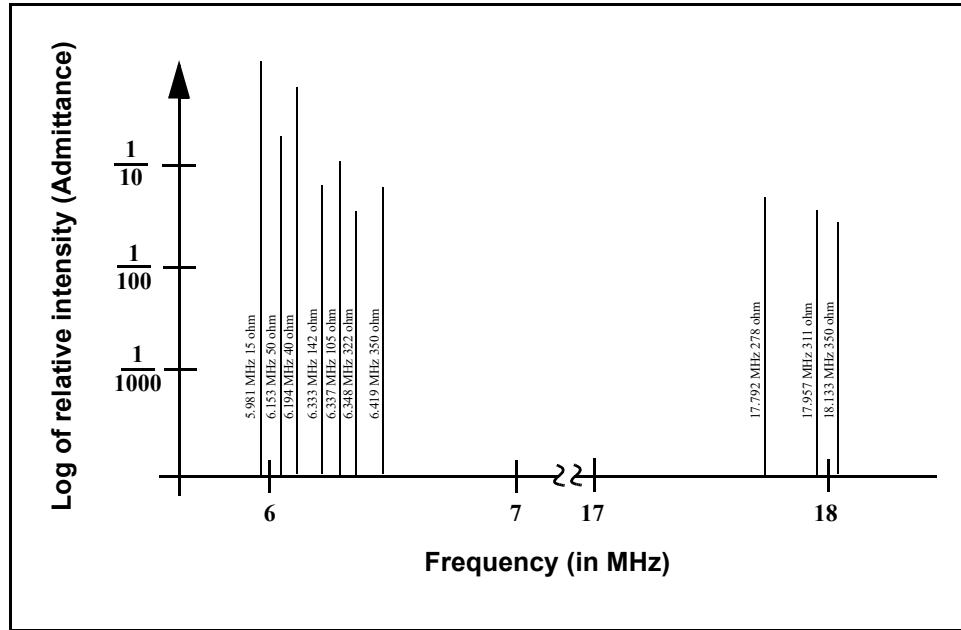


The use of an adhesion layer has improved the electrode-to-quartz bonding, reducing "rate spikes" caused by micro-tears between the electrode and the quartz as film stress rises. These micro-tears leave portions of the deposited film unattached and therefore unable to participate in the oscillation.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

The "AT" resonator is usually chosen for deposition monitoring because at room temperature it can be made to exhibit a very small frequency change due to temperature changes. Since there is presently no way to separate the frequency change caused by added mass (which is negative) or even the frequency changes caused by temperature gradients across the crystal or film induced stresses, it is essential to minimize these temperature-induced changes. It is only in this way that small changes in mass can be measured accurately.

*Figure 14-3  Thickness shear displacement*
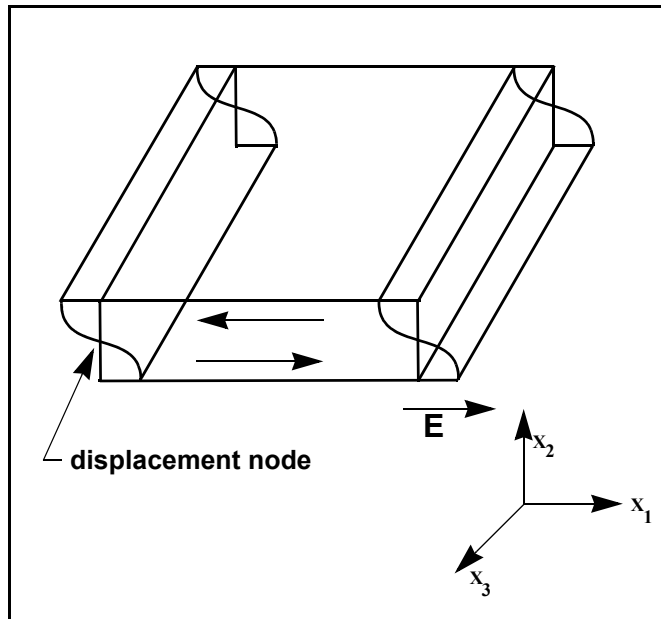


### 14.1.2  Period Measurement Technique

Although instruments using equation [2] were very useful, it was soon noted they had a very limited range of accuracy, typically holding accuracy for DF less than $0.02\ F_q$. In 1961 it was recognized by Behrndt[4] that:

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

[3]

where $T_c$ and Tq are the periods of oscillation of the crystal with film (composite) and the bare crystal respectively. The period measurement technique was the outgrowth of two factors; first, the digital implementation of time measurement, and second, the recognition of the mathematically rigorous formulation of the proportionality between the crystal's thickness, $I_q$, and the period of oscillation, $T_q$ = $1/F_q$. Electronically the period measurement technique uses a second crystal oscillator, or reference oscillator, not affected by the deposition and usually much higher in frequency than the monitor crystal. This reference oscillator is used to generate small precision time intervals which are used to determine the oscillation period of the monitor crystal. This is done by using two pulse accumulators. The first is used to accumulate a fixed number of cycles, m, of the monitor crystal. The second is turned on at the same time and accumulates cycles from the reference oscillator until m counts are accumulated in the first. Since the frequency of the reference is stable and known, the time to accumulate the m counts is known to an accuracy equal to $\pm\ 2/F_r$ where $F_r$ is the reference oscillator's frequency. The

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4.K. H. Behrndt, J. Vac. Sci. Technol. <u>8</u>, 622 (1961)

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

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

### 14.1.3 Z-match Technique

After learning of fundamental work by Miller and Bolef [5], which rigorously treated the resonating quartz and deposited film system as a one-dimensional continuous acoustic resonator, Lu and Lewis[6] developed the simplifying Z-match™ equation in 1972. Advances in electronics taking place at the same time, namely the micro-processor, made it practical to solve the Z-match equation in "real-time". Most deposition process controllers sold today use this sophisticated equation that takes into account the acoustic properties of the resonating quartz and film system as shown in equation [4].

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

where $Z=(d_q u_q/d_f u_f)^{1/2}$ is the acoustic impedance ratio and $u_q$ and $u_f$ are the shear moduli of the quartz and film, respectively. Finally, there was a fundamental understanding of the frequency-to-thickness conversion that could yield theoretically correct results in a time frame that was practical for process control. To achieve this new level of accuracy requires only that the user enter an additional material parameter, Z, for the film being deposited. This equation has been tested

5. J. G. Miller and D. I. Bolef, J. Appl. Phys. 39, 5815, 4589 (1968)
6. C. Lu and O. Lewis, J Appl. Phys. 43, 4385 (1972)

for a number of materials, and has been found to be valid for frequency shifts equivalent to $F_f = 0.4F_q$. Keep in mind that equation [2] was valid to only $0.02F_q$ and equation [3] was valid only to ~$0.05F_q$.

### 14.1.4  Active Oscillator

All of the instrumentation developed to date has relied on the use of an active oscillator circuit, generally the type schematically shown in Figure 14-4. This circuit actively keeps the crystal in resonance, so that any type of period or frequency measurement may be made. In this type of circuit, oscillation is sustained as long as the gain provided by the amplifiers is sufficient to offset losses in the crystal and circuit and the crystal can provide the required phase shift. The basic crystal oscillator's stability is derived from the rapid change of phase for a small change in the crystal's frequency near the series resonance point, as shown in Figure 14-5 on page 14-7.

*Figure 14-4  Active oscillator circuit*
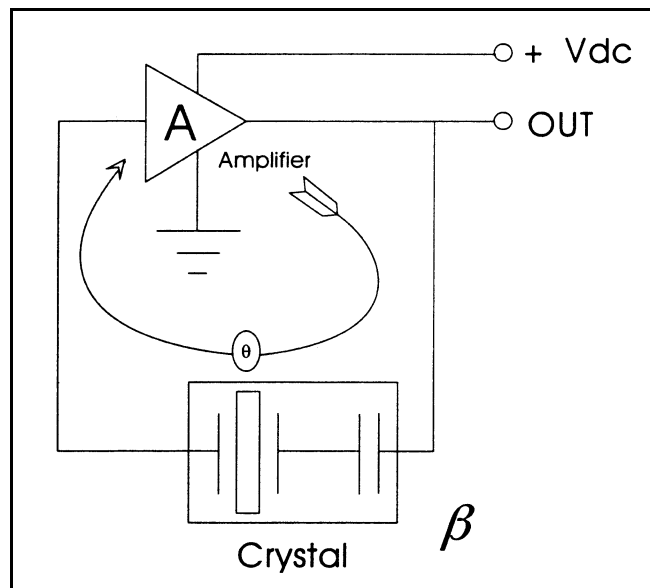


The active oscillator circuit is designed so the crystal is required to produce a phase shift of 0 degrees, which allows it to operate at the series resonance point. Long- and short-term frequency stabilities are a property of crystal oscillators because very small frequency changes are needed to sustain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

As mass is added to a crystal, its electrical characteristics change. Figure 14-6 on page 14-8 is the same plot as Figure 14-5 overlaid with the response of a heavily loaded crystal. The crystal has lost the steep slope displayed in Figure 14-5. Because the phase slope is less steep, any noise in the oscillator circuit translates

into a greater frequency shift than that which would be produced with a new crystal. In the extreme, the basic phase/frequency shape is not preserved and the crystal is not able to provide a full 90 degrees of phase shift.

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

*Figure 14-5  Crystal frequency near series resonance point*
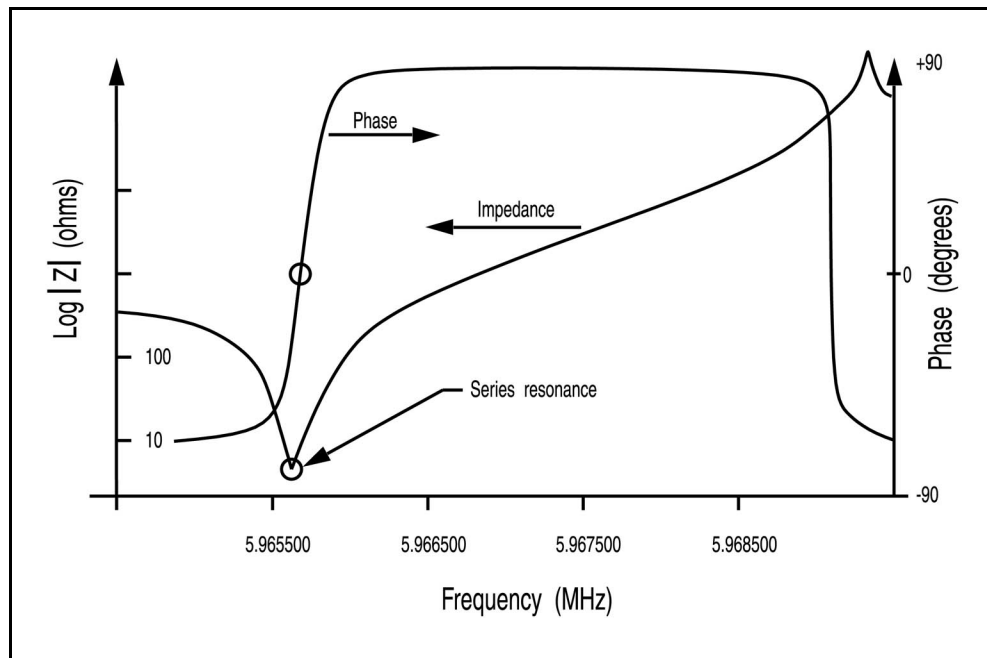


## 14.1.5  ModeLock Oscillator

INFICON created a new technology that eliminates the active oscillator and its limitations. This new system constantly tests the crystal's response to an applied frequency in order to not only determine the resonant frequency, but also to verify that the crystal is oscillating in the desired mode. This new system is essentially immune to mode hopping and the resulting inaccuracies. It is fast and accurate, determining the crystal's frequency to less than 0.005 Hz at a rate of 10 times per second. Because of the system's ability to identify and then measure particular crystal modes, it is now possible to offer new features that take advantage of the additional informational content of these modes. This new "intelligent"

measurement system uses the phase/frequency properties of the quartz crystal to determine the resonant frequency. It operates by applying a synthesized sine wave of specific frequency to the crystal and measuring the phase difference between the applied signal's voltage and the current passing through the crystal. At series resonance, this phase difference is exactly 0 degrees; that is, the crystal behaves like a pure resistance. By separating the applied voltage and the current returned from the crystal and monitoring the output of a phase comparator it is possible to establish whether the applied frequency is higher or lower than the crystal's resonance point. At frequencies well below the fundamental, the crystal's impedance is capacitive and at frequencies slightly higher than resonance it is inductive in nature. This information is useful if the resonance frequency of a crystal is unknown. A quick sweep of frequencies can be undertaken until the output of the phase comparator changes, marking the resonance event. For AT crystals we know that the lowest frequency event encountered is the fundamental. The events slightly higher in frequency are anharmonics. This information is useful not only for initialization, but also for the rare case when the instrument loses track of the fundamental. Once the frequency spectrum of the crystal is determined the instrument's task is to follow the changing resonance frequency and to periodically provide a measurement of the frequency for subsequent conversion to thickness.

*Figure 14-6  Heavily loaded crystal*
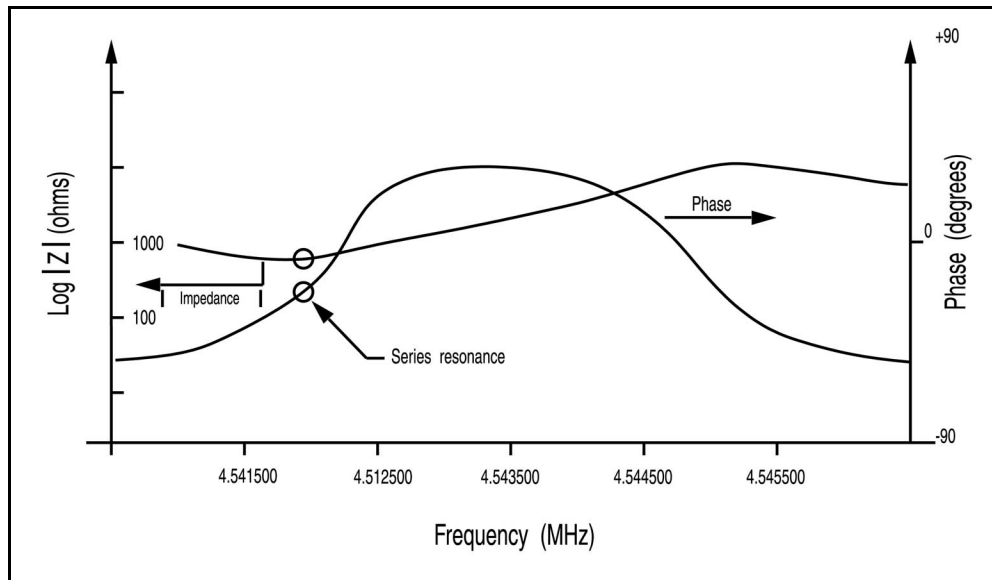


The use of the "intelligent" measurement system has a series of very apparent advantages when compared to the previous generation of active oscillators, namely immunity from mode hopping, speed of measurement and precision of measurement. The technique also allows the implementation of a sophisticated feature that cannot even be contemplated using the active oscillator approach. The same capability that allows the new technology to sweep and identify the fundamental can be used to identify other oscillation modes, such as the anharmonics and the quasiharmonic. Not only can the instrument track the

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

## 14.1.6  Auto-Z Theory

The one drawback in using equation [4] on page 14-5 is that the acoustic impedance must be known. There are several cases where accuracy has to be compromised because of incomplete or limited knowledge of the material constants of the deposited materials.

- Often the Z-Ratio for the bulk material is different from that of the deposited thin film. Thin films are especially sensitive to process parameters, particularly in a sputtering environment. Consequently, the values available for bulk materials may not be pertinent.

- For many exotic materials, including alloys, the Z-Ratio is not known nor easily available.

- There has always been a need to accurately measure layer thickness of multiple material films using the same crystal sensor. This is particularly true for multi-layer optical coatings and high-temperature superconductor fabrication. The effective Z-Ratio of the composite of multi-material layers is not known.

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

In 1989, A. Wajid became aware of the ModeLock oscillator[7]. He speculated there might be a relationship between the fundamental and one of the anharmonics similar to the relationship noted by Benes[8] between the fundamental and the third quasiharmonic. The frequencies of the fundamental and the anharmonics are very similar, solving the problem of capacitance of long cables. He found the ideas needed for establishing the required connections in papers published by Wilson[9] in 1974 and Tiersten and Smythe[10] in 1979.

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

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

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

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

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

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

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

$$\frac{(C_{55}/C_{66})_{coated}}{(C_{55}/C_{66})_{uncoated}} \sim \frac{1}{(1+MZ)} \tag{5}$$

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

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

or

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

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

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

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

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

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

## 14.1.7  Control Loop Theory

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

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

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

◆   Closed Loop Methods

◆   Open Loop Methods

◆   Frequency Response Methods

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

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

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

Three parameters are determined from the process reaction curve. They are the steady state gain, $K_p$, the dead time, L, and the time constant, $T_1$. Several methods have been proposed to extract the required parameters from the system response as graphed in Figure 14-7. These are: a one point fit at 63.2% of the transition (one time constant); a two point exponential fit; and a weighted least-square-exponential fit. From the above information a process is sufficiently characterized so that a controller algorithm may be customized.

*Figure 14-7  Response of process to an open loop step change*
*(At t=0 control signal is increased)*



$$T_1 = t_{(0.632)} - L$$

$$K_p = (\text{Change in Output}) / (\text{Change in Control Signal})$$
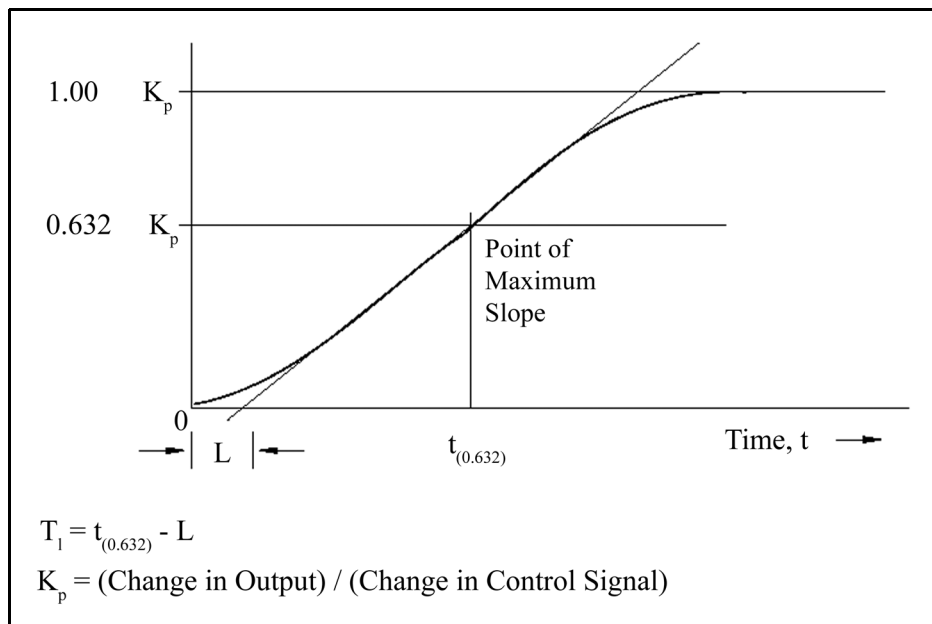
A controller model used extensively is the PID type, shown in Laplace form in equation [9].

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

Where

◆   M(s) = manipulated variable or power

◆   $K_c$ = controller gain (the proportional term)

- ◆ $T_i$ = integral time
- ◆ $T_d$ = derivative time
- ◆ E(s) = process error

Figure 14-8 represents the controller algorithm and a process with first order lag plus a dead time. The process block implicitly includes the dynamics of the measuring devices and the final control elements, in our case the evaporator power supply. R(s) represents the rate setpoint. The feedback mechanism is the error generated by the difference between the measured deposition rate, C(s), and the rate set point, R(s).

*Figure 14-8  PID controller block diagram*
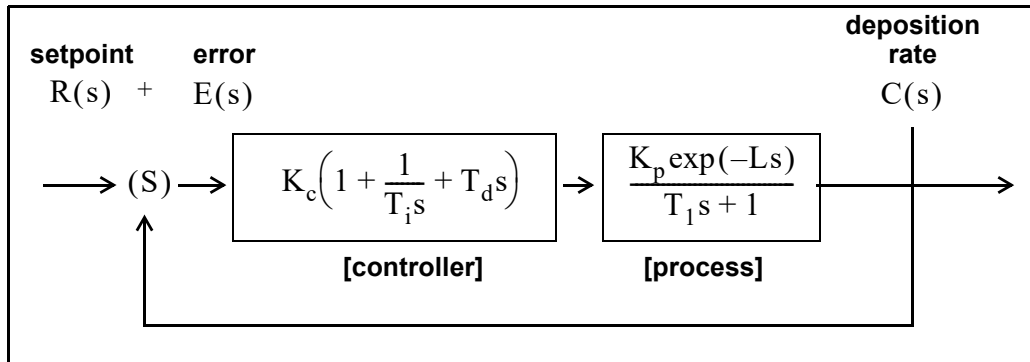


The key to using any control system is to choose the proper values of $K_c$, $T_d$ and $T_i$. Optimum control is a somewhat subjective quantity as noted by the presence of several mathematical definitions as shown below.

The Integral of the Squared Error (ISE) is a commonly proposed criterion of performance for control systems.

It can be described as:

$$\mathrm{ISE} = \int e^2(t)dt \qquad [10]$$

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

The Integral of the Absolute Value of the error (IAE) has been frequently proposed as a criterion of performance:

$$\mathrm{IAE} = \int |e(t)|dt \qquad [11]$$

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

Graham and Lathrop[12] introduced the Integral of Time multiplied by the Absolute Error (ITAE) as an alternate criterion of performance:

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

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

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

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

$$T_i = (1.19 T_1)(L / T_1)^{0.738} \tag{14}$$

$$T_d = (0.381 T_1)(L / T_1)^{0.995} \tag{15}$$

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

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

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

# Appendix A
# Material Table

## A.1 Introduction

The following Table A-1 represents the content of the Cygnus 2's Material library. The list is alphabetical by chemical formula.

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

Remote Communications Responses and Commands use the code value to represent a specific Material. An * is used to indicate that a Z-ratio has not been established for a certain material. A value of 1.000 is defaulted in these situations.

*Table A-1  Material Table*

| Code | Formula | Density | Z-Ratio | Material Name |
|------|---------|---------|---------|---------------|
| 0 | Ag | 10.500 | 0.529 | Silver |
| 1 | AgBr | 6.470 | 1.180 | Silver Bromide |
| 2 | AgCl | 5.560 | 1.320 | Silver Chloride |
| 3 | Al | 2.700 | 1.080 | Aluminum |
| 4 | $Al_2O_3$ | 3.970 | 0.336 | Aluminum Oxide |
| 5 | $Al_4C_3$ | 2.360 | *1.000 | Aluminum Carbide |
| 6 | $AlF_3$ | 3.070 | *1.000 | Aluminum Fluoride |
| 7 | AlN | 3.260 | *1.000 | Aluminum Nitride |
| 8 | AlSb | 4.360 | 0.743 | Aluminum Antimonide |
| 9 | As | 5.730 | 0.966 | Arsenic |
| 10 | $As_2Se_3$ | 4.750 | *1.000 | Arsenic Selenide |
| 11 | Au | 19.300 | 0.381 | Gold |
| 12 | B | 2.370 | 0.389 | Boron |
| 13 | $B_2O_3$ | 1.820 | *1.000 | Boron Oxide |
| 14 | $B_4C$ | 2.370 | *1.000 | Boron Carbide |
| 15 | BN | 1.860 | *1.000 | Boron Nitride |
| 16 | Ba | 3.500 | 2.100 | Barium |

*Table A-1  Material Table (continued)*

| Code | Formula | Density | Z-Ratio | Material Name |
|------|---------|---------|---------|---------------|
| 17 | $BaF_2$ | 4.886 | 0.793 | Barium Fluoride |
| 18 | $BaN_2O_6$ | 3.244 | 1.261 | Barium Nitrate |
| 19 | $BaO$ | 5.720 | *1.000 | Barium Oxide |
| 20 | $BaTiO_3$ | 5.999 | 0.464 | Barium Titanate (Tetr) |
| 21 | $BaTiO_3$ | 6.035 | 0.412 | Barium Titanate (Cubic) |
| 22 | $Be$ | 1.850 | 0.543 | Beryllium |
| 23 | $BeF_2$ | 1.990 | *1.000 | Beryllium Fluoride |
| 24 | $BeO$ | 3.010 | *1.000 | Beryllium Oxide |
| 25 | $Bi$ | 9.800 | 0.790 | Bismuth |
| 26 | $Bi_2O_3$ | 8.900 | *1.000 | Bismuth Oxide |
| 27 | $Bi_2S_3$ | 7.390 | *1.000 | Bismuth Trisulphide |
| 28 | $Bi_2Se_3$ | 6.820 | *1.000 | Bismuth Selenide |
| 29 | $Bi_2Te_3$ | 7.700 | *1.000 | Bismuth Telluride |
| 30 | $BiF_3$ | 5.320 | *1.000 | Bismuth Fluoride |
| 31 | $C$ | 2.250 | 3.260 | Carbon (Graphite) |
| 32 | $C$ | 3.520 | 0.220 | Carbon (Diamond) |
| 33 | $C_8H_8$ | 1.100 | *1.000 | Parlyene (Union Carbide) |
| 34 | $Ca$ | 1.550 | 2.620 | Calcium |
| 35 | $CaF_2$ | 3.180 | 0.775 | Calcium Fluoride |
| 36 | $CaO$ | 3.350 | *1.000 | Calcium Oxide |
| 37 | $CaO\text{-}SiO_2$ | 2.900 | *1.000 | Calcium Silicate (3) |
| 38 | $CaSO_4$ | 2.962 | 0.955 | Calcium Sulfate |
| 39 | $CaTiO_3$ | 4.100 | *1.000 | Calcium Titanate |
| 40 | $CaWO_4$ | 6.060 | *1.000 | Calcium Tungstate |
| 41 | $Cd$ | 8.640 | 0.682 | Cadmium |
| 42 | $CdF_2$ | 6.640 | *1.000 | Cadmium Fluoride |
| 43 | $CdO$ | 8.150 | *1.000 | Cadmium Oxide |
| 44 | $CdS$ | 4.830 | 1.020 | Cadmium Sulfide |
| 45 | $CdSe$ | 5.810 | *1.000 | Cadmium Selenide, |
| 46 | $CdTe$ | 6.200 | 0.980 | Cadmium Telluride |
| 47 | $Ce$ | 6.780 | *1.000 | Cerium |
| 48 | $CeF_3$ | 6.160 | *1.000 | Cerium (III) Fluoride |
| 49 | $CeO_2$ | 7.130 | *1.000 | Cerium (IV) Dioxide |

*Table A-1  Material Table (continued)*

| Code | Formula | Density | Z-Ratio | Material Name |
|------|---------|---------|---------|---------------|
| 50 | Co | 8.900 | 0.343 | Cobalt |
| 51 | CoO | 6.440 | 0.412 | Cobalt Oxide |
| 52 | Cr | 7.200 | 0.305 | Chromium |
| 53 | $Cr_2O_3$ | 5.210 | *1.000 | Chromium (III) Oxide |
| 54 | $Cr_3C_2$ | 6.680 | *1.000 | Chromium Carbide |
| 55 | CrB | 6.170 | *1.000 | Chromium Boride |
| 56 | Cs | 1.870 | *1.000 | Cesium |
| 57 | $Cs_2SO_4$ | 4.243 | 1.212 | Cesium Sulfate |
| 58 | CsBr | 4.456 | 1.410 | Cesium Bromide |
| 59 | CsCl | 3.988 | 1.399 | Cesium Chloride |
| 60 | CsI | 4.516 | 1.542 | Cesium Iodide |
| 61 | Cu | 8.930 | 0.437 | Copper |
| 62 | $Cu_2O$ | 6.000 | *1.000 | Copper Oxide |
| 63 | $Cu_2S$ | 5.600 | 0.690 | Copper (I) Sulfide (Alpha) |
| 64 | $Cu_2S$ | 5.800 | 0.670 | Copper (I) Sulfide (Beta) |
| 65 | CuS | 4.600 | 0.820 | Copper (II) Sulfide |
| 66 | Dy | 8.550 | 0.600 | Dysprosium |
| 67 | $DY_2O_3$ | 7.810 | *1.000 | Dysprosium Oxide |
| 68 | Er | 9.050 | 0.740 | Erbium |
| 69 | $Er_2O_3$ | 8.640 | *1.000 | Erbium Oxide |
| 70 | Eu | 5.260 | *1.000 | Europium |
| 71 | $EuF_2$ | 6.500 | *1.000 | Europium Fluoride |
| 72 | Fe | 7.860 | 0.349 | Iron |
| 73 | $Fe_2O_3$ | 5.240 | *1.000 | Iron Oxide |
| 74 | FeO | 5.700 | *1.000 | Iron Oxide |
| 75 | FeS | 4.840 | *1.000 | Iron Sulphide |
| 76 | Ga | 5.930 | 0.593 | Gallium |
| 77 | $Ga_2O_3$ | 5.880 | *1.000 | Gallium Oxide (B) |
| 78 | GaAs | 5.310 | 1.590 | Gallium Arsenide |
| 79 | GaN | 6.100 | *1.000 | Gallium Nitride |
| 80 | GaP | 4.100 | *1.000 | Gallium Phosphide |
| 81 | GaSb | 5.600 | *1.000 | Gallium Antimonide |
| 82 | Gd | 7.890 | 0.670 | Gadolinium |

*Table A-1  Material Table (continued)*

| Code | Formula | Density | Z-Ratio | Material Name |
|---|---|---|---|---|
| 83 | $Gd_2O_3$ | 7.410 | *1.000 | Gadolinium Oxide |
| 84 | Ge | 5.350 | 0.516 | Germanium |
| 85 | $Ge_3N_2$ | 5.200 | *1.000 | Germanium Nitride |
| 86 | $GeO_2$ | 6.240 | *1.000 | Germanium Oxide |
| 87 | GeTe | 6.200 | *1.000 | Germanium Telluride |
| 88 | Hf | 13.090 | 0.360 | Hafnium |
| 89 | $HfB_2$ | 10.500 | *1.000 | Hafnium Boride, |
| 90 | HfC | 12.200 | *1.000 | Hafnium Carbide |
| 91 | HfN | 13.800 | *1.000 | Hafnium Nitride |
| 92 | $HfO_2$ | 9.680 | *1.000 | Hafnium Oxide |
| 93 | $HfSi_2$ | 7.200 | *1.000 | Hafnium Silicide |
| 94 | Hg | 13.460 | 0.740 | Mercury |
| 95 | Ho | 8.800 | 0.580 | Holminum |
| 96 | $Ho_2O_3$ | 8.410 | *1.000 | Holminum Oxide |
| 97 | In | 7.300 | 0.841 | Indium |
| 98 | $In_2O_3$ | 7.180 | *1.000 | Indiurn Sesquioxide, |
| 99 | $In_2Se_3$ | 5.700 | *1.000 | Indium Selenide |
| 100 | $In_2Te_3$ | 5.800 | *1.000 | Indium Telluride |
| 101 | InAs | 5.700 | *1.000 | Indium Arsenide |
| 102 | InP | 4.800 | *1.000 | Indium Phosphide |
| 103 | InSb | 5.760 | 0.769 | Indium Antimonide |
| 104 | Ir | 22.400 | 0.129 | Iridium |
| 105 | K | 0.860 | 10.189 | Potassium |
| 106 | KBr | 2.750 | 1.893 | Potassium Bromide |
| 107 | KCl | 1.980 | 2.050 | Potassium Chloride |
| 108 | KF | 2.480 | *1.000 | Potassium Fluoride |
| 109 | KI | 3.128 | 2.077 | Potassium Iodide |
| 110 | La | 6.170 | 0.920 | Lanthanum |
| 111 | $La_2O_3$ | 6.510 | *1.000 | Lanthanum Oxide |
| 112 | $LaB_6$ | 2.610 | *1.000 | Lanthanurn Boride |
| 113 | $LaF_3$ | 5.940 | *1.000 | Lanthanum Fluoride |
| 114 | Li | 0.530 | 5.900 | Lithium |
| 115 | LiBr | 3.470 | 1.230 | Lithium Bromide |

*Table A-1  Material Table (continued)*

| Code | Formula | Density | Z-Ratio | Material Name |
|------|---------|---------|---------|---------------|
| 116 | LiF | 2.638 | 0.778 | Lithium Fluoride |
| 117 | $LiNbO_3$ | 4.700 | 0.463 | Lithium Niobate |
| 118 | Lu | 9.840 | *1.000 | Lutetium |
| 119 | Mg | 1.740 | 1.610 | Magnesium |
| 120 | $MgAl_2O_4$ | 3.600 | *1.000 | Magnesium Aluminate |
| 121 | $MgAl_2O_6$ | 8.000 | *1.000 | Spinel |
| 122 | $MgF_2$ | 3.180 | 0.637 | Magnesium Fluoride |
| 123 | MgO | 3.580 | 0.411 | Magnesium Oxide |
| 124 | Mn | 7.200 | 0.377 | Manganese |
| 125 | MnO | 5.390 | 0.467 | Manganese Oxide |
| 126 | MnS | 3.990 | 0.940 | Manganese (II) Sulfide |
| 127 | Mo | 10.200 | 0.257 | Molybdenum |
| 128 | $Mo_2C$ | 9.180 | *1.000 | Molybdenum Carbide |
| 129 | $MoB_2$ | 7.120 | *1.000 | Molybdenum Boride |
| 130 | $MoO_3$ | 4.700 | *1.000 | Molybdenum Trioxdide |
| 131 | $MoS_2$ | 4.800 | *1.000 | Molybdenum Disulfide |
| 132 | Na | 0.970 | 4.800 | Sodium |
| 133 | $Na_3AlF_6$ | 2.900 | *1.000 | Cryolite |
| 134 | $Na_5Al_3F_{14}$ | 2.900 | *1.000 | Chiolite |
| 135 | NaBr | 3.200 | *1.000 | Sodium Bromide |
| 136 | NaCl | 2.170 | 1.570 | Sodium Chloride |
| 137 | $NaClO_3$ | 2.164 | 1.565 | Sodium Chlorate |
| 138 | NaF | 2.558 | 1.645 | Sodium Fluoride |
| 139 | $NaNO_3$ | 2.270 | 1.194 | Sodium Nitrate |
| 140 | Nb | 8.578 | 0.492 | Niobium (Columbium) |
| 141 | $Nb_2O_3$ | 7.500 | *1.000 | Niobium Trioxide |
| 142 | $Nb_2O_5$ | 4.470 | *1.000 | Niobium (V) Oxide |
| 143 | $NbB_2$ | 6.970 | *1.000 | Niobium Boride |
| 144 | NbC | 7.820 | *1.000 | Niobium Carbide |
| 145 | NbN | 8.400 | *1.000 | Niobium Nitride |
| 146 | Nd | 7.000 | *1.000 | Neodynium |
| 147 | $Nd_2O_3$ | 7.240 | *1.000 | Neodynium Oxide |
| 148 | $NdF_3$ | 6.506 | *1.000 | Neodynium Fluoride |

*Table A-1  Material Table (continued)*

| Code | Formula | Density | Z-Ratio | Material Name |
|------|---------|---------|---------|---------------|
| 149 | Ni | 8.910 | 0.331 | Nickel |
| 150 | NiCr | 8.500 | *1.000 | Nichrome |
| 151 | NiCrFe | 8.500 | *1.000 | Inconel |
| 152 | NiFe | 8.700 | *1.000 | Permalloy |
| 153 | NiFeMo | 8.900 | *1.000 | Supermalloy |
| 154 | NiO | 7.450 | *1.000 | Nickel Oxide |
| 155 | $P_3N_5$ | 2.510 | *1.000 | Phosphorus Nitride |
| 156 | Pb | 11.300 | 1.130 | Lead |
| 157 | $PbCl_2$ | 5.850 | *1.000 | Lead Chloride |
| 158 | $PbF_2$ | 8.240 | 0.661 | Lead Fluoride |
| 159 | PbO | 9.530 | *1.000 | Lead Oxide |
| 160 | PbS | 7.500 | 0.566 | Lead Sulfide |
| 161 | PbSe | 8.100 | *1.000 | Lead Selenide |
| 162 | $PbSnO_3$ | 8.100 | *1.000 | Lead Stannate |
| 163 | PbTe | 8.160 | 0.651 | Lead Telluride |
| 164 | Pd | 12.038 | 0.357 | Palladium |
| 165 | PdO | 8.310 | *1.000 | Palladium Oxide |
| 166 | Po | 9.400 | *1.000 | Polonium |
| 167 | Pr | 6.780 | *1.000 | Praseodymium |
| 168 | $Pr_2O_3$ | 6.880 | *1.000 | Praseodymium Oxide |
| 169 | Pt | 21.400 | 0.245 | Platinum |
| 170 | $PtO_2$ | 10.200 | *1.000 | Platinum Oxide |
| 171 | Ra | 5.000 | *1.000 | Radium |
| 172 | Rb | 1.530 | 2.540 | Rubidium |
| 173 | RbI | 3.550 | *1.000 | Rubidiurn Iodide |
| 174 | Re | 21.040 | 0.150 | Rhenium |
| 175 | Rh | 12.410 | 0.210 | Rhodium |
| 176 | Ru | 12.362 | 0.182 | Ruthenium |
| 177 | $S_8$ | 2.070 | 2.290 | Sulphur |
| 178 | Sb | 6.620 | 0.768 | Antimony |
| 179 | $Sb_2O_3$ | 5.200 | *1.000 | Antimony Trioxide |
| 180 | $Sb_2S_3$ | 4.640 | *1.000 | Antimony Trisulfide |
| 181 | Sc | 3.000 | 0.910 | Scandium |

*Table A-1  Material Table (continued)*

| Code | Formula | Density | Z-Ratio | Material Name |
|------|---------|---------|---------|---------------|
| 182 | $Sc_2O_3$ | 3.860 | *1.000 | Scandium Oxide |
| 183 | Se | 4.810 | 0.864 | Selenium |
| 184 | Si | 2.320 | 0.712 | Silicon |
| 185 | $Si_3N_4$ | 3.440 | *1.000 | Silicon Nitride |
| 186 | SiC | 3.220 | *1.000 | Silicon Carbide |
| 187 | SiO | 2.130 | 0.870 | Silicon (II) Oxide |
| 188 | $SiO_2$ | 2.648 | 1.000 | Silicon Dioxide |
| 189 | Sm | 7.540 | 0.890 | Samarium |
| 190 | $Sm_2O_3$ | 7.430 | *1.000 | Samarium Oxide |
| 191 | Sn | 7.300 | 0.724 | Tin |
| 192 | $SnO_2$ | 6.950 | *1.000 | Tin Oxide |
| 193 | SnS | 5.080 | *1.000 | Tin Sulfide |
| 194 | SnSe | 6.180 | *1.000 | Tin Selenide |
| 195 | SnTe | 6.440 | *1.000 | Tin Telluride |
| 196 | Sr | 2.600 | *1.000 | Strontium |
| 197 | $SrF_2$ | 4.277 | 0.727 | Strontium Fluoride |
| 198 | SrO | 4.990 | 0.517 | Strontium Oxide |
| 199 | Ta | 16.600 | 0.262 | Tantalum |
| 200 | $Ta_2O_5$ | 8.200 | 0.300 | Tantalum (V) Oxide |
| 201 | $TaB_2$ | 11.150 | *1.000 | Tantalum Boride |
| 202 | TaC | 13.900 | *1.000 | Tantalum Carbide |
| 203 | TaN | 16.300 | *1.000 | Tantalum Nitride |
| 204 | Tb | 8.270 | 0.660 | Terbium |
| 205 | Tc | 11.500 | *1.000 | Technetium |
| 206 | Te | 6.250 | 0.900 | Tellurium |
| 207 | $TeO_2$ | 5.990 | 0.862 | Tellurium Oxide |
| 208 | Th | 11.694 | 0.484 | Thorium |
| 209 | $ThF_4$ | 6.320 | *1.000 | Thorium.(IV) Fluoride |
| 210 | $ThO_2$ | 9.860 | 0.284 | Thorium Dioxide |
| 211 | $ThOF_2$ | 9.100 | *1.000 | Thorium Oxyfluoride |
| 212 | Ti | 4.500 | 0.628 | Titanium |
| 213 | $Ti_2O_3$ | 4.600 | *1.000 | Titanium Sesquioxide |
| 214 | $TiB_2$ | 4.500 | *1.000 | Titanium Boride |

*Table A-1  Material Table (continued)*

| Code | Formula | Density | Z-Ratio | Material Name |
|------|---------|---------|---------|---------------|
| 215 | TiC | 4.930 | *1.000 | Titanium Carbide |
| 216 | TiN | 5.430 | *1.000 | Titanium Nitride |
| 217 | TiO | 4.900 | *1.000 | Titanium Oxide |
| 218 | $TiO_2$ | 4.260 | 0.400 | Titanium (IV) Oxide |
| 219 | Tl | 11.850 | 1.550 | Thallium |
| 220 | TlBr | 7.560 | *1.000 | Thallium Bromide |
| 221 | TlCl | 7.000 | *1.000 | Thallium Chloride |
| 222 | TlI | 7.090 | *1.000 | Thalliurn Iodide (B) |
| 223 | U | 19.050 | 0.238 | Uranium |
| 224 | $U_3O_8$ | 8.300 | *1.000 | Tri Uranium Octoxide |
| 225 | $U_4O_9$ | 10.969 | 0.348 | Uranium Oxide |
| 226 | $UO_2$ | 10.970 | 0.286 | Uranium Dioxide |
| 227 | V | 5.960 | 0.530 | Vanadium |
| 228 | $V_2O_5$ | 3.360 | *1.000 | Vanadium Pentoxide |
| 229 | $VB_2$ | 5.100 | *1.000 | Vanadium Boride |
| 230 | VC | 5.770 | *1.000 | Vanadium Carbide |
| 231 | VN | 6.130 | *1.000 | Vanadium Nitride |
| 232 | $VO_2$ | 4.340 | *1.000 | Vanadium Dioxide |
| 233 | W | 19.300 | 0.163 | Tungsten |
| 234 | $WB_2$ | 10.770 | *1.000 | Tungsten Boride |
| 235 | WC | 15.600 | 0.151 | Tungsten Carbide |
| 236 | $WO_3$ | 7.160 | *1.000 | Tungsten Trioxide |
| 237 | $WS_2$ | 7.500 | *1.000 | Tungsten Disulphide |
| 238 | $WSi_2$ | 9.400 | *1.000 | Tungsten Silicide |
| 239 | Y | 4.340 | 0.835 | Yttrium |
| 240 | $Y_2O_3$ | 5.010 | *1.000 | Yttrium Oxide |
| 241 | Yb | 6.980 | 1.130 | Ytterbium |
| 242 | $Yb_2O_3$ | 9.170 | *1.000 | Ytterbium Oxide |
| 243 | Zn | 7.040 | 0.514 | Zinc |
| 244 | $Zn_3Sb_2$ | 6.300 | *1.000 | Zinc Antimonide |
| 245 | $ZnF_2$ | 4.950 | *1.000 | Zinc Fluoride |
| 246 | ZnO | 5.610 | 0.556 | Zinc Oxide |
| 247 | ZnS | 4.090 | 0.775 | Zinc Sulfide |

*Table A-1  Material Table (continued)*

| Code | Formula | Density | Z-Ratio | Material Name |
|------|---------|---------|---------|---------------|
| 248 | ZnSe | 5.260 | 0.722 | Zinc Selenide |
| 249 | ZnTe | 6.340 | 0.770 | Zinc Telluride |
| 250 | Zr | 6.490 | 0.600 | Zirconium |
| 251 | $ZrB_2$ | 6.080 | *1.000 | Zirconium Boride |
| 252 | ZrC | 6.730 | 0.264 | Zirconium Carbide |
| 253 | ZrN | 7.090 | *1.000 | Zirconium Nitride |
| 254 | $ZrO_2$ | 5.600 | *1.000 | Zirconium Oxide |

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